APPENDIX C1

STUDY 3 – ALTERNATIVE DRY STORAGE METHODS FOR STANDARD SNF CANISTERS

Alternative 1 - Pad Storage Using STAD Canisters (S-PAD)

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C1-1.0 Description of Storage Alternative

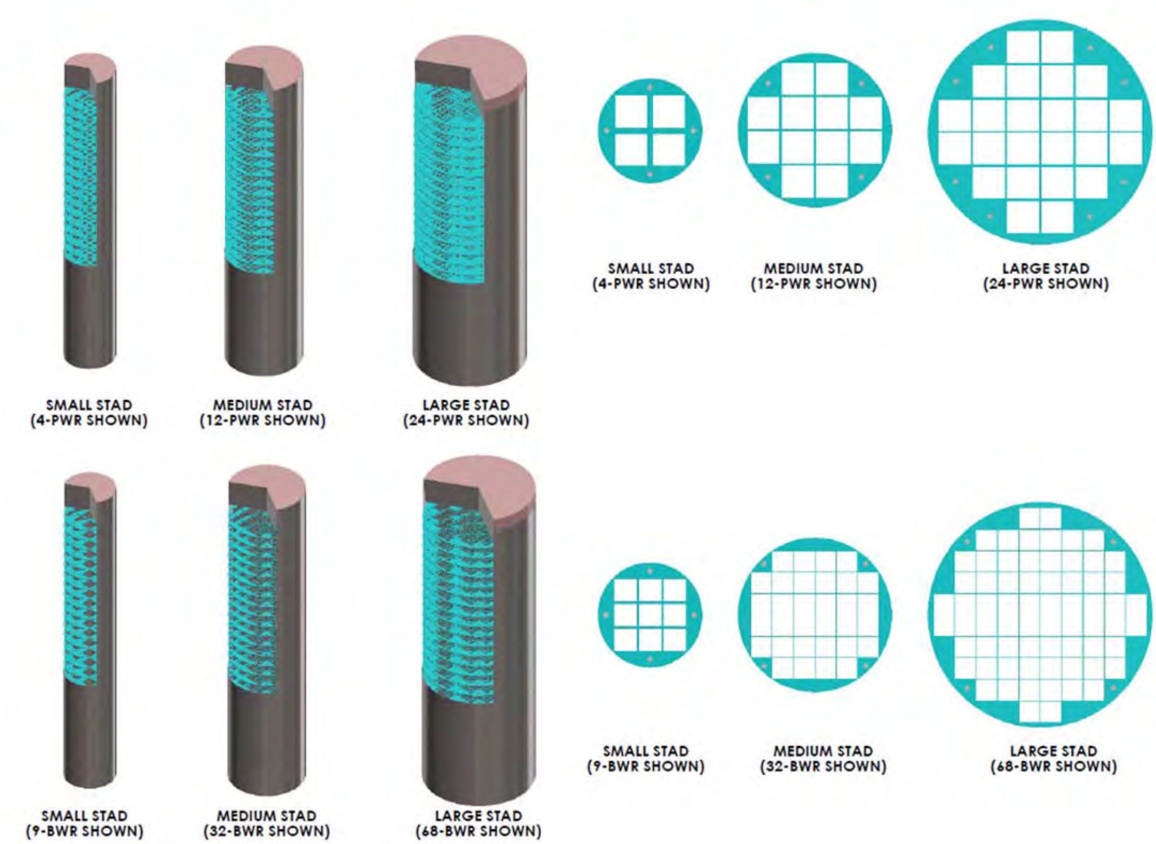
Alternative 1 evaluates the use of currently deployed and licensed above grade vertical and horizontal storage “canister-based” systems associated with dual purpose canister (DPC) design using Standardized Transportation, Aging and Disposal (STAD) canisters. Therefore, this Alternative is designated S-PAD for STAD canister stored on a concrete pad.

The use of STAD canisters is assumed to follow the initial placement of commercial DPCs from shutdown plants and not applicable to the initial Pilot interim storage facility (ISF) since there exists no current means to repackage SNF at most of these sites. This study also does not determine where the STAD canisters originated, only that they arrive at the ISF and must be processed and placed into storage.

The concept of STAD canisters was developed by the U.S. Department of Energy (DOE) as a means of addressing the variability of the spent nuclear fuel (SNF) storage and disposal issues that confronted the Department when faced with consolidating the SNF at a single location. In addition to the multitude of DPC dry storage designs that have been deployed at reactor sites, a few dry canister-based dry storage systems were not designed for transportation and may not be able to be certified for transport, even if packaged in a transport cask. These will need to be repackaged and the STAD canister could facilitate that.

The DOE has decided to consider three STAD canister designs which are shown in **Figure C1-1**. Small STAD canisters (4 PWR/9 BWR) and medium STAD canisters (12 PWR/32 BWR) are specified by the DOE “Performance Specification for Small and Medium Standardized Transportation, Aging and Disposal Canister Systems,” (Reference C1-1). Large STAD canisters (21 PWR/44 BWR) are specified by DOE “Transportation, Aging, and Disposal Canister System Performance Specification,” (Reference C1-2). All three of these STAD canister sizes are considered together in this alternative at the Interim Storage Facility (ISF). The variations in size will be called S-PADa for the small STAD canister, S-PADb for the medium STAD canister, and S-PADc for the large STAD canister. The small STAD canisters can also be packed in a 4-pack STAD multi-can storage container so that they can be handled as a single package, resulting in 16 PWR assemblies or 36 BWR assemblies being shipped in the multi-can storage container. A single shipment of small STAD canisters has a slightly larger capacity than the medium STAD canister as far as the ISF is concerned. The medium STAD canister will be more efficient to load and to handle at the generator’s site, but once it arrives at the ISF, it is the least efficient storage package for SNF.

Figure C1-1
Proposed STAD Canister Sizes



The following **Table C1-1** shows the capacities of each type of STAD canister.

Table C1-1
STAD Canister Capacities

Option	STAD	Shipment	PWR	BWR	MTHM per Overpack
S-PADa	Small	4 each	16	36	7.3
S-PADb	Medium	1 each	12	32	5.4
S-PADc	Large	1 each	21	44	9.5

This study has assumed that a 32 PWR assembly commercial DPC received at the ISF contains approximately 14.5 MTHM.[1] The large STAD canister contains only 66% of the number of PWR assemblies as the 32-assembly PWR DPC in current use. Part of the

[1] Some of the legacy DPCs contain fewer fuel assemblies so that the average mass per DPC is actually 11.1 MTHM for the ISF.

reasoning for this is that the lower-capacity STAD canister may be used to transport SNF with higher decay heat than could occur using a 32-assembly DPC. Smaller capacity packages generally can transport SNF with higher decay heat due to more efficient heat transfer in the smaller packages.

During transportation, the STAD canisters are loaded into a transport cask that provides shielding and structural protection to the STAD canister. Impact limiting devices are attached to the ends of the transport cask for additional protection during transit. The shipping package must comply with the requirements of 10CFR71 (Reference C1-3). Four small STAD canisters will be shipped in a Multi-can storage container that uses a common handling mechanism to enable handling all of four small STAD canisters as a single entity. For storage, the STAD canisters must comply with the requirements of 10CFR72 (Reference C1-4).

C1-2.0 Concept of Operations

C1-2.1 Facility Layout

S-PAD is a straightforward application of existing SNF storage technologies brought together at a common site. All STAD canisters are vertical storage systems, so the ISF systems can be simplified to a single storage technology. Also, the STAD canisters are all standardized in terms of length and diameters, so there is no need for inserts/adaptors. The overpacks are designed to match the STAD canister dimensions. Generally, STAD canisters are stored in single overpacks on a concrete pad. However, there is an alternative for ganging four small STAD canisters together in a single large STAD canister or eight small STAD canisters into a concrete “pillbox” overpack depending on if the small STAD canisters are shipped in the large STAD canister or as single small STAD canisters. These approaches restructure the layout of the concrete pads. Ganging four small STAD canisters reduces the use of cask transporters by consolidating STAD canisters, but do not appreciably impact operations or throughput of the ISF. **Figure C1-2** shows the arrangement of a 4-pack STAD canister and **Figure C1-3** shows an 8-pack small STAD overpack (this concept is only applicable to the small STAD canister).

The transport casks are delivered via rail to the site. They are brought on site by the dedicated ISF tug, which is a small locomotive that brings the railcars from the mainline siding to the inspection station located at the entrance of the ISF. There, site security officers will review the shipping paperwork and perform a thorough check of the rolling stock and the packaging to ensure that there is no contraband on the shipment. The railroad tracks have a powered derailer that is positioned at the gate to prevent unauthorized access to the site via rail. After the security inspection, the transport cask railcars are separated from the security railcar and are move onto the site's rail yard where they are staged until being moved into the CHB.

Figure C1-2
4-Pack Small STAD Canister

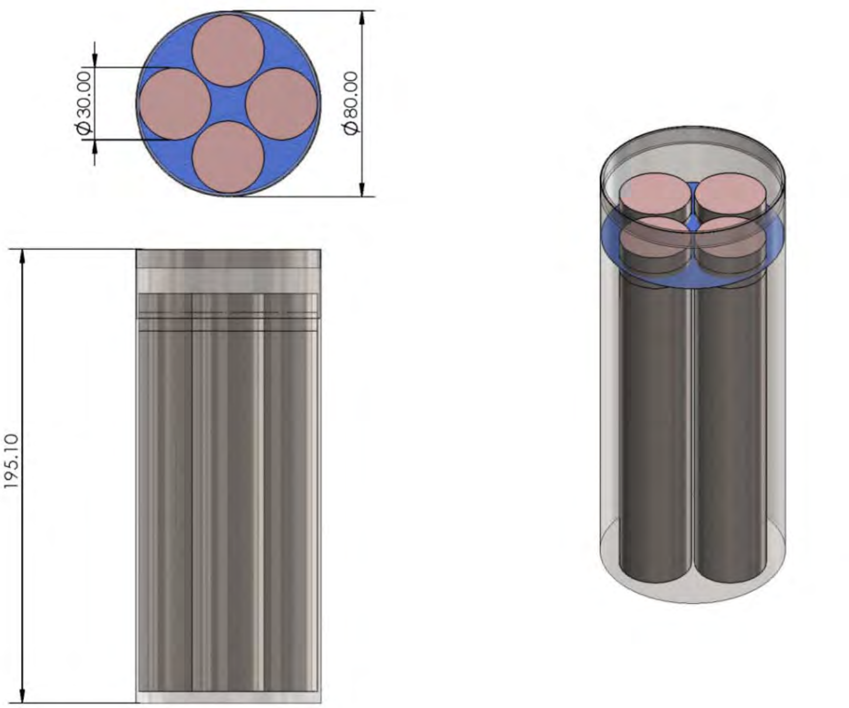
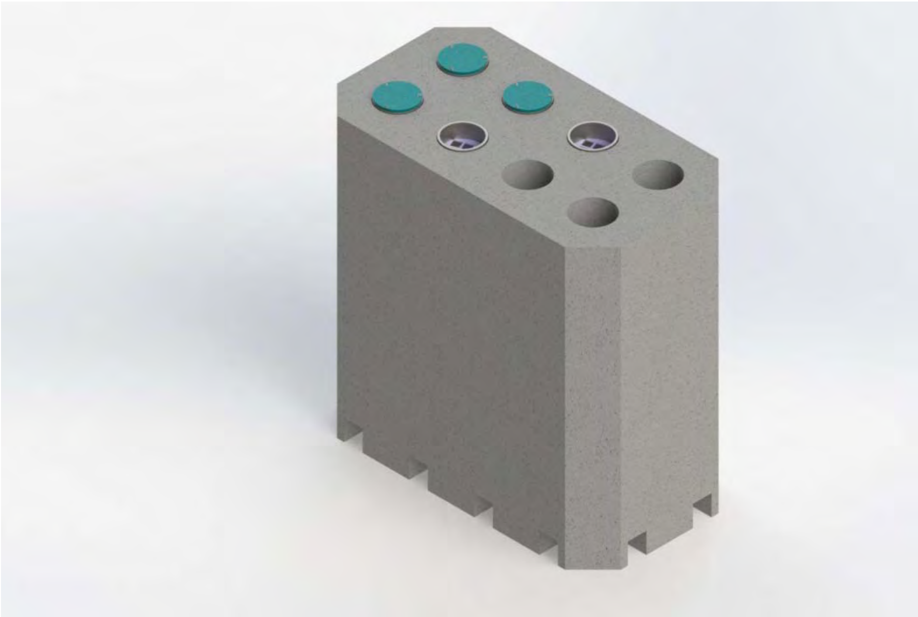


Figure C1-3
STAD Canister "Pillbox" Overpack



Whichever size STAD canister is used, they are taken to the CHB to be transferred from the transport cask to the storage overpack. A conceptual layout of the ISF is shown in **Figure C1-4 through Figure C1-7**.

The CHB has a single railbay with two rail lines. It is serviced by a single overhead traveling bridge (OTB) crane that can service railcars on either track. The operating floor of the CHB is dominated by two vertical transfer vaults, where the transport cask is unloaded and the STAD canister is transferred to the storage overpack. These shielded vaults accommodate the transport cask in the unloading cell, and the storage overpack in the receiving cell. The receiving cell can accommodate the 4-pack small STAD canister or the single overpack of the two larger STAD canisters.

Figure C1-4
ISF Layout for Small STAD Canister 8-Pack Pillbox Overpack Storage

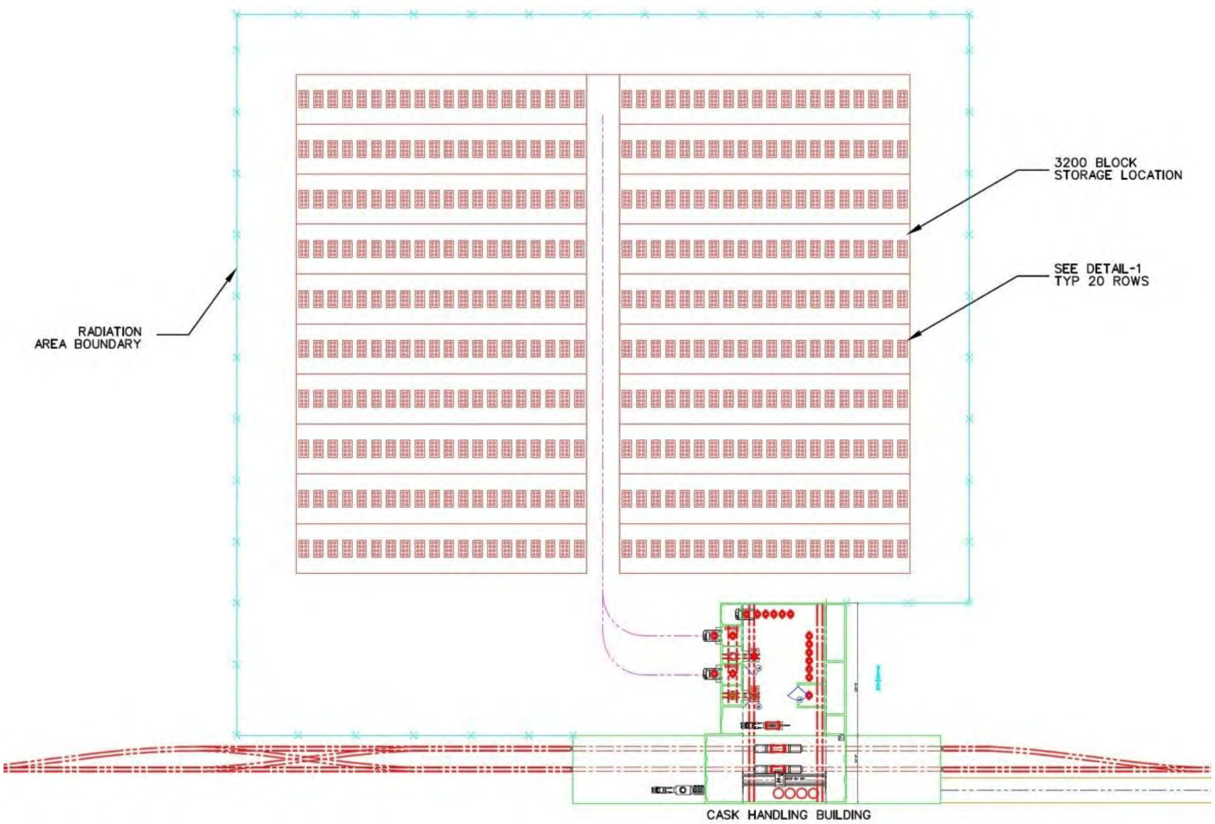
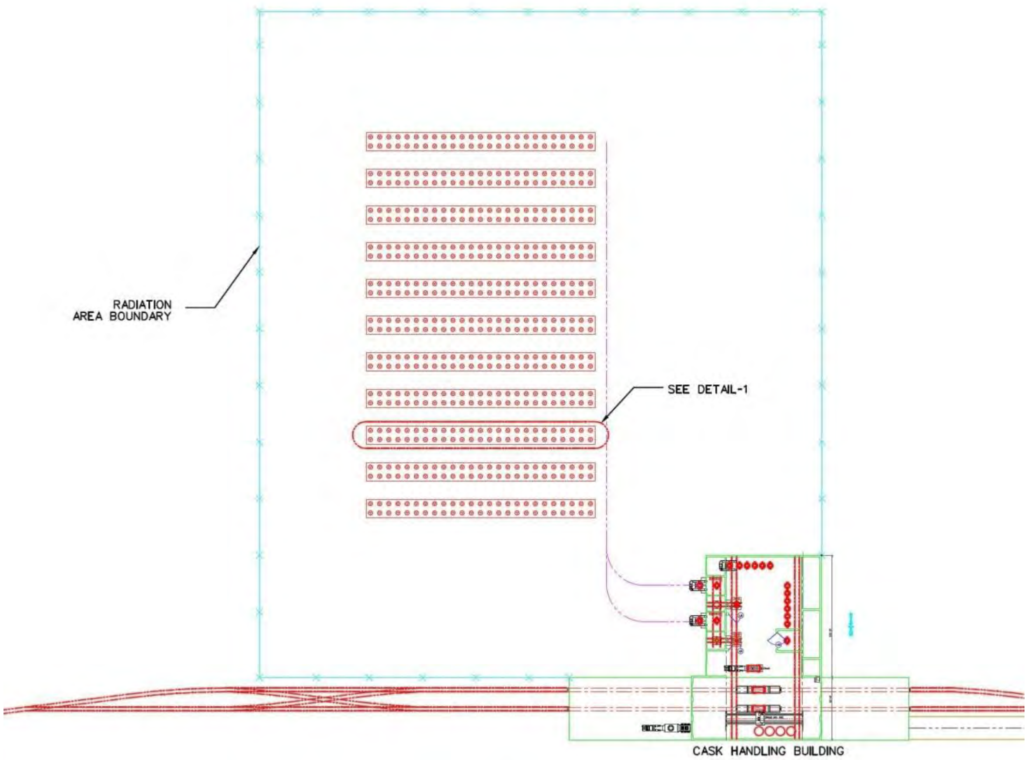


Figure C1-5
ISF Layout for Small STAD Canister 4-Pack Overpack Storage



Above the transfer cells is a mezzanine where two self-powered transfer sleeves on rails traverse over the transfer cells. These transfer sleeves can service either transfer cell and can index precisely over the casks in the transfer cells and are equipped with a single failure-proof hoist and powered grapple.

Once the transport cask is unloaded in the transfer cell, it is returned to the railbay to be recycled. The 4-pack overpack for the small STAD canister is loaded in the transfer cell. The 8-pack overpack for the small STAD canister remains on the pad and is loaded one STAD canister at a time by the VCT. The overpack for the medium and large STAD canister contains only one STAD canister. Once a storage overpack has been loaded in the transfer vault, it is picked by an overpack transporter and taken to the pad for storage.

Transporters can place and remove overpacks in the transfer cell from the outside loading pad and traverse to the storage pad via a dedicated heavy haul road.

Figure C1-6
ISF Layout for Medium STAD Canister Overpack Storage

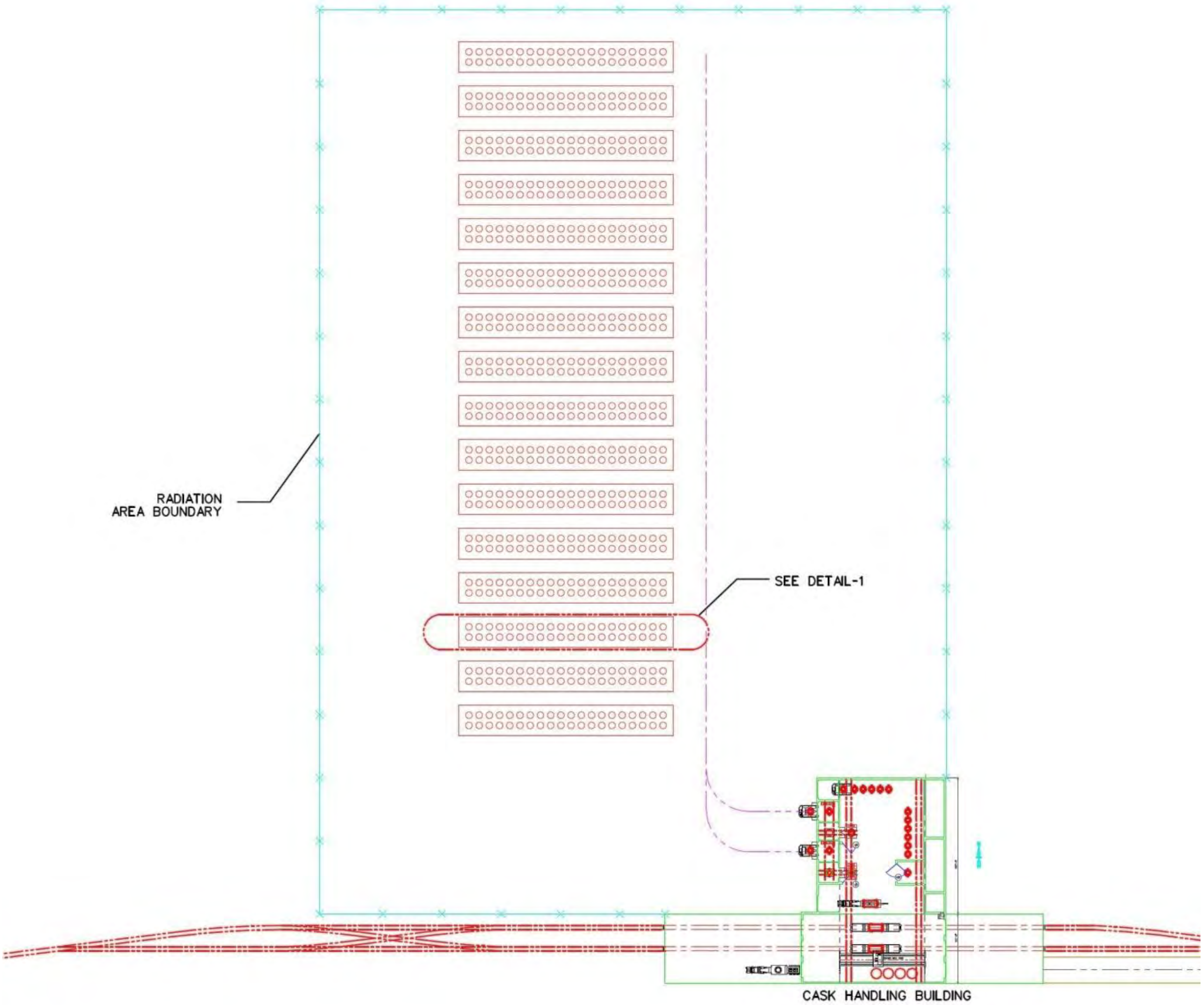
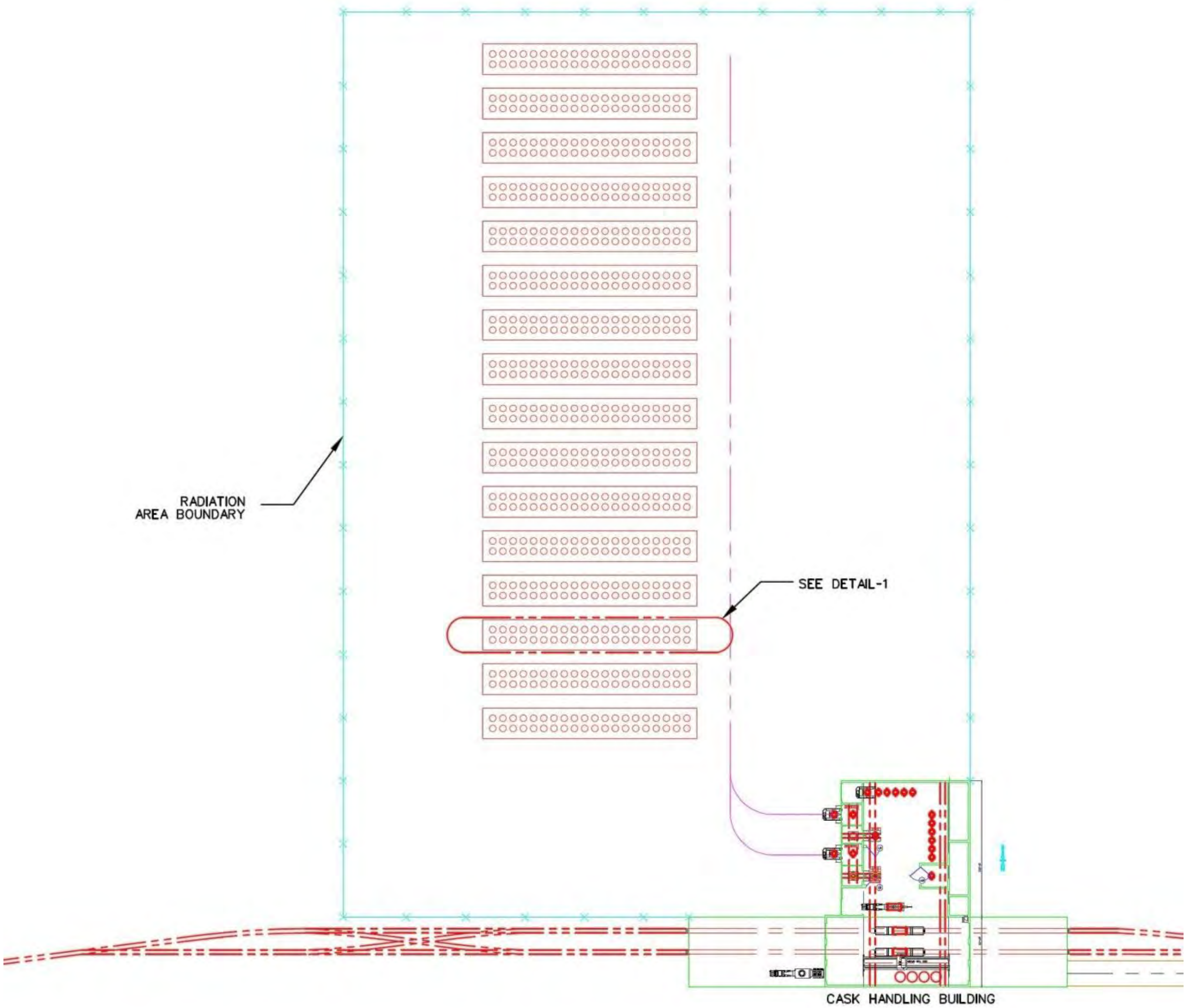


Figure C1-7
ISF Layout for Large STAD Canister Overpack Storage



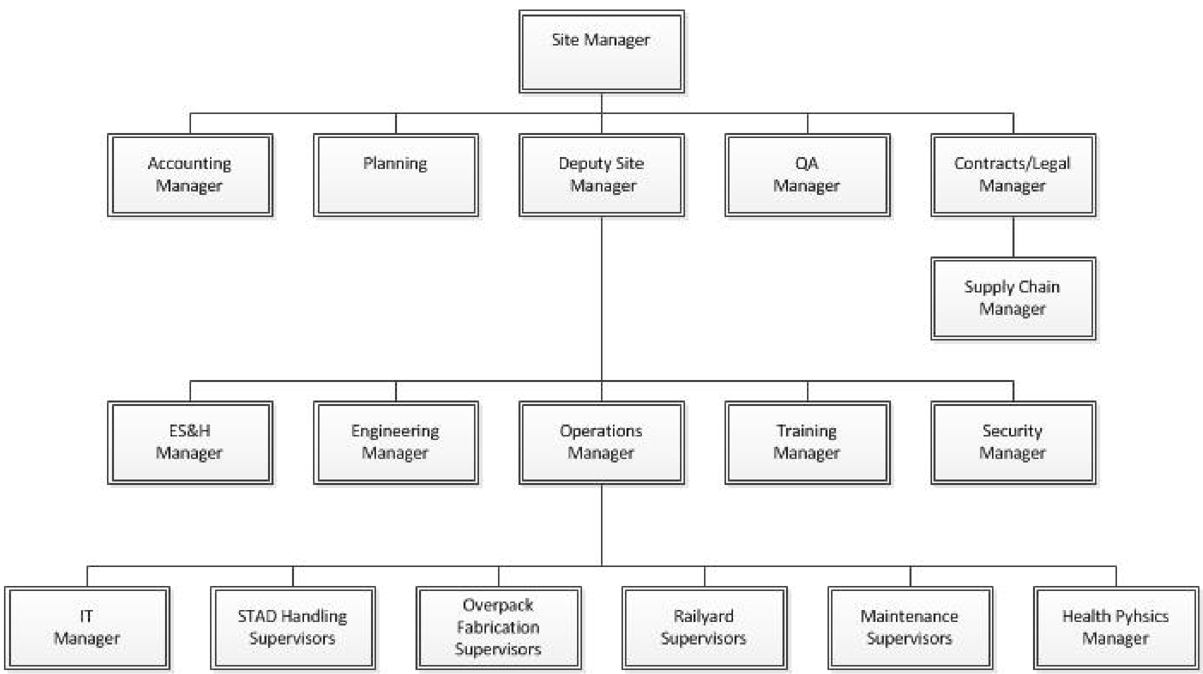
C1-2.2 ISF Operations

The ISF operates 24-hour, 7-days a week basis, but cask handling operations are limited to a single 8-hour shift, 40-hour work week. This has been done because the logistics issues associated with delivering a large number of transport casks to the site do not warrant around-the-clock cask handling operations. It also provides the ability to accommodate surges of work that might be necessary by the simple expedient of adding additional cask handling crew shifts. It is assumed that the ISF is operated by an independent contractor so that many of the administrative and Human Resource functions of an organization are not required within the site organization. The costs for these off-site services are covered in the overhead calculation for labor. **Figure C1-8** is the chart of the site organization.

There are two phases to ISF operations: Cask Handling Operations and Storage Facility Surveillance and Maintenance Operations. The Cask Handling Operations are the activities necessary to accept SNF packaged in STAD canisters from nuclear generators and to place the SNF into interim storage on site. This is a temporary activity lasting only as long as necessary to accept the design basis amount of SNF considered in this study. This activity lasts only a few years and involves the most labor intensive activities experienced at the ISF. Additional Cask Handling Operations will be necessary at the end of ISF life when the stored SNF is repackaged and shipped to its final destination.

Storage Facility Surveillance and Maintenance Operations are the ongoing activities that spans the entire operational lifetime of the ISF. This consists of all the activities necessary to plan, to monitor the performance and aging of the storage systems used to house and cool the SNF, and to provide for the safeguards and security necessary to protect the facility from unwanted intrusions and/or damage. The Storage Facility Surveillance and Maintenance Operations begin immediately upon the commissioning of the ISF and continue until the last STAD canister has been removed.

Figure C1-8
Typical ISF Organization Chart



During the Cask Handling Operations, many supporting activities need to be performed by the ISF staff. Fabrication of the storage overpacks is a full-time Cask Handling Operation activity, necessary to support STAD canister placement activities. The steel components of the storage systems most likely would be fabricated offsite by a vendor under contract to the

ISF. They are shipped to the site via rail and delivered to the overpack fabrication location near the concrete batch plant.

After receipt inspection to ensure that the components meet specifications, concrete is added to the steel components in accordance with the specification to complete the overpack design. It takes a minimum of 30-days after the arrival of the steel components from the manufacturer until the overpack is ready to accept SNF.[2]

The procurement activities necessary to support the overpack production must be well ahead of the delivery of the SNF because the lead time for overpack components, delivery and final fabrication is on the order of 6 to 12 months. Orders must be placed well ahead of the need in order to ensure that there is time fabricate and deliver the necessary components. Ideally, the system should support just-in-time delivery of all necessary overpack components so that they can be used directly by the Cask Handling Crews. However, as a practical matter, the system should allow for buffer storage of these components in order to assure that STAD canister shipments are not held up by the lack of availability of overpacks. This means that the Supply Chain Management must issue the purchase orders necessary to ensure the flow of material to the site. No shipment of SNF should be undertaken unless there is an appropriate overpack available on site.

Another major activity at the ISF necessary to support SNF placement is maintenance of the equipment necessary to perform the heavy lifts and heavy load movements associated with Cask Handling Operations. While Cask Handling Operations are underway, the major equipment necessary to move the heavy loads around the ISF must be available and in working order. Cranes, carts and wheeled vehicles that handle STAD canisters need to have single-failure-proof designs and be inspected and maintained rigorously to ensure operability and safety. Some of the commercially available machines may need to be modified to make them more robust to be able to meet the operational requirements and sustained work load during the early stages of the ISF life cycle.

In addition to physical labor provided by the Cask Handling Crews, the ISF requires planning and engineering staff to support operations. As already described, engineering, procurement and overpack fabrication activities need to be well ahead of actual SNF acceptance activities. The timescale of the work necessary to prepare the overpacks for the storage of SNF requires that the planning and engineering activities be performed nearly one year in advance of the SNF acceptance activities. Engineering activities are required for safety analyses and modifications to processes and materials to support SNF storage. Also, record keeping is required to identify the origin of each DPC at the ISF, its contents, the SNF

[2] It takes at least 30 days for the concrete to cure.

characteristics and its storage location at the ISF. In addition, all material certifications for SNF storage containers and other materials used for cask handling need to be meticulously maintained for easy retrieval in the future.

Finally, the largest functional activity at the ISF is physical security. The security group's functions will include daily, routing site security activities as well as inspection of all materials coming onto the site. This security function is the largest single group of the organization and is a 24-7 operation. In addition, IAEA oversight systems need to be developed and maintained in order to meet the potential oversight functions associated with safeguards and security systems.

Table C1-2 is a listing of the site organization staff. The organizational staff would be adequate to support the activities at the ISF necessary to support the cask handling activities. This staff totals 149 but does not include the cask handling crew. Many of the staff personnel are cross trained to enable them to support cask handling activities if necessary.

Table C1-2
Site Organization

Position	Staff	Position	Staff
Site Manager	1	Mechanical Engineers	4
Deputy Site Manager	1	I&C Engineers	1
Accounting Manager	1	Electrical Engineers	2
Planning Manager	1	Civil/Structural Engineers	4
QA – Manager	1	Quality Engineers	3
Contracts/Legal Manager	1	Buyers	2
Supply Chain Manager	1	Planners	3
Operations Manager	1	Security	54
ES&H Manager	1	Trainers	2
Engineering Manager	1	Railyard Operators	2
Training Manager	1	Supervisors	4
Security Manager	1	Mechanics	6
IT Manager	1	Electricians	4
DPC Handling Supervisors	1	Facility Operators	10
Fabrication Supervisors	1	IT Technicians	2
Railyard Supervisors	2	Administration Assistants	2
Maintenance Supervisors	2	EMT	1
Health Physics Manager	1	RR Tug Engineers/Brakemen	4
Nuclear Safety Engineers	2	Overpack Fabrication Team	15
Health Physicists	2		
		Total	149

C1-2.3 Cask Handling Crew Size

The Cask Handling Operations staff is dedicated to the movement of STAD canisters around the site. These operations are carried out by dedicated crews who focus on certain areas of the operation. This way, when multiple STAD canisters are processed each week, a crew learns specialized skills that will improve efficiency. The crews are: 1. the Railbay Crew, 2. the Cask Transfer Crew and 3. the Transporter Crew.

The Railbay Crew consists of the skilled crafts necessary to prepare the transport cask to be unloaded and later to be reassembled to be shipped off-site for subsequent transport operations. These activities include receipt inspection of the as-received package, removal and storage of the impact limiters, removal and storage of the transport cask cover, and removal and storage of the tie-down straps. Then, the Railbay Crew rigs the transport cask to be lifted by the overhead traveling bridge crane and places it on the transfer cart in the CHB.

Once the transport cask is returned to the railbay, the Railbay Crew inspects and surveys the cask, rigs it and repositions it back on the railcar, and then reassembles the transportation packaging for reshipment to the generator. This crew specializes in unloading the transport cask and repackaging empty transport casks for reshipment back to generators. There are two Railbay Crews that can be used in either bay since the activities are identical.

The Cask Transfer crews work in the CHB and transfer the STAD canister from the transport cask into the Storage Overpack before it is transported to the pad. As described above, there are two concepts for the overpack. The standard is a simple overpack similar to the designs used for vertical DPCs used at commercial nuclear facilities. The second approach utilizes uses a concrete "pillbox" overpack that houses eight small STAD canisters in a single overpack. These air-cooled overpacks are loaded in one of the CHB transfer vaults and the hauled to the concrete pad. These overpacks need a specialized transporter and **Figure C1-9** shows this transporter loading small STAD canisters into one of the "pillbox" overpacks.

Figure C1-9
Small STAD canister Pillbox Overpack and Transporter Concept

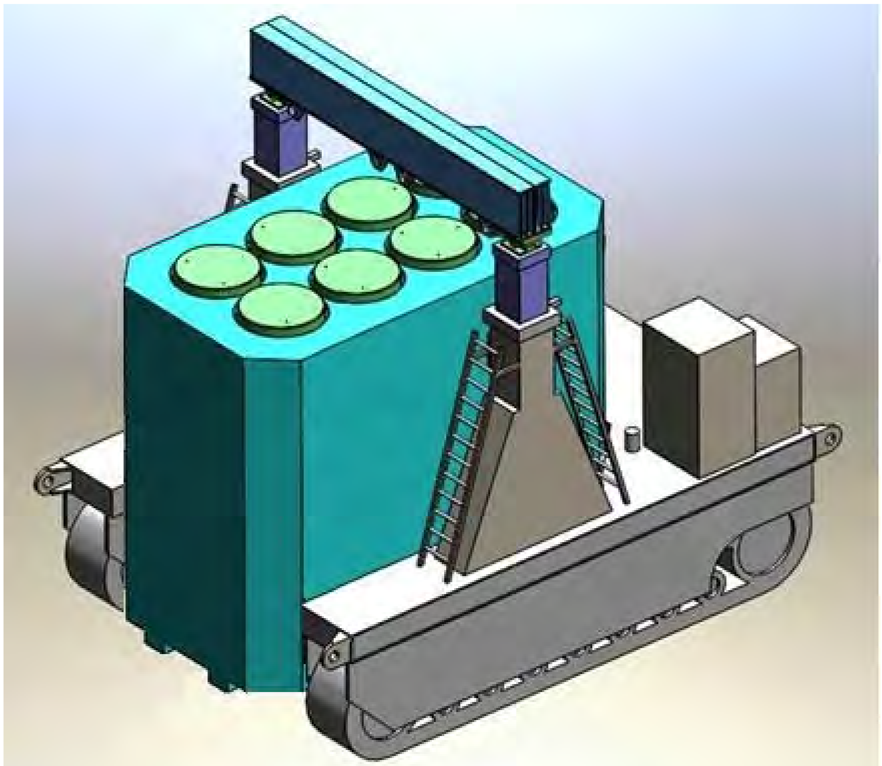


Table C1-3 shows the staffing for each major activity necessary to move STAD canisters from the transport cask to the pad. These staffing values are based on current experience with moving DPCs around operating nuclear sites to store the SNF at generator ISFSIs. Each STAD canister has a dedicated supervisor who is responsible for all activities associated with that package from receipt until the STAD canister is placed in the storage configuration at the ISF. In addition, a supervisor is assigned to each transport cask as it is serviced and reconfigured for reshipment.

Mechanics are responsible for removing the transport cask tie-downs, mechanical fasteners used for transport Cask lids closure, and the STAD canister lifting. Riggers are responsible for attaching the lifting devices to casks and for visually monitoring the lifts.

Electricians are instrumentation specialists who visually inspect the tamper proof seals on the transport casks and reinstall them for the reshipment. They also have a role in installing the instrumentation packages to the storage overpacks as part of the fabrication crew and attaching the instrumentation to the monitoring systems once the storage overpack is placed on the pad.

Health Physics teams are associated with all STAD canister handling activities as are QA/QC inspectors.

Crane Operators are needed for three different types of cranes. The railbay crane is a 200 ton OTB crane. The transfer sleeve hoist is a fixed hoist within a mobile transfer sleeve system. The transport cask lid crane is a jib crane dedicated to removing and holding the transport cask lid while the STAD canister is being removed. Crane operators also are responsible for operating a collection of other lifting devices and hoists associated with specialized transfer devices.

Heavy Equipment operators are the operators of the vertical cask transporters (VCT).

In order to size the crews, **Table C1-3** needs to be used with the time motion studies presented in **Section C1-2.6**. Several of the shifts do not require a full complement of workers for the entire shift. The idled workers will be rotated back to the matrixed workforce for other assignments as necessary. Certain workers such as the Supervisor, the Health Physics technicians and the QA/QC inspectors are area workers in that they either stay with the SNF canister throughout the process or cover a certain area of the ISF, such as the CHB HP techs. The Crane Operators use radio remote controllers for the OTB cranes, the shielded transfer sleeve hoists and for jib cranes so that one person could, in fact, operate all of the cranes in a certain area. The stick cranes used in the yard are controlled by a dedicated operator inside the control cab on the crane.

Table C1-3
Basis of Staffing – STAD canister in Overpacks on Concrete Pad

STADs - STADs in Overpacks on Pad		Supervisor	Mechanics	Electricians	Riggers	Ops *	HP	QA/QC	Crane	RR Ops *	Heavy Eq. Operator	Security *	Total Staff	Duration (hrs)
0)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	1	0	12	0.5
1)	Receive transport cask on railcar at Cask Handling Building	1	2	2	0	1	2	1	0	2	0	2	13	1
2)	Remove impact limiters and place in temporary storage	1	2	0	2	0	2	0	1	0	0	0	8	3
3)	Upend and lift transport cask off of railcar and place on unloading cell transfer cart	1	0	0	2	0	2	0	1	0	0	0	6	2
3a)	Remove railcar from railbay	0	0	0	0	1	0	0	0	2	0	2	5	1
4)	Unbolt and remove transport cask lid using jib crane	1	2	0	2	0	2	0	1	0	0	1	9	1
4a)	Secure transport cask on unloading cell transfer cart	1	2	0	2	0	0	1	1	0	0	0	7	0.5
4b)	Plan of the day and safety meeting	1	2	0	2	0	2	1	1	0	1	0	10	0.5
5)	Attach lifting lug to top of STAD	1	2	0	2	0	2	1	1	0	1	0	10	1
6)	Position transport cask transfer cart in unloading cell and close shield doors	1	0	0	2	0	2	0	0	0	1	0	6	1
7)	Stage empty storage cask in receiving cell using a transfer cart	1	2	0	2	0	0	1	0	0	1	0	7	1
8)	Unbolt empty storage cask lid and hoist on VCT	1	2	0	2	0	0	0	0	0	1	0	6	1
9)	Retract VCT from receiving cell and close shield doors	1	0	0	2	0	0	0	0	0	1	0	4	0.5
10)	Position shielded transfer sleeve cart over unloading cell	1	0	0	2	0	2	1	0	0	1	0	7	0.5
11)	Lower shield sleeve hoist and grapple STAD lifting lug	1	0	0	2	0	2	0	0	0	1	0	6	0.5
12)	Raise STAD into shield sleeve	1	0	0	2	0	2	1	0	0	1	0	7	1
13)	Position shielded transfer sleeve cart over storage cask in receiving cell	1	2	0	2	0	2	0	0	0	1	0	8	0.5
14)	Lower STAD into empty storage cask, release grapple, and retract hoist	1	0	0	2	0	2	0	0	0	0	0	5	1
15)	Open receiving cell shield doors and position VCT at storage cask	1	2	0	2	0	2	0	0	0	1	0	8	0.5
16)	Remove lifting lug from STAD	1	2	0	2	0	2	0	0	0	1	0	8	0.5
17)	Install storage cask lid	1	2	0	2	0	2	1	0	0	1	0	9	1
17a)	Secure seismic restraints	1	2	0	2	0	0	1	1	0	0	0	7	0.5
17b)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	1	0	12	0.5
18)	Pick up storage cask and transfer to pad using VCT**	1	0	0	0	0	0	0	0	0	1	0	2	2
18a)	Turnover to operations**	0	0	2	0	2	2	1	0	0	0	0	7	24
19)	Return VCT to CHB**	1	0	0	0	0	0	0	0	0	1	0	2	2
20)	Open unloading cell shield doors and position transfer cart under jib crane	1	2	0	0	0	2	0	1	0	0	0	6	1
21)	Install transport cask lid	1	3	0	0	0	2	1	1	0	0	0	8	1
22)	Lift transport cask and transfer to maintenance	1	0	0	2	0	2	0	1	0	0	0	6	1
22a)	Survey and wipedown transport cask	1	0	0	0	0	2	0	0	0	0	0	3	1
22b)	Reposition empty railcar to railbay	0	0	0	0	1	0	0	0	2	0	2	5	1
23)	Lift transport cask and place on railcar	1	2	2	2	0	0	0	1	0	0	0	8	1
24)	Install impact limiters on transport cask	1	2	0	2	0	0	1	1	0	0	0	7	2
25)	Release railcar for shipment	1	0	0	0	1	2	1	0	2	0	2	9	1

* These categories are loaned to the Cask Handling Crew

** For small STADs, these activities occur after 8 STADs have been placed in the overpack

The results of this effort are summarized in **Table C1-4** below. This staffing estimate is approximate since not all crafts are required for an entire shift. Also, some intermediate steps may include time periods in which certain crafts are not required. However, the craft personnel are still accounted in the total staffing, since these time periods provide opportunities for breaks for the workers and do not materially impact the assessment. The ISF labor pool will be a matrix structure where necessary craft and managers will be drawn from the site organization staff as necessary to achieve the desired operations. This is an obvious requirement because of the variability in the Cask Handling Crew size by shift in **Table C1-4**. Based on this study, the site organization staff will need to be increased by 44 workers to achieve the desired ISF throughput during the cask handling phase of the facility's life cycle. This results in a total ISF staff of 193.

Table C1-4
Cask Handling Crew Makeup

	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Average*
Supervisor	4	4	4	4	4	4
Mechanics	8	8	8	8	8	8
Electricians	4	4	4	4	4	4
Riggers	10	10	10	10	10	10
HP	8	8	8	8	8	8
QA/QC	4	4	4	4	4	4
Crane Operator	3	3	3	3	3	3
Heavy Eq. Operator	3	3	3	3	3	3
	44	44	44	44	44	44

	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Maximum*
Supervisor	4	4	4	4	4	4
Mechanics	8	8	8	8	8	8
Electricians	4	4	4	4	4	4
Riggers	10	10	10	10	10	10
HP	8	8	8	8	8	8
QA/QC	4	4	4	4	4	4
Crane Operator	3	3	3	3	3	3
Heavy Eq. Operator	3	3	3	3	3	3
	44	44	44	44	44	44

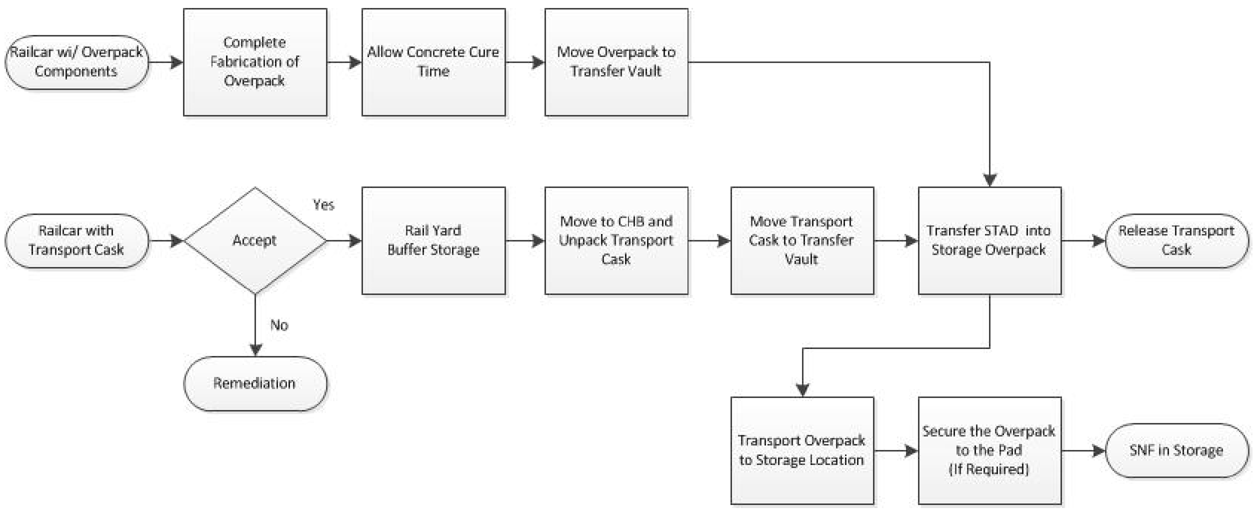
* To the nearest whole person

C1-2.4 Material Handling Flow Diagram

Figure C1-10 is a representation of the material handling flow for the S-PAD alternative for the ISF. It describes the three large material flows of the operation. The central flow is the movement of STAD canister containing SNF to the site. But equally important to the operations of the ISF are the material flows necessary to support the production of suitable storage overpacks to place the STAD canister into after being accepted by the site for storage.

The STAD canister storage overpacks are prefabricated by the vendors and shipped to the site as steel structures packaged to protect them during transit. The site crew will inspect these packages when they arrive on site to ensure that they are undamaged and then complete the fabrication by pouring concrete necessary to complete the storage cask in accordance with the vendor's specification.

Figure C1-10
Cask Handling Material Handling Flow Diagram[3]



The preparation time for a storage system is at least two months after receipt of the hardware from the storage system vendor. The lead time for this shipment could be 6 to 12 months. Therefore, up to a year ahead of the receipt of the SNF at the site, the supply chain manager needs to place an order for the necessary storage system components. The coordination of the supply chain for the Overpack Fabrication and the SNF storage operations will be the largest management challenge for this design alternative.

C1-2.5 Operations

C1-2.5.1 Operational Sequence

Cask handling operations are a series of heavy lifts and heavy equipment movements that move the SNF in sealed STAD canisters from the rail head to the storage pad. The operational sequence was benchmarked against current ISFSI operations at operating nuclear plants. Although no one has actually performed all of the operations at an ISF, each operation has a

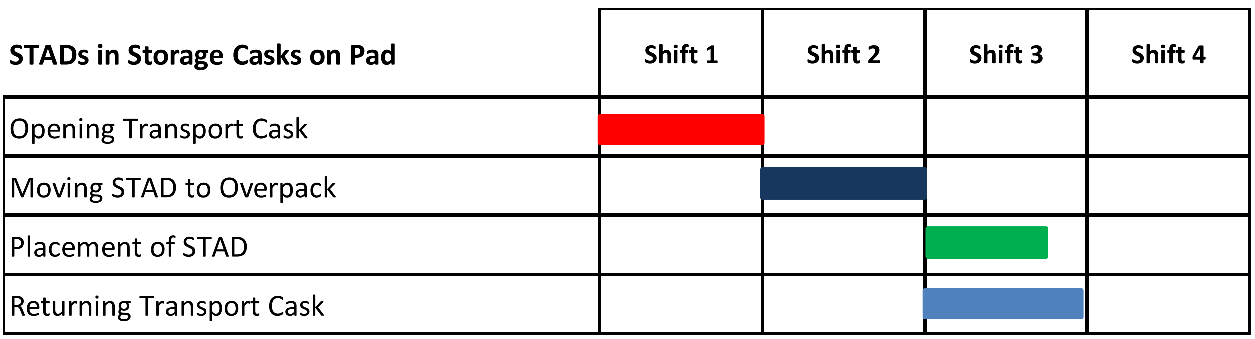
[3] Remediation is not part of this study's work scope and is not addressed other than to note that the packages are not accepted on site regardless of their condition.

precedent established in the nuclear industry. The crew sizes and the durations necessary to perform each activity therefore has basis. This benchmarking provides the underpinning supporting this operational sequence and the Time and Motion analysis the follows in **Section C1-2.6.**

Figure C1-11 shows the high-level schedule for the two storage concepts in S-PAD assuming 8-hour shifts. The operational sequence once the transport cask is accepted into the CHB can be divided into four large operations:

1. Opening the transport cask
2. Moving the STAD canister into the Transfer device or system
3. Placement of the STAD canister in the storage overpack and
4. Preparing for the turnaround of the transport cask.

Figure C1-11
High-Level Operational Sequences



It should be noted that this is essentially a three shift exercise regardless of the STAD canister size considered. If the "pillbox" overpack is used, the only change is that the placement of the STAD canisters in the pillbox overpack at the concrete pad rather than inside the CHB. It has no other impact on the operational sequence.

Once the transport cask is received in the CHB, the most time consuming operation is unpacking the transport cask from the railcar. This is a very labor intensive process that requires the removal of the cask cover, impact limiters, and the tie-down straps. This process takes an entire 8-hour shift to accomplish.

The STAD canisters are transferred out of the transport cask into the overpack in the transfer cell. A lifting lug is affixed to the top of the STAD canister while it is still in the transport cask. Then the transport cask is placed in one of the transfer cells via a transfer cart. A new storage overpack is placed in the adjoining cell by the transporter. The shield doors are closed and the STAD canister is withdrawn from the transport cask up into a transfer cask via a transfer port in the mezzanine floor. Once the STAD canister is in the transfer sleeve, the transfer sleeve is repositioned over the storage overpack access port and the STAD canister is lowered into the storage overpack. In the case of the small 4-pack STAD canister, the 4-pack STAD canister and transfer sleeve is positioned over one of the opening of the storage overpack. For the 8-pack STAD canister, the VCT transports each small STAD canister inside a transfer cask out to the pad, places the transfer cask on the pill box overpack and transfers the STAD canister into the pill-box overpack.

Inside the CHB, the lifting lug is removed from the STAD canister and the overpack lid is installed and bolted shut. Then the VCT, or other transport device, picks the storage cask and transports it to and places it on the storage pad. If the seismic requirements dictate, the storage overpack may be secured to the pad.

The transport cask is returned to the railbay where it is surveyed and inspected for damage. Then the transport cask is mated with its original railcar and the shipping package is reassembled: tie-down straps are installed, the transport cask cover is secured and the impact limiters are reinstalled, and the transport cask cover is secured. This process takes about one shift to accomplish.

C1-2.5.2 Limits to Operation

Railbay

S-PAD Cask Handling Operations are a three shift process. Two of those shifts take place in the railbay. Therefore, the railbay is central to ISF operation and its design limits the ISF throughput. Since there is only one railbay, this limits the number of railcars that can be unloaded to maintain a constant supply of transport casks to be unloaded. Since there are two rail lines in the railbay, the CHB is able to supply two STAD canisters to be place into overpacks every four days.

Overhead Traveling Bridge Cranes

The railbay requires a heavy lift crane in order to maneuver the transport cask off of the railcar and onto the transfer cart in the CHB. It also requires a crane to reverse this process and to replace the transport cask onto the railcar. While these activities are underway, they dominate the OTB crane and it is unavailable for any other activity. The CHB has only one OTB crane. This is adequate to support the existing design with only two rail lines in the railbay, but it limits the potential throughput to 2½ STAD canisters per week. As described above, if the railbay is expanded to support three rail lines instead of two, the OTB crane availability would need to be doubled in order to increase throughput.

The OTB cranes would probably need to operate on the same set of rails, so doubling them would not necessarily double the throughput. It would be necessary to ensure that the next crane to transfer a load to or from the railbay would be shuffled to ensure that the cranes would not interfere with each other during operations.

Transfer Vaults

The transfers of STAD canisters require the vertical movement out of the transport cask into a transfer sleeve that moves laterally over the overpack and lowers the STAD canister into the overpack. This process takes a little more than a shift to accomplish and with a little non-critical path activity prepositioning the overpack into the vault can be accomplished in a shift. Since the operational sequence requires the transfer cells to be used on consecutive shifts, there need to be two vaults. This will enable one cell to be used to transfer the STAD canister while the next overpack is being prepositioned in the second vault. So, two cells are necessary.

With the current design, the cells are being used approximately 50% of the time. This permits enough time for necessary maintenance.

C1-2.6 Time and Motion Analysis

C1-2.6.1 Methodology

No one has operated a national scale ISF for the dry storage of SNF and there is no operational experience with STAD canister designs. For this reason, this study is based on a theoretical construct based on a high-level operational sequence developed by the concept designers. These high-level activities were decomposed down to their constituent activities. At this level, the activities were generally ones that had been performed by operators at existing nuclear facilities, or that could be estimated by small extrapolations of existing operational experience. Interviews were conducted with several individuals with real, hands-on operational experience with moving SNF to achieve a consensus on the completeness, the durations and the staff size necessary to achieve each of these constituent activities. These were then pieced together to develop a bottom up estimate of durations and crew sizes for each step.

Based on feedback from these individuals, additional steps were added to recognize the practice of having a "Plan of the Day" meeting and a safety meeting at the start of each shift. Also, steps such as HP surveys of the emptied transport casks, and adding seismic restraints to packages containing SNF at the end of a shift were added to allow time for these necessary steps.

Once the operational sequence was developed, the sequences were considered in parallel to determine how many STAD canisters could be placed per week. Several basic assumptions were made. The first was that a large supply of transport casks on railcars was staged on the site ready for processing. If the ISF Railyard is empty or contains only two railcars during a week, this time and motion study does not apply. The two railcars will be processed and the Cask

Handling Crews will be given other duties to fill up the week. So, the first inherent assumption is that the logistics supply chain is adequate to fully challenge the capacity of the ISF.

Secondly, this study only considers operations that are already developed and in operation at existing operating nuclear plant experience. No unusual enhancements were considered.

Finally, no operation involving the movement of a STAD canister would be started during a shift if it could not be completed by the end of that shift. This is necessary because the CHB does not operate continuously, so no load would be left hanging or in some other unstable condition that would jeopardize the integrity of the SNF or its confining structures in the event of a design basis event. Therefore, the STAD canister is not allowed to be abandoned in any operation at the end of a shift without first securing the STAD canister.

As stated earlier, this study considers only a single 8-hour shift per week with no overtime. Clearly, the throughput could easily be increased by adding workers and shifts, and indeed that would be a cost effective expedient if additional capacity is desired. However, a working assumption of this study is only a single, 40-hour shift is necessary per week. Based on the certain problems with the logistics of moving SNF to the site, it is considered that this is a reasonable approach.

C1-2.6.2 Conclusion

It was determined that the S-PAD throughput with all of the assumptions is five STAD canisters (or five 4-pack small STAD canisters) placed into storage each week. This conclusion is independent of what size STAD canisters were considered. So, while the movement of STAD canisters is the same, the placement of SNF into storage is very different**.** **Table C1-5** captures the differences among the STAD canister options available.

Table C1-5
ISF Throughput Using STAD Canisters

Option	STAD Canister	STAD Capacity		MTHM per Year (260 STADs/yr)	5000 MTHM Time
		PWR	BWR		
S-PADa	Small	16	36	1898	2.6 years
S-PADb	Medium	12	32	1404	3.6 years
S-PADc	Large	21	44	2470	2.0 years

Several observations came out of the Time and Motion Analysis. First, the use of “pillbox” overpacks that accommodate eight STAD canisters in a single overpack has no impact on the ISF throughout. It has a negligible impact on dose rates and Cash Handling Crew size, but otherwise no significant impact on the cask handling operations.

Second, with the CHB having two railbays, it is the OTB cranes that determine the maximum throughput of the CHB. The single OTB crane is the limiting element in the throughput of this alternative. It precludes increasing the throughput of the facility and should it fail or experience an outage, it would effectively prevent the CHB from functioning.

Third, two overpack transporters are needed to be operational in order to maintain full ISF throughput. These are extremely slow moving machines. Their size and mass make them destructive of the road bed if they move too rapidly. Moreover, they are restrained from moving too rapidly when carrying a STAD canister in order to limit the potential impact should there be a failure of any kind. They become critical path constraints if any one of them is out of service. In addition, they are currently designed for a limited amount of duty. The ISF would use these machines far more than their design. This could force a great deal of maintenance to keep them available. One or two spares are considered necessary for the long-term functionality of the ISF.

Figure C1-12 below shows the schedules for the S-PAD alternative. It should be noted that all of the schedules are the same. The only difference occurs if the “pillbox” overpack is used. Then the steps (#18, 18a, & 19) are only performed after every eighth STAD canister.

The activities on the Y-axis are the steps necessary to process the STAD canister from when they enter the Cask Handling Building until the empty transport cask has been reinstalled on the railcar and removed from the CHB. The time across the top of the schedule is in hours. The red bars are critical path activities; the blue are near critical path activities. It has been assumed that once a DPC has been placed in the storage configuration on the ISF pad, a period of 24-hours is necessary to perform the required surveillance and safeguards activities. This activity is shown as a green dashed line on this chart but is not really part of the cask handling crew’s scope. These activities are done by ISF Operations. The activities include a series of temperature, air flow and radiation measurements over the initial 24-hour period to validate that the expected performance has been achieved.

The repackaging of the emptied transport cask was stretched out as a result of the Time Motion study to permit the OTB crane to finish unloading a new transport cask. Unloading new transport casks is given priority over repackaging the emptied transport cask.

The schedules in **Figure C1-12** were then placed in series and in parallel to establish the maximum throughput of the ISF. **Figure C1-13** is a week of this operational sequence schedule. It shows how the work flows from one transport cask to the next. The bars are color coded based on the major equipment needed for the activity. One can look vertically down a scheduled hour to verify that the same piece of equipment is not being used for two activities at the same time. **Figure C1-13** is an extract of a four week schedule. It takes four weeks for the sequence to repeat. In four weeks, this system is able to place 10 STAD canisters into storage.

Figure C1-12 - Time Motion Schedules for S-PAD

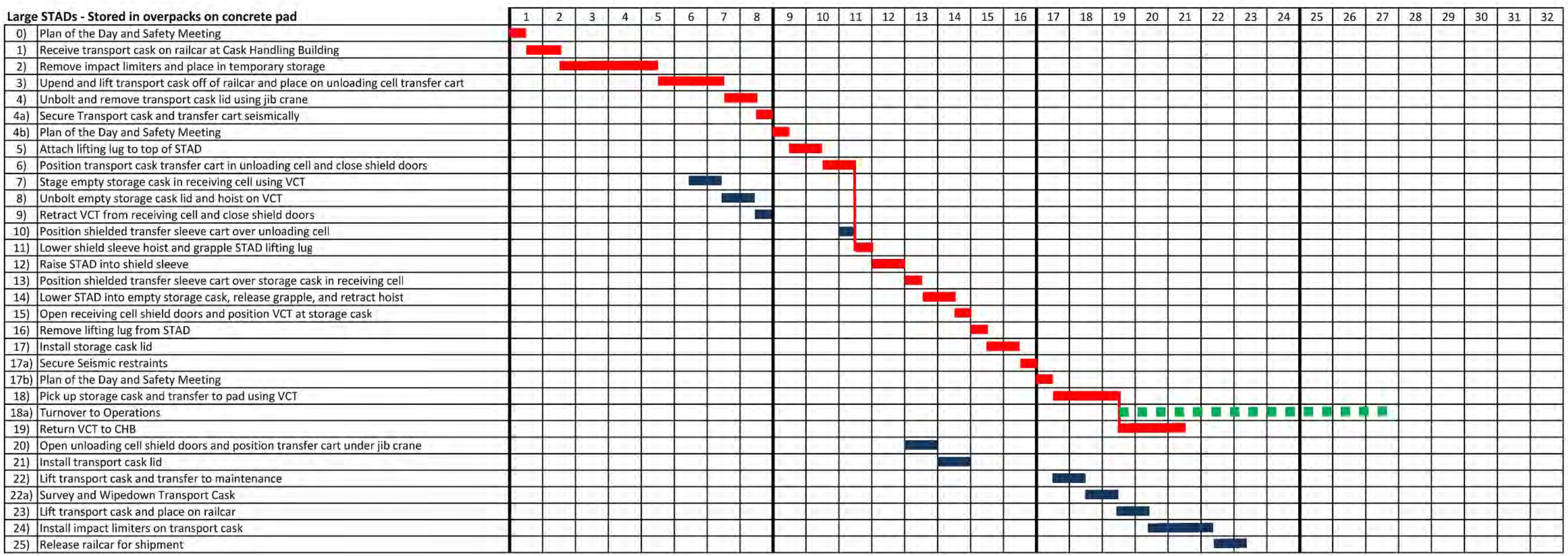


Figure C1-13 – Typical Work Plan for S-PAD

	Week 1					Week 2				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Railbay #1	Transport Cask #1 Unload	STAD #1 Transfer to Pad	Transport Cask #1 Reload		Transport Cask #5 Unload	STAD #5 Transfer to Pad	Transport Cask #5 Reload		Transport Cask #9 Unload	STAD #9 Transfer to Pad
Railbay #1		Transport Cask #2 Unload	STAD #2 Transfer to Pad	Transport Cask #2 Reload		Transport Cask #6 Unload	STAD #6 Transfer to Pad	Transport Cask #6 Reload		Transport Cask #10 Unload
Railbay #2	Transport Cask #19 Reload		Transport Cask #3 Unload	STAD #3 Transfer to Pad	Transport Cask #3 Reload		Transport Cask #7 Unload	STAD #7 Transfer to Pad	Transport Cask #7 Reload	
Railbay #2	STAD #20 Transfer to Pad	Transport Cask #20 Reload		Transport Cask #4 Unload	STAD #4 Transfer to Pad	Transport Cask #4 Reload		Transport Cask #8 Unload	STAD #8 Transfer to Pad	Transport Cask #8 Reload

	Week 3					Week 4				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Railbay #1	Transport Cask #9 Reload		Transport Cask #13 Unload	STAD #13 Transfer to Pad	Transport Cask #13 Reload		Transport Cask #17 Unload	STAD #17 Transfer to Pad	Transport Cask #17 Reload	
Railbay #1	STAD #10 Transfer to Pad	Transport Cask #10 Reload		Transport Cask #14 Unload	STAD #14 Transfer to Pad	Transport Cask #14 Reload		Transport Cask #18 Unload	STAD #18 Transfer to Pad	Transport Cask #18 Reload
Railbay #2	Transport Cask #11 Unload	STAD #11 Transfer to Pad	Transport Cask #11 Reload		Transport Cask #15 Unload	STAD #15 Transfer to Pad	Transport Cask #15 Reload		Transport Cask #19 Unload	STAD #19 Transfer to Pad
Railbay #2		Transport Cask #12 Unload	STAD #12 Transfer to Pad	Transport Cask #12 Reload		Transport Cask #16 Unload	STAD #16 Transfer to Pad	Transport Cask #16 Reload		Transport Cask #20 Unload

NOTES:

1. The highlighted boxes show the critical path activity in the railbays. Note that work is always on going in the railbays.
2. The railcars are removed after the work crews are done with them and replaced by the next railcar to be processed.
3. The cycle is four shifts long.
4. This process is the same for all STAD canister sizes.
5. The STAD canister to pad design can process 20 STAD canisters in four weeks; averaging 5 a week

C1-3.0 ISF Construction

The ISF will consist of a number of features and structures that will need to be constructed for the facility to operate. They include:

- ISF Site (with access road and utilities)
- Railroad spur and yard
- Storage area
- Cask Handling Building
- Protected Area (security boundary, cameras, intrusion detection and lighting)
- Overpack fabrication area
- Concrete batch plant
- Administration building
- Security/access control building
- Warehouse/maintenance facilities

C1-3.1 ISF Site

The ISF site is assumed to be placed on approximately one square mile of property. Not all of the land will require construction, only the area for the initial storage area. An access road and electrical utilities will need to be constructed into the property. The site access road will consist of an asphalt paved 2 lane road from the nearest highway into the ISF. The location of the site will determine if mechanical utilities (domestic water, wastewater, natural gas) can be supplied from local means or if these will need to be self-contained. A remote site requiring self-contained utilities can use water wells or trucked-in tanks of water depending on the underground water capability. Wastewater can be discharged through drain fields. Propane gas can be supplied if no natural gas lines are near the site.

The site will require an Owner Controlled Area (OCA) fence which will likely consist of a chain link fence to discourage trespassers from entering the site and keep animals out. The fence requires minimal construction and establishes a good facility boundary. Just inside the fence a gravel security road can be constructed to enable guard patrols around the site. This fence must be placed nearly a half mile from the actual storage area in order to meet regulatory requirements which maintain a safe distance from the storage area to minimize radiation doses to the public.

The purpose of the OCA is to establish the portion of the property that maintains a level of secured control. Within this boundary, security maintains control and patrols for unauthorized individuals. In addition, 10 CFR 72.106 requires that all SNF storage and handling operations be maintained at least 100 meters from the OCA boundary. All CSF functions are contained within this boundary.

C1-3.2 Railroad Spur and Yard

The ISF will need railroad tracks from the mainline to receive incoming train consists and prepare for outgoing train consists. A rail portal at the Protected Area boundary and a rail yard near the storage area will also be required.

The purpose for the rail yard is to provide adequate railcar storage for incoming and outgoing SNF train consists, and access to the CHB. The rail yard must be designed to allow flexibility for maneuvering yard switchers, railcars, buffer cars, and escort cars.

It is assumed that the rail yard will consist of at least 4 tracks – 2 tracks to receive inbound trains and 2 tracks for staging outbound trains. The yard includes a runaround track to permit the yard switchers access around the tracks. The yard also includes a lead line and a spur off the lead line accessing the CHB.

Construction of the rail yards will involve excavation, structural fill, potential geotextile materials to maintain soil stability, gradation to establish various elevations to ease railcar movements, heavy steel rail, ties, several rail turnouts, ballast placement, lighting, and other minor railroad related features.

C1-3.3 Storage Area

For the S-PAD storage alternative, the storage area will consist of reinforced concrete storage pads to support all of the STAD overpacks. The storage pads would be designed to ensure adequate safety and to mitigate the effects of site environmental conditions, natural phenomena, and accidents including stability and liquefaction caused by earthquake conditions and settling over the life of the facility.

A typical storage pad consists of a reinforced concrete slab 30 to 36 inches thick. The size of the storage pad depends on the type of storage system (horizontal or vertical), the number of storage units to support, and the shape and limitations of the physical space where the pad is to be placed.

The STAD overpacks are likely to be placed on a storage pad in an array like current commercial overpacks. Any array wider than two overpacks prevents a VCT from ready access to all the overpacks. An overpack requires spacing from adjacent overpacks for heat rejection and VCT maneuverability.

To store up to 5,000 MTHM of SNF, the ISF will need to store approximately 926 small STAD canisters (4-pack canister) or 348 small STAD canisters (8-block pill box), 926 medium STAD canisters, or 463 large STAD canisters. This will likely consume more than the 250 acres used for the commercial pad ISF arrangement.

C1-3.4 Cask Handling Building

The S-PAD storage alternative would require some facility in order to offload transport casks from the railcars and perform canister transfer operations for all DPCs. The Cask Handling Building (CHB) provides these functions. The CHB for this report has been designed with 2 rail bays, 2 truck bays, 4 vertical canister transfer cells, 2 - 200 ton single-failure-proof overhead bridge cranes, laydown area for impact limiters, staging area for transport casks and office area. The CHB would be a reinforced concrete structure with thick walls to protect all SNF casks, canisters, overpacks, and cask-handling equipment from the effects of earthquakes, tornado winds, tornado-generated missiles, fire, and explosions. The throughput would be 3,000 MTHM/yr with one shift per day, 5 days per week.

C1-3.5 Protected Area

The PA is an area within the OCA large enough to encompass the ISF rail yards, CHB, and storage pads. The PA consists of two physical barriers: (1) a security fence and (2) a nuisance fence separated by a 20-foot wide isolation zone. Within the isolation zone is an intrusion detection system that provides ground surveillance to detect any unauthorized entry into the PA. Assessment of unauthorized intruders is provided by illumination along the PA perimeter and throughout the storage area and a CCTV system, consisting of both fixed and pan-tilt-zoom cameras to monitor activities around the PA boundary from the security building.

The PA is surrounded by a passive vehicle barrier system (VBS) that is constructed of large concrete blocks to prevent any vehicles from getting near the PA boundary. The VBS is physically placed at a distance so that a pressure wave from a vehicle-born improvised explosive device cannot affect the storage containers or cask handling activities. Active VBSs are placed at large gates that accommodate railcars loaded with SNF transport casks or vehicles to prevent any unauthorized entry. These VBSs can be lowered once the railcar or vehicles are inspected and cleared for entry.

Security equipment is typically powered from normal off-site power supplies. However, in the event of a loss of off-site power, an Uninterruptable Power System (UPS) consisting of batteries would be used to provide seamless power to all electronic security equipment. The UPS and site lighting would be backed up by an emergency diesel-powered generator located within the PA.

Bullet resistant enclosures would be situated at strategic locations within the PA to provide protected locations for security force personnel during a security event.

C1-3.6 Overpack Fabrication Area

All pad type storage overpacks required some level of fabrication. The vertical storage overpacks are steel shells that are manufactured in a qualified QA plant. The shells are designed with a size and weight that allows them to be shipped to an ISFSI via rail. Once at the site, the shells are fitted or filled with concrete for radiation shielding. The placement of concrete is the only fabrication activity that is required onsite. The work is performed on a dedicated fabrication pad. It may also make sense to manufacture the steel shells however, this activity requires overhead cranes, CNC cutting machines, steel rolling mills, heavy welding machines, stress relieving furnaces and other equipment that requires a major commitment. If the ISF requires up to 250 vertical overpacks per year, a major steel manufacturing facility could be beneficial.

Both horizontal type modules and vertical type overpacks require a considerable quantity of concrete which would make up much of the fabrication area activities.

C1-3.7 Concrete Batch Plant

Because of large amount of concrete that would be continually need to be supplied for construction of pads and overpack fabrication, the ISF would include a site concrete batch plant. In addition to the batch plant, the ISF would need to include equipment associated with concrete supply operations such as concrete trucks, concrete pumper trucks, mobile cranes, backhoes for excavation, front-end loaders and dump trucks for moving soil, compaction equipment, powered concrete tools and small concrete finishing tools.

C1-3.8 Site Support Buildings

The ISF will need to include a number of support buildings. An administration building will need to be constructed to house managers, admin staff, engineers, document storage, licensing records, health physics personnel, radiological records, training rooms, etc.

A security/access control building will need to be constructed to house security personnel, security managers, the Central Alarm Station, safeguards information, etc. The building can be sited at the Protected Area boundary to provide access control for personnel entering the storage area. This most likely would include a badging station, explosion detectors, metal detector to monitor persons entering the secured area, x-ray machines to monitor materials brought onsite, and turnstiles delineating the PA boundary.

A warehouse/maintenance building will need to be constructed to stockpile materials shipped to the ISF for overpack fabrication, pad construction, inspection equipment, general supplies, etc. This structure could also double as a maintenance building for general maintenance activities as well as transporter and canister handling equipment maintenance.

The ISF would also include a number of other features such as fire protection, potable water, sanitary drains, electrical power and distribution, and communications.

C1-4.0 ISF Expansion

C1-4.1 Storage Area Impact

ISF expansion of another 5,000 MTHM would require doubling the storage area size. Construction of the second 5,000 MTHM storage area should be performed outside of the ISF Protected Area to facilitate construction activities without stressing security. Once the pads are constructed, the PA would be expanded to encompass the additional storage pads. Of course, this type of construction would mean that a significant corridor would need to be placed between storage areas, and large separation corridors to ensure that construction workers receive as low as reasonably achievable (ALARA) radiation dose from the existing loaded storage units.

The PA would be expanded in size as required to accommodate the new storage pads including fencing, intrusion detection system equipment, number of CCTV cameras and yard illumination.

Electrical power would need to increase to accommodate a larger ISF to account for the additional security, lighting and temperature monitoring equipment. The Uninterruptable Power System (UPS) and security backup emergency diesel-powered generator would need to be able to accommodate the new loads of the larger site.

C1-4.2 Increased Throughput Impact

The CHB constructed for the ISF has a throughput capacity of 3,000 MTHM/yr which may be adequate for an Expanded ISF. Even if the throughput requirements are increased to 4,500 MTHM/yr, the CHB would not need to be enlarged. Rather, adding a second shift would effectively double the throughput of the building to 6,000 MTHM.

To expand the ISF, the rail yards, Administration Building Warehouse/Maintenance Building, Security/Access Control Building and other site infrastructure utilities may not require many modifications. Backup electrical power service for illumination and security of the larger storage area, additional security guards, increased CCTV and intrusion detection equipment are a few modifications that may be required to accommodate the Expanded ISF. For example, these additions may require a larger Security/Access Control Building for the additional security personnel as well as a larger CAS for the increased CCTV and intrusion detection systems. However, if the ISF is designed with the understanding of the Expanded ISF that increses the storage area, then these items could easily be included in the initial design.

After the expansion, the ISF may need to procure additional vertical cask transporters (VCTs) to accommodate the expansion of the site. Although one VCT may be able to handle the throughput, it is recommended that the ISF should employ at least three. With the continual work, it is very likely one transporter (on average) could be in maintenance status at all times and the third transporter could alleviate any backups that may occur.

C1-4.3 Modular Expansion Impact

For pad storage, the only modular construction is the concrete storage pads and overpack fabrication. These modular units are very small which allows construction activities to be conducted over a long period of time. This advantage distributes capital costs over several years which is one reason why this storage alternative is useful at reactor sites since SNF growth also occurs over a long period of time.

C1-5.0 Performance of Structures, Systems and Components

C1-5.1 Structural and Seismic Evaluation

Seismic evaluations for pad mounted storage systems will need to be performed to ensure that the STAD storage system is capable of withstanding the accelerations generated by the design earthquake, that the pad is sized to maintain structural integrity under loading applied by the storage systems, that the seismic restraints (if any) will transfer the inertia loading from the storage systems to the pad, and that the pad has sufficient engagement in the soil to prevent soil failure.

Seismic evaluations will need to show that the STAD overpack has the capacity to resist accelerations applied at the top of the pad for both the 0.25g and 0.75g cases.

The sliding and tip-over resistances of the STAD storage systems will need to show that they have an overturning moment that is less than the restoring moments for both the 0.25G or 0.75g earthquakes. If they cannot, then seismic restraints which couple the storage systems to the pads must be installed to increase the seismic inertia loading applied to the pad and the storage systems.

C1-5.2 Thermal Evaluation

Thermal evaluations for existing vertical storage systems are documented in vendor Safety Analysis Reports. Vertical storage overpacks have multiple openings at the bottom to introduce air to the space between the exterior surface of the STAD canister and the interior surface of the overpack. The air is drawn up along the sides of the STAD canister, is warmed by the STAD canister via free convection, and is exhausted through vents in the overpack at the top.

In the vendor SARs, the storage system thermal models show that there is sufficient margin between the maximum calculated cladding temperature and the allowable cladding temperature to consider the STADs qualified for pad storage in their corresponding storage overpacks for the common set of normal, off-normal, and accident environmental conditions.

A detailed discussion of the thermal evaluation is provided in **Section 6.2** of the report.

C1-5.3 Radiological Evaluation

The exposures to radiation for the workers in this study are based on historical radiological source terms from dry storage systems at commercial nuclear plants. They demonstrate differences among the various options rather predict actual doses. STAD canisters would be licensed for newer spent fuel with different source terms that are yet to be determined. Therefore, doses from STAD canisters were not calculated for this study. However, some factors are noteworthy:

1. Due to self-shielding within the STAD canister, the contact dose rate for any size STAD should be within a few percent of the contact dose rate for other size STAD canister containing the same SNF. Since worker dose rates are determined by a few activities that involve close contact with the canister, the worker exposures for the different STAD canisters are based primarily on the handling activities required not the STAD type.
2. The activities necessary to transfer a STAD canister from a rail car to the storage location are assumed in this report to be similar to the commercial DPC processes in order to provide a comparison of the different storage alternatives. STAD canisters and their associated transport, transfer casks or storage units can be designed to remove or reduce dose intensive activities. For example, attaching and removing lifting lugs to DPCs is major contributor to dose rates. An integral lifting means on the STAD will remove considerable worker dose.
3. STAD transport casks, transfer casks and storage units can be designed with improved shielding. STAD canisters are smaller and lighter than commercial DPCs, so the various shielding casks can be heavier without impact shipping or lifting infrastructure. This can reduce worker dose without changes to rolling stock or cask handling equipment.
4. STAD handling systems can be designed with more automated features reducing manual activities next to the canister. Commercial systems were developed as temporary expedients to address fuel pool capacity and life extension issues. STAD canisters can be designed to improve performance based on industry experience.
5. Study #1 determined that worker doses are fairly consistent for all alternative storage methods. Study #2 determined that the method used to process incoming SNF shipments has a greater effect on worker dose than the storage method – more automation can substantially reduce worker doses versus manual handling. Similar results are likely to be the same with STAD canisters.
6. Offsite doses to the public are expected to be very similar to commercial systems. Offsite dose is a function of shielding and distance. Doses to the public can be reduced with additional system or building shielding and/or by increasing the distance from the storage area to the Owner Controlled Area boundary. The exposures to radiation for the workers due to STAD canister processing at the ISF cannot be assessed at this time since they are still conceptual. It is very difficult to predict what overall dose would be received for each canister transfer let alone the dose each worker receives.

C1-5.4 Design Life, Aging and Maintenance Evaluation

Currently, storage systems may be designed for 40 to 100 years but are only permitted to be licensed for a period of up to 40 years. Prior to February 16, 2011, when 10 CFR 72.42, Duration of License; Renewal (for specific licenses) and 10 CFR 72.240, Conditions for Spent Fuel Storage Cask Renewal (for CoCs for general licenses) were revised to permit 40 year license durations, licenses and CoCs for storage systems had a duration of 20 years. Therefore, most of the storage systems currently in place at ISFSIs are only licensed for 20 years. In order to renew the license and extend the storage license, NUREG-1927, Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance (Reference C1-5) requires that an applicant demonstrate that the effects of aging will be adequately managed so that the intended safety function(s) of SSCs identified in the scope of license renewal will be maintained consistent with the current licensing basis for the period of extended operation. The NRC requires that an Aging Management Review (AMR) be performed that consists of identifying ISFSI components relied on for safety, susceptible materials in those components, environments to which susceptible materials are exposed, aging effects, and development of an aging management program to manage aging effects and protect against degradation of age-sensitive components (such as by performing inspections of age-sensitive components and replacing components that have a life expectancy of less than the license renewal period being requested in the anticipated environment). For purposes of this section, it is assumed that the original license has a duration of 20 years and a 40 year license extension is requested, so the licensee will need to demonstrate the in-scope component materials will withstand the anticipated environment for a total of 60 years, or provide a plan for replacing age-sensitive components at acceptable analyzed intervals. If the initial license was for a 40 year duration, and a 40 year license extension is requested, then the licensee would need to demonstrate the in-scope components are acceptable for 80 years in the storage environment.

The AMR identifies susceptible materials of subcomponents in the in-scope SSCs that are exposed to environments that could cause age-related degradation. The functions required to be performed by the individual subcomponents of these in-scope SCCs (determined in previous section) are identified in applicable tables in this AMR section of the application for ISFSI license renewal.

The NRC's Draft Revision 1 of NUREG-1927, Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel (Reference C1-6 explains the purpose of the AMR as follows:

> "The purpose of the aging management review (AMR) is to assess the proposed aging management activities (AMAs) for structures, systems, and components (SSCs) determined to be within the scope of renewal. The AMR addresses aging mechanisms and effects[1] that

could adversely affect the ability of the SSCs (and associated subcomponents) from performing their intended functions during the period of extended operation. The reviewer should verify that the renewal application includes specific information that clearly describes the AMR performed on SSCs within the scope of renewal."

Footnote 1 in this quotation states: "In order to effectively manage an aging effect, it is necessary to determine the aging mechanisms that are potentially at work for a given material and environment application. Therefore, the aging management review process identifies both the aging effects and the associated aging mechanisms that cause them."

The license application needs to include an Aging Management Review (AMR) that is comprised of four major steps that are summarized as follows:

1) <u>Identification of In-Scope Subcomponents Requiring AMR</u>

Structures, Systems and Components (SSCs) within scope of the aging evaluation are identified as those that are 1) classified as important to safety (ITS), and 2) classified as not important to safety but whose failure could prevent an ITS function from being fulfilled. SSCs within scope are determined based on review of the ISFSI Materials License, ISFSI SAR, ISFSI Tech Specs, NRC's SER for the ISFSI and docketed licensing correspondence related to the ISFSI.

2) <u>Identification of Susceptible Materials and Applicable Environmental Conditions</u>

For the subcomponents of in-scope SSCs that require AMR, the next step is identification of materials of construction susceptible to aging and the environments (e.g., temperature, pressure, radiation, wet vs. dry, etc.) that these materials normally experience.

3) <u>Identification of Aging Mechanisms and Effects Requiring Management</u>

Aging mechanisms potentially at work on susceptible materials in given environments (corrosion, cyclic stress fatigue, radiation embrittlement, etc.) are determined. Aging effects (manifestation of aging mechanisms) of material / environment combinations are compiled from industry and plant operating experience through use of industry standards and reference materials, including metallurgical literary references. During this process, the question is asked, are the potential aging effects credible given the identified materials and environmental conditions of storage?

4) <u>Determination of Activities Required to Manage Aging Effects (Aging Management Program)</u>

The final step in the AMR process involves the determination of activities necessary to manage the effects of aging. If the aging review determines that certain materials may not be able to support a 60 year life in the environment that they are normally exposed to, then an Aging Management Program needs to be established for those subcomponents to extend the life of the storage system to 60 years (such as by performing inspections of vulnerable subcomponents to determine their continued adequacy, or replacing the associated subcomponent at specified intervals).

Each of the four above steps of the AMR process are discussed in more detail in the following paragraphs.

C1-5.4.1 Aging Management Review (AMR)

Identification of In-Scope Components Requiring AMR

During this first step in the AMR process, the in-scope SSCs are further reviewed to identify and describe the subcomponents that support the SSC intended function. Intended functions of interest in the AMR are sub-criticality control, pressure boundary integrity (confinement of fission products), heat transfer, structural support (protection against environmental phenomena) and shielding. The subcomponents and associated intended functions are identified by reviewing the applicable current licensing basis (CLB) documentation sources.

SSCs and associated subcomponents within the scope of renewal fall into the following scoping categories:

(1) They are classified as important to safety (ITS), as they are relied on to do one of the following functions:

i. Maintain the conditions required by the regulations, specific license, or CoC to store spent fuel safely;

ii. Prevent damage to the spent fuel during handling and storage; or

iii. Provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

These SSCs ensure that important safety functions are met for (1) confinement, (2) radiation shielding, (3) sub-criticality control, (4) heat-removal capability, (5) structural integrity, and (6) retrievability of the spent fuel.

(2) They are classified as not important to safety but, according to the design bases, their failure could prevent fulfillment of a function that is important to safety.

Subcomponents that perform or support any one of the identified intended functions will require an AMR. Those components that do not support an intended function can be excluded from further evaluation in the AMR with supporting justification. The SSCs within the scope of renewal are screened to identify and describe the subcomponents with intended functions. It should be recognized that SSC subcomponents may degrade by different modes, or have different criteria for evaluation from the overall component (i.e., different materials or environments). SSC subcomponents may also have different performance requirements for support of safety functions.

Typically, the application for ISFSI license renewal tabulates the results of the AMR, including a listing of subcomponents and the intended function provided by each subcomponent, material group, environment, aging effects requiring management and aging management activity required. The AMR results tables also identify subcomponents that did not support the SSC intended function and are not subject to AMR, with justification for their exclusion.

Identification of Materials and Environments

The second step of the AMR process requires the identification of materials of construction and the environments to which these materials are exposed, for the in-scope ISFSI subcomponents that require an AMR. Environmental data may include: temperature, wind, relative humidity, relevant atmospheric pollutants and deposits, exposure to precipitation, marine fog, salt, or water exposure, radiation field (gamma and neutron), the service environment (e.g., embedded, sheltered, or outdoor), and gas compositions (e.g., external: air; internal: inert gas such as helium).

The environments to which components are exposed play a critical role in the determination of potential aging mechanisms and effects. A documentation review is required to quantify the environmental conditions to which the in-scope ISFSI SSCs are continuously or frequently exposed (conditions known to exist on a recurring basis). As noted in the next section, normal operating conditions are evaluated and not accident conditions.

The storage system FSAR is typically used to determine the intended functions and materials of construction for cask subcomponents that are in-scope of ISFSI license renewal. Additional documentation, drawings and technical reports should also be reviewed during the AMR process as required to obtain clarifications of the intended materials of construction and functions performed by in-scope ISFSI subcomponents.

The specific materials of construction for the cask and fuel assembly subcomponents requiring aging management review are identified and evaluated for the renewal period.

Identification of Aging Mechanisms and Effects Requiring Management

The third step in the AMR process is to identify the aging mechanisms and effects requiring management. A Material Aging Effects Report (MAER) is typically prepared for the storage system in question. This report needs to include aging mechanisms and effects that theoretically occur as well those that have actually occurred based on industry operating experience and the ISF operating experience for the appropriate material and environmental conditions. Aging effects are presented in this report in terms of material / environment combinations.

The environments considered in the evaluation are the environments that the subcomponents normally experience. Environmental stressors that are conditions not normally experienced, such as accident conditions, or that may be caused by a design problem, are considered event-driven situations and are not characterized as sources of aging. Such event-driven situations would be evaluated at the time of event, with corrective actions taken as necessary.

To effectively manage an aging effect, it is necessary to determine the aging mechanisms that are potentially at work for a given material and environment application. Therefore, the AMR process needs to address both the aging mechanisms as well as the aging effects. Selective mechanisms are only applicable under certain environmental conditions, such as high temperature or moisture. The identified aging mechanisms need to be characterized by a set of applicable conditions that must be met for the mechanism to occur and/or propagate. The application for ISFSI license renewal should identify aging effects based on the aging mechanisms potentially at work in given environments on susceptible subcomponent materials (e.g., general corrosion of carbon steel, stress corrosion cracking and crevice and pitting corrosion of stainless steel, cyclic stress fatigue, radiation embrittlement, boron depletion of neutron absorber due to neutron flux, etc.). Aging effects (manifestation of aging mechanisms) of material / environment combinations are compiled from industry and plant operating experience through use of industry standards and reference materials, including metallurgical literary references. The majority of aging mechanisms will be extracted from industry documents (including NRC and EPRI) for the applicable material/environmental combinations. For instance, the EPRI Dry Cask Characterization Project final report (Reference C1-7) is a primary source for fuel assembly and dual purpose canister internals aging mechanism evaluations. During the process of identifying aging effects the question is asked, are the potential aging effects credible given the identified materials and environmental conditions of storage?

Appendix D, Table D-1, of NUREG-1927 lists potential aging effects and possible aging mechanisms that should be considered. This information is also available from a table in Appendix C to NUREG-1557 (Reference C1-8). Section 3.4 of the NRC's Draft Revision 1 of

NUREG-1927 lists the following sources of information that should be used to identify applicable aging mechanisms and effects:

- site maintenance, repair, and modification records;
- corrective action reports, including root cause evaluations;
- lead system inspection results ;
- maintenance and inspection records from ISFSI sites with similar SSC materials and operating environments;
- industry records;
- applicable operating experience outside the nuclear industry;
- applicable consensus codes and standards;
- NRC reports;
- other applicable guidance for determining if an aging mechanism or effect should be managed for the period of extended operation.

Section 3.4 of the NRC's Draft Revision 1 of NUREG-1927 gives the following examples of potential aging mechanisms and effects that may be identified by reviewing the above sources of information:

> "(1) cracking or loss of strength as a result of cement aggregate reactions in the concrete, (2) cracking or loss of material as a result of freeze-thaw degradation of the concrete (requires the presence of moisture combined with temperatures below freezing), (3) reinforcement corrosion and concrete cracking as a result of chloride ingress, (4) accelerated corrosion of steel structures and components and stress corrosion cracking of austenitic stainless steels as a result of atmospheric deposition of chloride salts."

Other possible aging effects are settlement, change in dimension and change in material properties. The applicant for renewal of an ISFSI specific license is not required to take further action if an SSC is determined to be within the scope of renewal but is found to have no potential aging effects for the period of extended operation.

The AMR defines two methods for addressing potential aging mechanisms and effects: TLAA and AMP, both of which are discussed below.

Time-Limited Aging Analyses to Identify Aging Effects

Time-Limited Aging Analyses (TLAAs) are calculations performed to evaluate the life of subcomponents of interest. TLAAs are defined in Section 3.5 of the NRC's Draft Revision 1 of NUREG 1927, as those licensee calculations and analyses that meet all of the following criteria:

1. Involve SSCs important to safety within the scope of the specific-license renewal, as delineated in Subpart F of 10 CFR Part 72;

2. Consider the effects of aging;

3. Involve time-limited assumptions defined by the current operating term;

4. Were determined to be relevant by the specific licensee or certificate holder in making a safety determination;

5. Involve conclusions or provide the basis of conclusions related to the capability of SSCs to perform their intended safety functions (analyses that do not affect the intended functions of the SSCs are not considered TLAAs); and

6. Are contained or incorporated by reference in the design bases.

The defined operating term should be explicit in the analyses. Simply asserting that the SSC is designed for a service life or ISFSI life is not sufficient. The assertions must be supported by a calculation, analyses, or testing that explicitly include a time limit.

Examples of TLAAs described in the past applications for license renewal are: 1) cracking of the dual purpose canister (DPC) shell due to fatigue from thermal cycling; 2) change in material properties of epoxy seal in DPC penetration (for temperature monitoring) due to exposure to ionizing radiation; and 3) canister basket poison plate depletion of boron due to increase in neutron exposure for 60 year life of ISFSI; change in properties of boron-polyethylene front access cover plate due to increased radiation exposure over 60 year life of ISFSI.

Operating Experience Review for Process Confirmation

Typically, the potential aging effects for the ISFSI material and environment combinations are compiled from common industry and plant operating experience through the use of accepted industry standards and reference materials, including various metallurgical literary references relating specific materials and environments to aging effects and mechanisms.

A further review of industry and plant specific operating experience for the ISFSI should also be performed in order to confirm the applicability of previously identified potential aging mechanisms/effects and to identify any aging effects not previously addressed.

The application for ISFSI license renewal will need to address the various observations resulting from ISFSI operating experience with the storage systems. This information should address items specific to the subcomponents. As an example; Dominion identified corrosion of lid bolts and outer metallic lid seals on some of the TN-32 casks stored at the Surrey ISFSI. The corrosion was most prevalent on the down-slope side of the cask lid. As part of the investigation, the bolt torque was checked and it was determined that there had been no torque relaxation. The corrosion of the lid bolts and outer metallic seal was the result of external water intrusion in the vicinity of the lid bolts and outer metallic seal. It was determined that the connector seal for the electrical connector in the cask protective cover was leaking due to improper installation of the connectors. Therefore, this degradation was not related to aging.

Activities Required to Manage Aging Effects (Aging Management Program)

The fourth and final step in the AMR process involves the determination of the aging management activities or Aging Management Programs (AMPs) to be credited or developed for managing the effects of aging. Section 3.6 of Draft Revision 1 of NUREG-1927 states the following regarding AMPs:

> "Aging management programs (AMPs) monitor and control the degradation of SSCs within the scope of renewal so that aging effects will not result in a loss of intended functions during the period of extended operation. An AMP includes all activities that are credited for managing aging mechanisms or effects for specific SSCs. An effective AMP prevents, mitigates, or detects the aging effects and provides for the prediction of the extent of the effects of aging and timely corrective actions before there is a loss of intended function."
>
> "Aging management programs should be informed, and enhanced when necessary, based on the ongoing review of both site-specific and industry-wide operating experience. Operating experience provides direct confirmation of the effectiveness of an AMP and critical feedback for the need for improvement. As new knowledge and data become available from new analyses, experiments, and operating experience, licensees and CoC holders should revise existing AMPs (or pertinent procedures for AMP implementation) to address program improvements or aging issues."

Section 3.6.1 of the NRC's Draft Revision 1 of NUREG-1927 indicates that an AMP should contain the following elements:

1. Scope of Program,
2. Preventive actions,
3. Parameters monitored or inspected,
4. Detection of aging effects,
5. Monitoring and trending,
6. Acceptance criteria,
7. Corrective actions,
8. Confirmation process,
9. Administrative controls, and

10. Operating experience.

To the extent practical, existing ISFSI programs and/or activities are credited for the management of aging effects that could cause a loss of component intended function during the license renewal period. If the aging review determines that certain materials cannot support the required life in the environment that they are normally exposed to, then an AMP needs to be established for those subcomponents to extend the life of the storage system for the duration of the license renewal period (such as by performing inspections of vulnerable subcomponents to determine their continued adequacy, or replacing the associated subcomponent at specified intervals). The application for ISFSI license renewal will need to discuss development of AMPs to address subcomponents whose materials are susceptible to age-related degradation. AMPs for ISFSIs typically include visual inspections of cask external surfaces to look for signs of deterioration due to corrosion (general corrosion for carbon steel subcomponents due to moist atmospheric environments, and crevice and/or pitting corrosion for stainless steel surfaces that are subject to wetting), and monitoring area radiation levels, airborne and smearable contamination levels at selected areas of the ISFSI. Increased radiation / radioactivity levels could indicate reduction in shielding, breach of the SFA cladding or loss of cask confinement. Inspection intervals are established at frequencies that provide confidence the subcomponents of interest will not experience age-related adverse effects that could prevent them from performing their intended functions.

C1-5.5 Postulated Accident Evaluation

The accident descriptions to follow refer to "Design Event" levels given in ANSI/ANS 57.9, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)" (Reference C1-9). As explained in NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" (Reference C1-10): "Off-normal events are those expected to occur with moderate frequency or once per calendar year. ANSI/ANS 57.9 refers to these events as Design Event II. Accident events are considered to occur infrequently, if ever, during the lifetime of the facility. ANSI/ANS 57.9 subdivides this class of accidents into Design Event III, a set of infrequent events that could be expected to occur during the lifetime of the ISFSI, and Design Event IV, events that are postulated because they establish a conservative design basis for SSCs important to safety. The effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches, are considered to be accident events."

Section 15.4 of NUREG-1567 identifies acceptance criteria for accidents, including the following:

> Criticality: 10 CFR 72.124(a) requires that the spent fuel must be maintained in a subcritical condition (i.e., keff $\leq$ 0.95), and at least two unlikely, independent and

concurrent or sequential changes must be postulated to occur in the conditions essential to nuclear criticality safety before a nuclear criticality accident is possible (double contingency).

Confinement: 10 CFR 72.128(a)(3) requires that the systems important to safety must be evaluated, using appropriate tests or by other means acceptable to the Commission, to demonstrate that they will reasonably keep radioactive material confined under credible accident conditions. NUREG-1567 states that “A breach of a confinement barrier is not acceptable for any accident event.”

Retrievability: 10 CFR 72.122(l) requires that “Storage systems must be designed to allow ready retrieval of spent fuel, high-level radioactive waste, and reactor-related GTCC waste for further processing or disposal.” The definition for Important to Safety SSCs in 10 CFR 72.3 includes those features whose function is to “provide reasonable assurance that spent fuel, high-level radioactive waste, or reactor-related GTCC waste can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.”

Instrumentation: 10 CFR 72.122(i) states in part: “Instrumentation systems for dry storage casks must be provided in accordance with cask design requirements to monitor conditions that are important to safety over anticipated ranges for normal conditions and off-normal conditions. Systems that are required under accident conditions must be identified in the Safety Analysis Report.”

Radiological Dose: 10 CFR 72.104 requires that for off-normal events, annual dose equivalent to any individual located beyond the controlled area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as a result of exposure to planned discharges to the general environment, direct radiation from operations of the ISFSI, and cumulative radiation from uranium fuel cycle operations in the area. 10 CFR 72.106(b) requires that any individual located at or beyond the nearest controlled area boundary must not receive a dose greater than 5 rem to the whole body or any organ from any design basis accident.

C1-5.5.1 Earthquake

An earthquake is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. Earthquakes are associated with faults in the upper crust of the earth’s surface. SSCs classified as Important to Safety are required to be designed to resist the effects of the design basis ground motion in accordance with the requirements of 10 CFR 72.122(b).

10 CFR Part 72.103, "Geological and Seismological Characteristics for Applications for Dry Cask Modes of Storage on or after October 16, 2003," gives requirements for determining Design Earthquake Ground Motion (DE) at sites for spent fuel storage, and NRC Regulatory Guide 3.73 "Site Evaluations and Design Earthquake Ground Motion for Dry Cask Independent Spent Fuel Storage and Monitored Retrievable Storage Installations" (Reference C1-11) provides guidance on applying the rules in Part 72.103 to arrive at an acceptable DE that satisfies the requirements of Part 72. In general, Part 72.103 allows use of a standardized DE described by an appropriate response spectrum anchored at 0.25 g for sites in non-seismically-active areas east of the Rocky Mountain Front and requires a seismic evaluation elsewhere. For the ISF, a probabilistically-derived horizontal ground acceleration design value of 0.75 g is used to provide a bounding value for all potential ISF sites.

Depending on the specific storage system, the acceptance criteria for seismic design may include some or all of the following:

i. The loaded overpacks will not impact each other during the DE event.
ii. The loaded overpack will not slide excessively.
iii. The loaded overpack will not tip over.
iv. The confinement boundary will not be breached.

C1-5.5.2 Tornado Winds and Missiles

The storage system is designed to withstand loads associated with the most severe meteorological conditions, including extreme winds, pressure differentials, and missiles generated by a tornado. The extreme design basis wind is derived from the design basis tornado. Extreme wind is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. The design basis tornado loading is defined for a given region (identified in NRC Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants" (Reference C1-12). It is conservatively assumed that Region I design basis tornado loading applies to the ISF. The design basis tornado wind loading for this region is defined as a tornado with a maximum wind speed of 230 mph and a 1.2 psi pressure drop occurring at a rate of 0.5 psi/sec.

In addition, the ISF is designed to withstand the effects of tornado-generated missiles that could be created by the passage of the tornado as identified in Regulatory Guide 1.76, Rev. 1, and discussed in Sections 3.3.2 (Tornado Loadings) and 3.5.1.4 (Missiles Generated by Extreme Winds) of NUREG 0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, (Reference C1-13). Tornado-driven missiles, identified in the following table, are assumed to impact a storage system in a manner that produces maximum damage. Regulatory Guide 1.76, Rev. 1, identifies the following design basis missiles for Region I:

Missile Description	Total Mass (lbs)	Velocity (mph)
Automobile	4000	92
Schedule 40 Pipe (6. 625 inch-diameter), 15 ft long	287	92
Solid Sphere (1-inch-diameter)	0.147	17.7

Alternatively, there are other spectrums of tornado missiles that have been accepted by the NRC (for which spent fuel storage systems have been qualified) that could be reviewed for potential use at the ISF.

The combination of tornado winds with the most massive missile, a 4,000 lb automobile traveling at 92 mph, needs to be evaluated in accordance with Section 3 of NUREG-0800, since it tests storage system stability. The wind tip-over moment is applied to the cask at its maximum rotation position following the worst-case missile strike. The schedule 40 pipe missile tests the capacity of the storage system to resist penetration, and the small solid steel sphere missile tests barrier openings. Canister tip-over potential and reduction in shielding from tornado-borne projectile strikes are evaluated.

C1-5.5.3 Flood

Flooding is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. 10 CFR 72.122(b)(2) requires that SSCs Important to Safety must be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lighting, hurricanes, floods, tsunami, and seiches, without impairing their capability to perform safety functions.

The probable maximum flood (PMF) is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions.

Other potential sources of flooding considered include effects from an upstream dam breach, seismically induced flooding due to landslides in the site area, occurrence of the PMF with superposition of wind-wave activity on nearby water bodies, flooding due to tsunamis and ice conditions, and flooding from local intense precipitation.

The storage system is designed to withstand severe flooding, including pressure and water forces associated with deep and moving flood waters. Resultant loads on the storage system consist of buoyancy effects, static pressure loads, and velocity pressure due to water velocity. The flood is assumed to deeply submerge the storage system without the canisters collapsing, buckling, or allowing water in-leakage under the hydrostatic pressure from the flood; and, where applicable, without sliding and cask tip-over occurring. Full blockage of the air inlets by submergence in water is addressed by emergency action planning based on the individual storage device's capabilities. For more information on blockage of air inlets, refer to "Loss of Cooling Accident."

C1-5.5.4 Fire

Fire is classified as a human-induced Design Event IV as defined in ANSI/ANS-57.9. The storage system must withstand elevated temperatures due to a fire event. Credible fires from various sources such as buildings, fuel spills, and other combustible materials are analyzed for heat flux using standard analysis techniques from NFPA and compared with acceptance criteria for the storage system. Possible effects from wildfires are also evaluated, addressing fire magnitude, duration, propagation, and heat generation.

Fires analyzed include those that could occur during transfer operations and those affecting stored fuel. Canister integrity during smaller fire events is qualified by heat flux comparison with a bounding fire for which an approved canister analysis has been performed. Fires affecting structures in which transfer operations and storage of fuel occur have been analyzed to ensure continued reliability.

Based on the analyses, the canister storage and transfer systems meet the general design criteria of 10 CFR 72.122(c), which states that SSCs Important to Safety must be designed and located so that they can continue to perform their safety functions effectively under credible fire exposure conditions. A fire at the ISF (or a wildfire adjacent to the ISF Protected Area) would not cause a radioactive release, even if no credit were taken for firefighting by personnel or for automatic fire detection/suppression systems.

C1-5.5.5 Explosion

Explosion is classified as a human-induced Design Event IV as defined in ANSI/ANS-57.9. The ISF storage system must withstand loads due to an explosion. Potential onsite (internal and external) and offsite explosions are investigated.

NRC Regulatory Guide 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plants" (Reference C1-14) provides guidance for calculating safe distances from transportation routes, based on calculated overpressures at various distances created by postulated explosions from accidents. The Regulatory Guide indicates that overpressures which do not exceed 1 psi at the storage site would not cause significant damage and states:

> under these conditions, a detailed review of the transport of explosives on these transportation routes would not be required.

In lieu of the 1 psi overpressure selected in the Regulatory Guide, the overpressure for which the storage system is qualified (e.g., 3 psi, 5 psi, 10 psi) is used to determine the safe standoff distance from the source of the potential explosion.

There are no credible internal explosive events since the canister is comprised of non-explosive materials, it is filled with an inert gas, and materials are compatible with the operating environment. Likewise, the mandatory use of the protective measures at the ISF site to prevent fires and explosions and the absence of any need for an explosive material during canister loading, transfer, and unloading operations eliminates the scenario of an onsite explosion as a credible event, except during canister movement, which requires investigation of any nearby onsite-specific potential explosive sources.

Any design basis overpressure from an offsite explosion (e.g., from a truck, rail car, barge, fuel storage tank, munition depot, chemical processing plant, petroleum refinery, natural gas facility, etc.) must be investigated and, if credible, analyzed.

Based on the analyses, the canister storage and transfer systems meet the general design criteria of 10 CFR 72.122(c), which states that SSCs Important to Safety must be designed and located so that they can continue to perform their safety functions effectively under credible explosion exposure conditions.

C1-5.5.6 Canister Drop Accident

NUREG-1567 considers both off-normal cask drops and more severe cask drop accidents. With regards to an off-normal event involving a cask drop that is less than the design allowable lift height, Section 15.5.1.1 of NUREG-1567 states:

> The drop of the confinement cask at less than design allowable height is one of the hypothetical off-normal scenarios that the applicant must evaluate. The evaluation must show that the cask integrity and fuel spacing geometry are not compromised if the cask is dropped from a relatively low height. It must also show that the cask will continue to store fuel safely after such a drop.

For accident conditions, the hypothetical drop of a storage canister is classified as Design Event IV as defined by ANSI/ANS-57.9.

With regards to a cask drop accident, Section 15.5.2.2 of NUREG-1567 identifies the key items to be evaluated assuming a cask drop, including decelerations, evaluation of calculated stress intensities against the allowable stresses identified in the applicable code, evaluation of buckling stability for each component of the cask confinement subjected to compressive loading, and evaluation of deformation of cask internal members that could contribute to fuel assembly spacing geometry (for criticality concerns). While this guidance may apply to transport casks that do provide a confinement boundary, it may not be directly applicable to the transfer casks that are used to transfer canisters from transport casks to storage overpacks. In addition, in the event the spent fuel cask handling systems meet the NRC criteria for "single-failure-proof" (discussed in Section 9.1.5 of NUREG-0800, "Overhead Heavy Load Handling Systems"), the NRC does not require a cask drop accident to be postulated nor its consequences to be analyzed.

Within the alternative storage systems, there are two basic drop situations, with certain potential drop accidents that necessitate analysis and/or operational restrictions, as identified below:

(1) Handling inside the transport cask receiving structure and canister transfer facility:

- A drop of the transport cask with its impact limiters removed prior to being handled by the single-failure-proof crane requires analysis and operational restrictions.

- Transport cask drop accidents (other than above) and transfer cask drop accidents are precluded by the use of a single-failure-proof handling system, consisting of an overhead crane whose main hoist meets the NRC criteria for a single-failure-proof crane (i.e., NUREG-0554, "Single-Failure-Proof Cranes for Nuclear Power Plants," (Reference C1-15) or ASME NOG-1, "Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)" (Reference C1-16)).

(2) Handling outside the transport cask receiving structure and canister transfer facility (i.e., during cask transfer to the storage area):

- For some transport systems, it is required to assume a cask drop and, therefore, the lift height is limited to a height that has been fully analyzed for the assumed cask drop accident (e.g., TransNuclear transfer casks and NAC storage casks).

- For other systems (e.g., Holtec Vertical Cask Transporter), the lifting apparatus is required to meet ANSI N14.6 "American National Standard for Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10 000 Pounds (4500 kg) or More" (Reference C1-17) criteria for allowable stresses and to have redundant drop protection features. For these systems, no height restriction is required for cask transfer.

- For potential drops when a canister is being handled, lifts of canisters loaded with spent nuclear fuel are performed using single-failure-proof equipment and lifting devices that comply with the stress limits of ANSI N14.6 and have redundant drop protection to render an uncontrolled lowering of the payload non-credible, so a canister drop accident need not be postulated.

C1-5.5.7 Loss of Cooling Accident (LOCA)

The various spent fuel storage system alternatives all use passive air cooling of the dry storage canisters. The cooling air flow is driven by natural convection with cool air at ambient temperature entering the canister storage area near the bottom of the canister(s), rising as it is heated by the relatively hot outer surface of the canister(s), and exiting the canister storage area by outlet vents above the canisters.

It is credible that various types of debris or materials such as plastic sheets could blow into the canister storage area and block some of the air vents, thus reducing air flow and causing canister temperatures and spent fuel cladding temperatures to increase. Complete blockage of the air inlet ducts is classified as a Design Event IV accident condition as defined by ANSI/ANS-57.9. In addition, partial blockage of the cooling air vents is also analyzed as an off-normal condition, such as by assuming that one-half of the area of the air inlet vents is blocked. Thermal analyses are required to be performed to determine storage system temperatures, including canister and spent fuel cladding temperatures. The resulting temperatures are compared with the applicable temperature limits for off-normal (partial vent blockage) and accident or faulted conditions (complete blockage of air inlets).

Typically, the thermal analysis of partial blockage determines final steady-state temperatures of the storage system that result from the reduced air flow rates and these are compared to the maximum allowable temperatures of the various components to demonstrate the storage system can acceptably withstand this partial blockage with no operator actions.

For the accident condition involving postulated complete blockage of the air inlet vents, a transient thermal analysis is performed that determines the time at which temperatures of storage system components that are classified as Important to Safety exceed their maximum allowable temperatures for accident conditions, such as spent fuel cladding, canister confinement or canister basket material temperatures. This time is then used to establish a conservative required frequency of inspection or temperature monitoring of the storage system that ensures temperature limits will not be exceeded. This inspection frequency is then incorporated into the Technical Specifications that govern operations of the spent fuel storage facility. With regard to this inspection frequency requirement, Section 6.5.1.1 of NUREG-1567 recommends the following paragraph be incorporated into the Technical Specifications, based on results of the accident analysis that assumes complete blockage of air inlet vents:

> Surveillance requirement: Periodic surveillance will be performed to ensure that there is no blockage of cooling air flow in the heat removal system. This surveillance [typically based on the minimum time for stored material cladding or other material Important to Safety (e.g., shielding) to reach a threshold temperature in the event of a complete blockage occurring immediately following the prior surveillance.

Surveillance of cooling air vents for blockage can either be performed by visual inspection of the air inlet and outlet vents or by checking temperature readings of the temperature monitoring system to verify temperatures for each storage system are within allowable limits. ISFSIs frequently use temperature detectors mounted in the outlet vents to assess the performance of the natural convection air cooling system, since blockage of cooling air vents will result in reduced airflow with consequent increased air outlet temperatures. For ISFSIs with a relatively large number of storage systems, temperature monitoring is used to ensure worker doses are ALARA, since significant dose can be accrued by workers performing routine inspections of storage system air vents (typically, daily inspections are required), which requires the inspector to be in the near vicinity of the spent fuel storage systems.

C1-5.5.8 Off-Normal and Extreme Environmental Temperature

Ambient environmental temperatures must be evaluated for periods during which handling operations take place and also for the long time period over which spent fuel storage will occur. The various cask vendors have analyzed their products for intended use typically to cover all ISFSI sites in the continental U.S.

Minimum short-term temperature limitations are specified to ensure a sufficient safety margin against brittle fracture during handling. A typical operational limitation would be around 0°F, so it is likely that operational temperature restrictions imposed for other reasons may be more stringent (e.g., the minimum allowable temperature for crane operation). The lower bound off-normal temperature limit, applicable to long-term storage, is typically about -40°F.

Storage systems are designed for upper bound off-normal temperatures in the range of about 100°F, which is assumed to persist for a sufficient duration to allow the system to reach thermal equilibrium. The accident condition extreme ambient environmental temperature is typically around 125°F. Upper bound limitations are based on analyses that determine the storage system's ability to properly convey heat away from the spent fuel. Extreme environmental temperature is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9.

C1-5.5.9 Lightning

Lightning is classified as a natural phenomenon Design Event III as defined in ANSI/ANS-57.9. Because a direct lightning strike of a storage SSC is a credible occurrence, the ISF storage system must withstand loads due to lightning, with the canister retaining its confinement integrity, and thereby preventing release of radioactivity. The lightning path to ground will vary, depending on the storage system alternative; but for each alternative, the canister will be protected from the effects of a lightning strike. (For example, for above-ground vertical cask storage, the steel shell of the overpack will convey the lightning to ground and the lightning will not pass through the canister, which is surrounded by the cask steel, so the strike will not affect the canister integrity.) Therefore, no offsite doses would result from this accident.

C1-5.5.10 C1 Alternative Applicability

Each of the previously discussed design basis accidents for each alternative will be slightly different since each of the alternatives' design handles each of the accidents differently. The below list summarizes the applicability of the accidents with regard to Alternative C1:

1. Seismic (C1-5.5.1)

   The S-PAD will need to show that it can adhere fully to the seismic accelerations. A site-specific seismic analysis will be performed to ensure all components of the S-PAD are qualified for the chosen ISF site's seismic input.

2. Tornado Winds / Missiles (C1-5.5.2)

   The STAD canisters will need to show they can qualify to the NRC's tornado winds and missile criteria as discussed in C1-5.5.2.

3. Flooding (C1-5.5.3)

   The S-PAD would need to comply with all flooding requirements discussed in C1-5.5.3 and would also be designed such that the upper surfaces of the storage pads are situated above the elevation of the PMF from offsite sources.

4. Fire (C1-5.5.4)

   The S-PAD would need to comply with all fire protection requirements discussed in C1-5.5.4, including fire sources from nearby buildings, fuel spills, combustibles, and wildfires.

5. Explosion (C1-5.5.5)

   The S-PAD would need to comply with all explosion requirements from NRC Reg Guide 1.91 as discussed in C1-5.5.5.

6. Canister Drop Accident (C1-5.5.6)

   The S-PAD system would need to comply with all canister drop requirements from NUREG-1567 as discussed in C1-5.5.6 as all existing dry fuel storage system comply with NUREG-1567. All material handling systems will be classified as Single-Failure-Proof as and thus not require postulation of a dropped canister.

7. Loss of Cooling Accident (LOCA) (C1-5.5.7)

   The S-PAD would need to comply with all LOCA requirements discussed in C1-5.5.7. The various spent fuel storage system alternatives all use passive air cooling of the dry storage canisters, whether they are in vertical or horizontal storage overpacks on an ISFSI pad. The cooling air flow is driven by natural convection with cool air at ambient temperature entering the canister storage area near the bottom of the canister(s), rising as it is heated by the relatively hot outer surface of the canister, and exiting the canister storage area by outlet vents above the canisters.

8. Off-Normal and Extreme Environmental Temperature (C1-5.5.8)

   The S-PAD would need to comply with all off-normal and extreme environment temperature requirements discussed in C1-5.5.8 since all of the existing dry fuel storage systems have been analyzed for conditions anywhere within the US.

9. Lightning (C1-5.5.9)

   The S-PAD would need to comply with all lightning requirements discussed in C1-5.5.9 since all of the existing dry fuel storage systems have been analyzed for lightning.

C1-5.6 Licensing Evaluation

C1-5.6.1 Overview

10 CFR Part 72 governs ISFSI licensing. There are two options for licensing an ISFSI: (1) a specific license and (2) a general license. However, 10 CFR 72.210 only authorizes the use of a general license at a power reactor site with a 10 CFR Part 50 or 10 CFR Part 52 license. Since it is not anticipated that the ISF would be located at the site of a nuclear power plant, the ISF would be governed by a 10 CFR Part 72 specific license.

The process for obtaining a specific ISFSI license is similar to that for obtaining a license for a fuel cycle facility under 10 CFR Part 70 (Reference C1-18). The applicant submits a License Application (LA) in accordance with 10 CFR 72.16 that includes the information required by 10 CFR 72.22 through 10 CFR 72.28. The primary documents comprising the LA are as follows:

- Safety Analysis Report (SAR) that assesses safety of the storage system and the ISFSI facility (used as basis for NRC preparation of the Safety Evaluation Report)
- Environmental Report (used as basis for NRC preparation of the Environment Impact Statement)
- Proposed Technical Specifications
- Quality Assurance (QA) program

- Decommissioning Plan
- Emergency Plan
- Security Plan

C1-5.6.2 Licensing Process

Upon receipt of the application, the NRC establishes a docket number and reviews the application for completeness. If the application is deemed complete, the NRC prepares and publishes a notice of docketing in the Federal Register (FR). The notice of docketing identifies the site of the ISF and includes either a notice of hearing or a notice of proposed action and opportunity for hearing pursuant to 10 CFR 72.46. 10 CFR 72.46 provides the regulations governing the hearing process with references to 10 CFR Part 2 (Reference C1-19), as appropriate.

The NRC will request a hearing upon the notice of docketing if a statute specifically requires it, or if they believe it to be in the public interest, notwithstanding any requests for hearing submitted by parties who believe they having standing in the licensing action. 10 CFR 2.105(a)(7) specifies that if the NRC is not required by statute to conduct a hearing and does not find that a hearing is in the public interest, a notice of proposed action is instead published in the FR.

The notice of proposed action includes the time frame for any person whose interest may be affected by the proceeding to file a request for a hearing or a petition for leave to intervene if a hearing has already been requested. A request for hearing on a 10 CFR Part 72 License Application must be submitted, with the contentions upon which the hearing would be litigated, within 60 days of the notice of docketing. It is worth noting that if the 10 CFR Part 72 specific license applicant is incorporating design information pertaining to a previously NRC-certified spent fuel storage cask design by reference into the application, any hearing held to consider the application will not include any cask design issues pursuant to 10 CFR 72.46(e).

If any requests for hearing are received on the notice or proposed action, the NRC will establish an Atomic Safety Licensing Board (ASLB) to review the hearing requests and contentions for admittance. For the ASLB to admit a contention and grant a hearing, the requestor needs to have standing in the proceeding per 10 CFR 2.309(d), and at least one contention must meet the criteria in 10 CFR 2.309(f). The NRC may also permit discretionary intervention of someone not having standing under the strict requirements of 10 CFR 2.309(e).

Admitted contentions are litigated through a review of documents submitted by the petitioner and may require court testimony and/or documents to be submitted by the applicant, at the discretion of the ASLB. Hearings would take place after issuance of the Final Environmental Impact Statement (EIS). The ASLB may decide to start the hearings prior to completion of the

NRC staff Safety Evaluation Report (SER). A license would not be granted until all hearings are completed and the contentions resolved in favor of the applicant. At that point, the Director of the Office of Nuclear Material Safety and Safeguards would request Commission authorization to issue the license pursuant to 10 CFR 72.46(d). While petitioners may appeal the resolution of contentions in the courts, the license would likely be issued without awaiting resolution of those court appeals.

The NRC reviews the application for a specific license, and generally there are several rounds of requests for additional information.

10 CFR 72.42, Duration of License; Renewal, paragraph (a) states the following:

> Each license issued under this part must be for a fixed period of time to be specified in the license. The license term for an ISFSI must not exceed 40 years from the date of issuance. The license term for an MRS must not exceed 40 years from the date of issuance. Licenses for either type of installation may be renewed by the Commission at the expiration of the license term upon application by the licensee for a period not to exceed 40 years and under the requirements of this rule.

C1-5.6.3 License Application

NUREG-1571, "NRC Information Handbook on Independent Spent Fuel Storage Installations," (Reference C1-20) summarizes key requirements for a specific license application, as follows:

- Siting Evaluation Factors (10 CFR 72 Subpart E)—The site characteristics, including external, natural, and manmade events, that may directly affect the safety or the environmental impact of the ISFSI.
- General Design Criteria (10 CFR 72 Subpart F)—Applies to the design, fabrication, construction, testing, maintenance, and performance requirements for structures, systems, and components important to safety.
- Quality Assurance (10 CFR 72 Subpart G)—The planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service as applied to design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, modification, and decommissioning.
- Physical Protection (10 CFR 72 Subpart H)—The detailed plans for ISFSI security.
- Personnel Training (10 CFR 72 Subpart I)—The program for training, proficiency testing, and certification of ISFSI personnel who operate equipment or controls important to safety.

The NRC will review the specific license application and complete an evaluation of potential environmental impacts of the ISFSI in accordance with the National Environmental Policy Act of 1969 (NEPA), as amended (Reference C1-21). The NRC will prepare an EIS in accordance with 10 CFR Part 51 (Reference C1-22). Following its safety review and resolution of comments, the NRC issues a Materials License along with its SER and final EIS. The SER describes the conclusions of the staff's safety review based on the applicant's SAR and assesses the technical adequacy of the ISFSI and the spent fuel storage system(s).

Safety Analysis Report

The level of effort associated with preparation of the ISFSI SAR for a specific license can be reduced considerably by taking advantage of the permission granted in 10 CFR 72.46(e) to select storage systems with SARs that have been reviewed and approved by the NRC (with Certificate of Compliances [CoC] having been issued for the storage systems), or storage systems that are currently undergoing NRC review per 10 CFR 72, Subpart L. 10 CFR 72.46(e) states: "If an application for (or an amendment to) a specific license issued under this part incorporates by reference information on the design of a spent fuel storage cask for which NRC approval pursuant to subpart L of this part has been issued or is being sought, the scope of any public hearing held to consider the application will not include any cask design issues." With this approach, the NRC will focus its review on site-specific issues and storage system/site interface issues. This helps streamline the specific licensing process. Should the applicant select a storage system that has neither been reviewed and approved by the NRC nor is currently undergoing NRC review, the NRC must review information associated with the proposed spent fuel storage system as part of the specific license application, which would extend the review time.

Detailed guidance as to information that needs to be included in the ISFSI SAR that is submitted with the license application is provided by Regulatory Guide 3.48, "Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage)" (Reference C1-23). Additional information to enable the NRC staff review in accordance with NUREG-1567 should also be included in the SAR, along with information from any applicable NRC Interim Staff Guidance (ISG). The SAR for the ISF will need to identify and evaluate each of the storage systems that will be used at the ISF to store SNF. For each individual system, the ISF SAR will need to address the following key topics specified in the NUREG-1567 Standard Review Plan:

- General description of the storage system
- Design criteria
- Structural evaluation
- Thermal evaluation
- Shielding evaluation

- Criticality evaluation
- Confinement evaluation
- Material evaluation
- Operating procedures
- Acceptance tests and maintenance program
- Radiation protection (occupational exposures, public exposures, ALARA measures)
- Accident analyses
- Operating controls (technical specifications)
- Quality assurance
- Decommissioning

The previous topics are addressed in the storage system vendors' SARs that have been approved by the NRC for general and specific ISFSI licenses; these documents can be incorporated by reference into the ISF SAR. It is envisioned that the ISF SAR will have a main body that describes and analyzes the ISF design and generic operations, with a separate appendix that serves as the SAR for each individual storage system. The ISF SAR will benefit in that it will primarily use SNF storage systems that have already been licensed under the provisions of 10 CFR Part 72, Subpart K, and have existing Final Safety Analysis Reports (FSARs) that have been approved by the NRC and can be referenced. A specific revision of the vendors' FSARs would need to be chosen for incorporation into the ISF ISFSI SAR. Changes to the vendors' FSARs thereafter would not automatically be incorporated by reference into the ISF SAR, but would require evaluation by the ISF license applicant for incorporation.

The SAR would include descriptions of the safety analyses and other technical evaluations for the ISFSI in each SAR chapter, incorporating by reference any required information for the storage system designs. The format and content would coincide with the chapters of the SRP in NUREG-1567 and any applicable Interim Staff Guidance documents amending that guidance. Formatting the ISFSI SAR in this manner sets the stage for a more efficient NRC technical review because the SRP establishes the format and content template for the NRC's SER.

Environmental Report

The Environmental Report (ER) that is submitted with the License Application is prepared to address the requirements of Subpart E of 10 CFR Part 72, Siting Evaluation Factors, and Subpart A of 10 CFR Part 51, National Environmental Policy Act - Regulations Implementing Section 102(2), using the guidance provided in NRC NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs," (Reference C1-24). The ER contains the following key topics:

- General description of the proposed activities and discussion of need for the facility

- Site interfaces with the environment, including geography, demography, land use, ecology, climatology, hydrology, geology and seismology, historical and cultural features, and background radiation levels.
- Description of the facility, including appearance, construction, operations and effluent control
- Environmental effects of facility construction and operation, including transportation of radioactive material, and effects of decontamination and decommissioning
- Environmental effects of accidents involving radioactive materials, including transportation accidents
- Proposed environmental monitoring programs
- Economic and social effects of facility construction and operation, including cost benefit analysis
- Facility siting (site selection process) and design alternatives
- Environmental approvals including federal, state, and local regulations and permits

As noted above, the NRC will need to prepare a complete EIS for the ISF based on the ER submitted by the licensee, in accordance with 10 CFR Part 51 requirements.

C1-5.6.4 Licensing of Alternative Systems

The approach to licensing of the different alternative systems would be the same as that described above. Key differences involve the information that would be required in the License Application are discussed in the following paragraphs.

Alternative 1, Pad Storage with STAD Canisters

This alternative is very similar to the current method of storage that is used at existing reactor site ISFSIs. A major advantage of these systems from a licensing standpoint is that they have already been designed and licensed and it is expected that the STAD canisters would have similar capabilities.

The SAR will need to address criteria by the NRC and approved for use including design criteria, structural, thermal, shielding, criticality and confinement information.

The STAD canisters will need to demonstrate that they can be used at the particular location selected for the ISF site. The STAD canister license documents will need to show that the systems are qualified for the characteristics of the particular sites, such as site-specific seismic, tornado winds and missiles, ambient temperatures and fires and explosions.

This alternative uses reinforced concrete storage pads to support the STAD overpacks. The license will need to show that the storage pads and underlying soil which need to consider size, weight, pad stability and tipping potential, etc. of the various storage overpacks and modules that will be used at the ISF.

C1-5.7 Security Evaluation

The purpose of security at an interim storage facility is to protect the SNF against acts of radiological sabotage and theft or diversion that could lead to an unreasonable risk to the health and safety of the public. The ISF must meet the requirements of 10 CFR 73 (Reference C1-25). In order to accomplish this task the ISF will need to establish and maintain a physical protection system which consists of the following:

- Controlled access
- Visual surveillance
- Detection and assessment of unauthorized individuals
- Adversary response
- Measures to resistance explosive devices

The physical security systems must be designed to protect against loss of control of the ISF.

Controlled Access

Controlled access is maintaining control of a clearly demarcated area and isolation of the material or persons within it. The features at the ISF that afford controlled access include a fenced Owner Controlled Area (OCA) typically established at the property boundaries, vehicular access gates into the property where security personnel can verify the identification and authorization of all persons and vehicles entering the site, a Protected Area (PA) with two physical barriers (fences or structures) designed to thwart physical intrusion, and personnel and vehicle access barriers into the PA. All of these features are required of the ISF regardless of the storage system utilized. However, the area required may vary depending on the storage alternative used thus affecting the OCA and PA boundary distances.

For STAD Pad storage, the PA will need to be 300 - 400 acres in size which would require a perimeter fence roughly 3-4 miles in length.

Visual Surveillance

Visual surveillance is establishing security guards around the PA who maintain an unobstructed view of the PA at all times. This may be performed from bullet resistant enclosures (BREs) placed around the PA which are occupied by security guards, closed circuit TV (CCTV) cameras that are viewed by security guards at the Central Alarm Station (CAS) or secondary Alarm Station (SAS) or security guards patrolling the site. BREs are situated at strategic locations within the PA to provide protected locations for security force personnel during a security event.

STAD Pad storage will primarily impact the number of BREs or cameras that are required to maintain line of sight around the overpacks. All vertical storage overpacks are much more difficult to maintain visual surveillance. A matrix of 20-foot high overpacks affords an unauthorized person the ability to hide between the overpacks. Placing BREs or cameras at every row and column of the matrix would be excessive. However, the arrangement of the overpacks will likely require some additional BREs or cameras to ensure that visual coverage throughout the cask pad is maintained. Having a wide space between the storage area and the PA fence could also assist in providing adequate assessment should an intruder penetrate the PA boundary.

Detection and assessment of unauthorized individuals

Detection of unauthorized individuals is maintained by establishing an intrusion detection system that can detect unauthorized penetration through the isolation zone located between the PA boundary fences and tamper devices on doors and equipment that send an alarm to alert security staff when the PA or security equipment is breached. Assessment of unauthorized individual is established by illuminating the PA with sufficient lighting that security guards can adequately determine the nature of the intrusion either visually or by the CCTV system. The intrusion and CCTV systems are monitored continually by security staff at the CAS and SAS.

STAD Pad storage will only affect the detection and assessment capabilities based on the size of the PA discussed above. A longer PA boundary means more intrusion detection equipment and more cameras.

Adversary Response

Adversary response is the ability to prevent or delay the attempted theft of SNF or radiological sabotage by armed response personnel. Adversary response also includes the ability to provide timely communication to a designated response force such as the local law enforcement agency whenever necessary.

STAD Pad storage will not affect adversary response since this is primarily a function of security staff and communication equipment.

Measures to resistance to explosive devices

Resistance to explosive devices intended to disable security personnel or radiological sabotage is maintained by establishing engineered barriers that prevent such explosions from damaging SNF storage containers or disabling security personnel. Engineered barriers consist of access points designed to slow the speed of approaching vehicles by turns, speed humps, or a serpentine design and a vehicle barrier system (VBS) made of thick reinforce concrete walls or heavy steel portal gates that are installed at a prescribed distance from the SNF or cask handling activities. The VBS prevents entry of vehicle-borne explosive devices. Its distance from the storage area minimizes the impact of an explosion if one were to occur.

Resistance to explosive devices is also maintained by passing persons through explosive and metal detectors, checking all hand-carried items by X-ray machines and inspecting all vehicles and deliveries by security personnel.

STAD overpacks will need to be analyzed and tested to show that they can withstand high explosion pressure waves.

C1-6.0 Summary

In general, the use of STAD canisters offers a standardized method of SNF storage. Use of a single storage system simplifies handling equipment and operations. Only one storage overpack and concrete storage pad design is required which reduces analyses, design and licensing time.

There are also dry cask storage industry issues that can be resolved with STAD canisters. Elimination of the need to affix a temporary lifting lug to the top of the STAD canister would significantly reduce dose rates. Also the transport cask could be designed with lids on either end so that traditional canister transfer is eliminated and the canister could be directly transferred into a storage unit from the transport cask.

However, STAD canisters represent a marked increase in the number of units required due to the reduced capacity from current commercial storage systems. This increase will affect the cost as a whole. The size of the STAD canister also factors into the cost – the more canisters required, the higher the costs. The use of a 4-pack container for the small STAD canisters helps defray some of the storage issues as well as cost. STAD canisters contain fewer assemblies than a current DPCs being used in the industry. This means that for a given amount of effort less MTHM will be placed into storage. Instead of 450 overpacks as in other commercial alternatives, the STAD canister forces the use of between 500 and 1000 overpacks, depending on the size STAD canister ultimately selected. The storage pad would need to be substantially larger for STAD alternatives and the cost could be a significant penalty.

STAD canisters do not currently exist and no design standard has been accepted. Moreover, the NRC has not reviewed STAD canisters yet in any licensing application, so it is not clear what the final configuration of STAD canisters will be. Likewise, there eventually will need to be a transfer system developed that takes SNF assemblies out of their NRC-licensed canisters and to repackage them in STAD canisters. The process for doing this is undefined, it is not licensed, and there are no facilities available to make this exchange.

In summary, the pros and cons of this alternative in comparison with the other alternative using STAD canisters is listed from the highest most significant impact to the lowest least significant impact are as follows:

<u>Pros</u>

- The Pad Storage of STAD canisters in vertical concrete overpacks represents no departure from current practice. All of the processes, licensing expectations, and equipment needed will be completely standards and unremarkable. There will still need to be a new licensing effort but it is likely to be minimal.

- Pad Storage is very simple and easy to implement. It offers the ability to grow as capacity is required thereby spreading the capital costs over time.

Cons

- STAD overpacks that rest on a concrete pad must be designed for seismic stability. This becomes even more critical for smaller packages because the height to width ratio is smaller such that the resistance to tipover in an earthquake is lessened. In high seismic areas, STAD overpacks may need to be bolted to the pad which increases pad thickness and overall cost.

C1-7.0 References

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18. 10 CFR 70, Domestic Licensing of Special Nuclear Material.

19. 10 CFR 2, Agency Rules of Practice and Procedure.

20. NUREG-1571, NRC Information Handbook on Independent Spent Fuel Storage Installations, December 1996.

21. National Environmental Policy Act of 1969 (NEPA), as amended.

22. 10 CFR 51, Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.

23. NRC Regulatory Guide 3.48, Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage), Rev. 1, 1989.

24. NRC NUREG-1748, Environmental Review Guidance for Licensing Actions Associated with NMSS Programs, August 2003.

25. 10 CFR 73, Physical Protection of Plants and Materials.

APPENDIX C2

STUDY 3 – ALTERNATIVE DRY STORAGE METHODS FOR STANDARD SNF CANISTERS

Alternative 2 – Underground Storage Using STAD Canisters (S-UGS)

Alternative 2 – Underground Storage Using STAD Canisters (S-UGS)

C2-1.0 Description of Storage Alternative

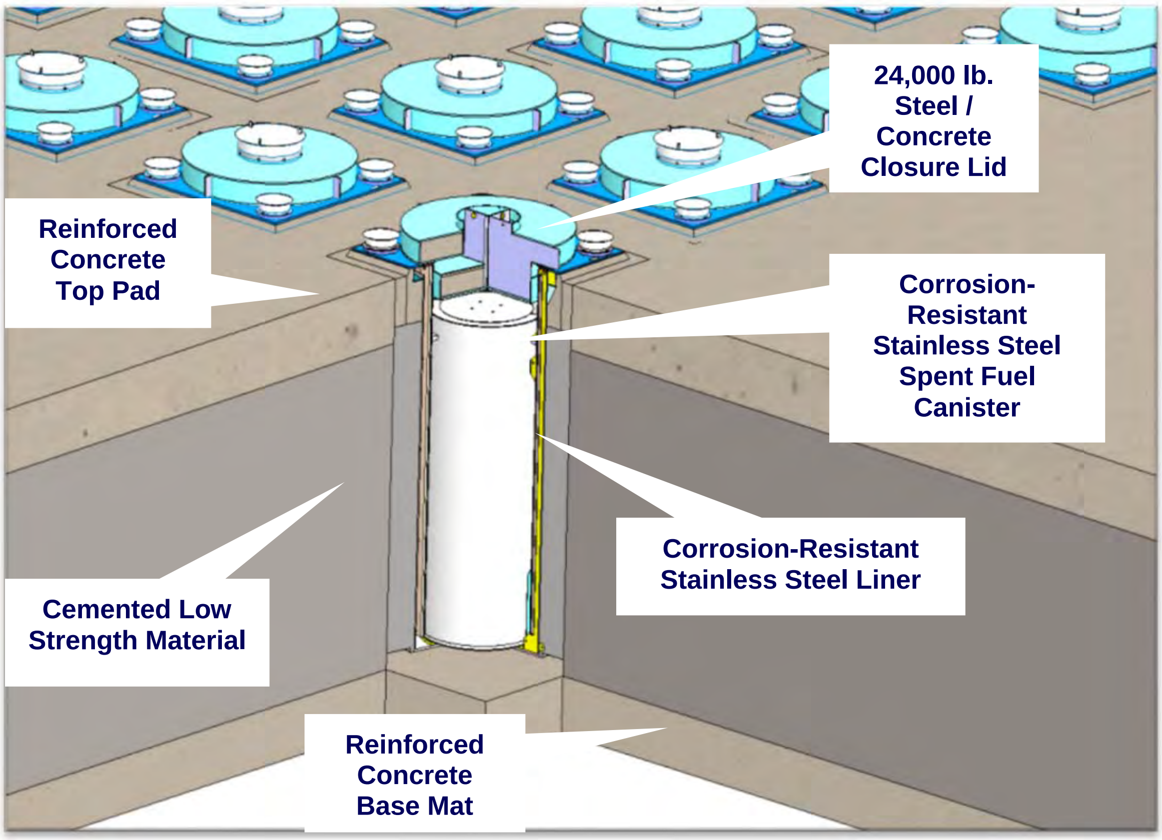
Alternative 2 evaluates the use of a system that stores a commercial spent nuclear fuel (SNF) in Standardized Transportation, Aging and Disposal (STAD) canisters in an underground silo. This alternative is designated S-UGS, for a STAD canister stored in an underground system. Currently there is only one company that provides an underground storage system, Holtec International. The storage systems are as follows:

- Holtec International
  - HI-STORM 100U (Reference C2-1)
  - HI-STORM UMAX (Reference C2-2)

The HI-STORM UMAX (UMAX) system is the only underground storage system being used at this time. The Callaway nuclear plant is constructing the first UMAX system and San Onofre units 2 and 3 have ordered a UMAX system. The UMAX storage system is an underground SNF storage concept that consists of two monolithic slabs of concrete with cemented low strength material (CLSM) in-between. Embedded within the concrete and CLSM are metallic cavity enclosure containers (CECs), where the STADs are stored individually. Each storage location is individually cooled via passive cooling channels in the UMAX vertical ventilation module (VVM). The VVM consists of the closure lid, the divider shell and the CEC. The STAD is placed inside the divider shell that is concentric to the CEC with air inlets at the bottom. The air inside the divider shell is warmed by the decay heat from the fuel inside the SNF and rises and is released from the stack built into the closure lid. Cool air is drawn into the VVM via cool air inlets at the periphery of the closure lid and introduced into the inside of the divider shell via the penetrations at the bottom of the divider shell. The inlets and exhaust stacks on the closure lid have been designed to be able to function regardless of wind blowing across the storage site.

This approach is more resistant to seismic events than other approaches and is less exposed to environmental and other hazards than above ground approaches. It provides greater shielding for the radiation given off by the SNF in storage since it is underground. The closure lid is very substantial and is designed to withstand a wide range of postulated events. This concept also presents a more acceptable appearance to the public than conventional above ground SNF storage systems. More importantly, the low profile of the finished storage location makes it easier for the site security team to visually ascertain that no intruders are advancing on the site using the storage overpacks as cover for their movement. This system is currently licensed and deployed for the storage of SNF. The S-UGS alternative description borrows heavily from the UMAX design approach. The UMAX system is shown in **Figure C2-1**.

Figure C2-1
Holtec HI-STORM UMAX Concept



Source: Holtec International

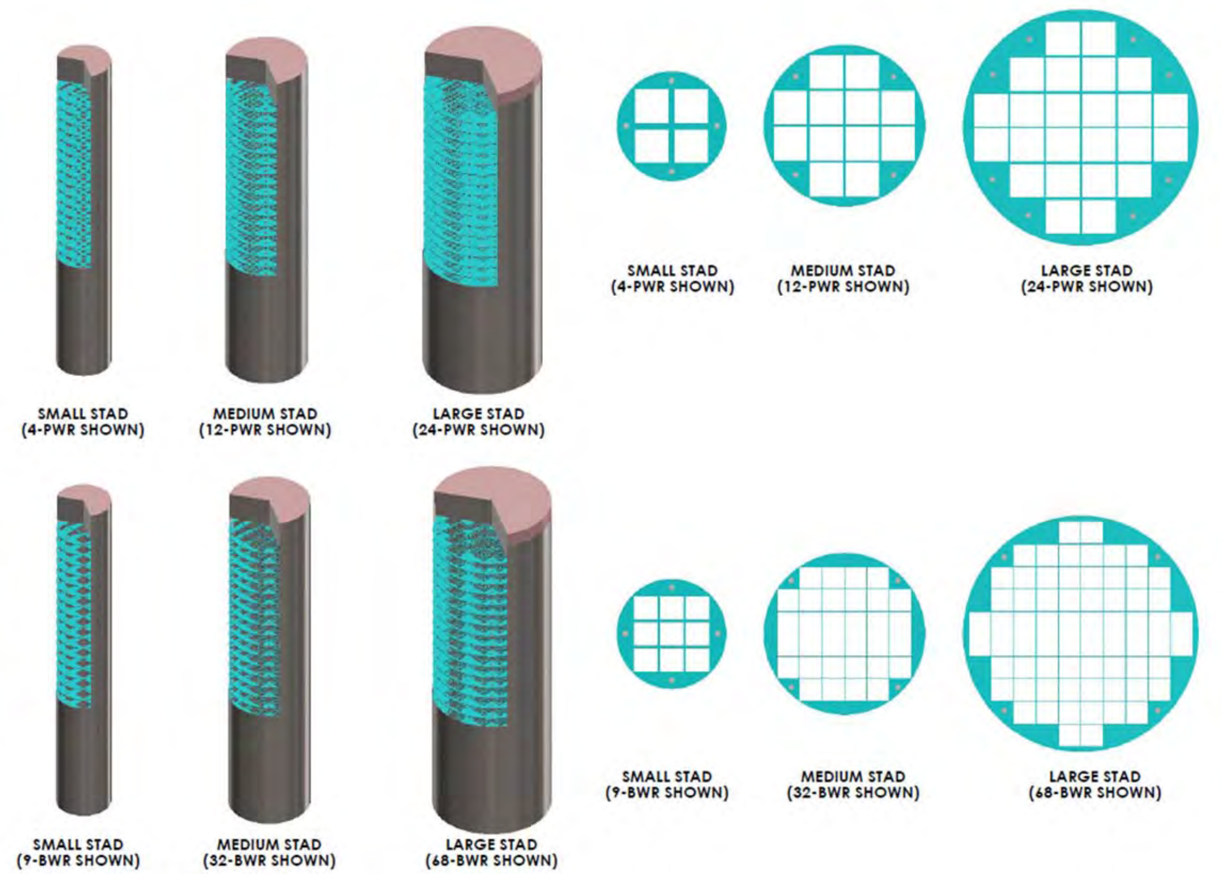
The major difference between the UMAX concept and Alternative 2 is that this alternative uses STAD canisters in the underground CECs.

The concept of STAD canisters were developed by DOE as a means of addressing the variability of the SNF storage issues that confronted the Department when faced with consolidating the SNF at a single location. Some dual purpose canister (DPC) systems were not designed for shipping and where either too large or unlicensed for this activity. In addition, some legacy sites were no longer serviced by rail, requiring that the SNF be repackaged in truck-shippable canisters.

The DOE has decided to consider three STAD canister designs which are shown in **Figure C2-2**. Small STAD canisters (4 PWR/9 BWR) and medium STAD canisters (12 PWR/32 BWR) are specified by the DOE "Performance Specification for Small and Medium Standardized Transportation, Aging and Disposal Canister Systems," (Reference C2-3). Large STAD canisters (21 PWR/44 BWR) are specified by DOE "Transportation, Aging, and Disposal

Canister System Performance Specification," (Reference C2-4). All three of these STAD canister sizes are considered together in this alternative at the Interim Storage Facility (ISF). The variations in size will be called S-UGSa for the small STAD canister, S-UGSb for the medium STAD canister, and S-UGSc for the large STAD canister. The small STAD canisters can also be packed in a 4-pack STAD multi-can storage container so that they can be handled as a single package, resulting in 16 PWR assemblies or 36 BWR assemblies being shipped in the multi-can storage container. They are therefore slightly larger in capacity than the medium STAD as far as the ISF is concerned. The medium STAD will be more efficient to load and to handle at the generator's site, but once it arrives at the ISF, it is the least efficient storage package of SNF.

Figure C2-2
Proposed STAD Sizes



This study has assumed that a 32 PWR assembly commercial DPC received at the ISF contains approximately 14.5 MTHM.[1] The large STAD canister contains only 66% of the number of PWR assemblies as the 32-assembly PWR DPC in current use. Part of the reasoning for this is that the lower-capacity STAD canister may be used to transport SNF with higher decay heat than

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[1] Some of the legacy DPCs contain fewer fuel assemblies so that the average mass per DPC is actually 11.1 MTHM for the ISF.

could occur using a 32-assembly DPC. Smaller capacity packages generally can transport SNF with higher decay heat due to more efficient heat transfer in the smaller packages.

The following **Table C2-1** shows the capacities of each type of STAD canister.

Table C2-1
STAD Canister Capacities

Option	STAD	Shipment	PWR	BWR	MTHM per Overpack
S-UGSa	Small	4 each	16	36	7.3
S-UGSb	Medium	1 each	12	32	5.4
S-UGSc	Large	1 each	21	44	9.5

During transportation, the STAD canisters are loaded into a transport cask that provides shielding and structural protection to the STAD canister. Impact limiting devices are attached to the ends of the transport cask for additional protection during transit. The shipping package must comply with the requirements of 10CFR71 (Reference C2-5). Four small STAD canisters will be shipped in a Multi-can storage container that uses a common handling mechanism to enable handling all of four small STAD canisters as a single entity. For storage, the STAD canisters must comply with the requirements of 10CFR72 (Reference C2-6).

During SNF loading and STAD transfer between the fuel pool and dry storage or shipping, a metal transfer cask provides physical protection and radiation shielding. During transportation, a metal shipping cask protects the STAD from any credible accident that might occur. The casks are metal and provide the confinement boundary for the SNF assemblies. The metal cask is fitted with impact limiting devices for additional protection during transit. The shipping cask must comply with the requirements of 10CFR71.

In the underground storage system, the STAD is stored in the VVM that provides the physical protection and heat removal capability. Since the VVMs are all of one size, the various sized STAD canisters will need be fitted with the necessary spacers or adaptor frames to permit storage in the underground silos.

Construction at the Callaway ISFSI shows the components that make up the UMAX system in **Figures C2-3 through Figure C2-7**.

Figure C2-3
Excavation for the Holtec HI-STORM UMAX at the Callaway ISFSI

Source: Holtec International

Figure C2-4
Holtec UMAX Cavity Enclosure Containers set on the Base Mat at the Callaway ISFSI

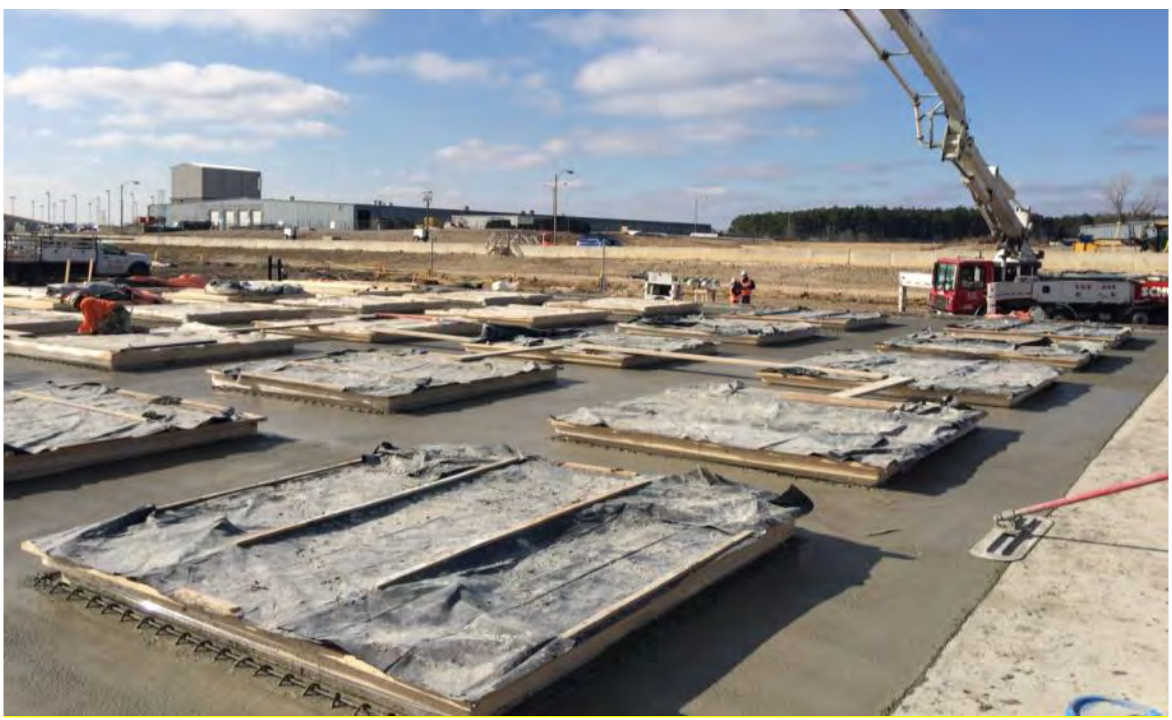
Source: Holtec International

Figure C2-5

Form work for the Top Pad of the Holtec UMAX at the Callaway ISFSI

Source: Holtec International

Figure C2-6
Holtec HI-STORM UMAX Top Pad Placement at the Callaway ISFSI



Source: Holtec International

Figure C2-7
Holtec HI-STORM UMAX, Completed Pad Construction, Callaway ISFSI

Source: Holtec International

C2-2.0 Concept of Operations

C2-2.1 Facility Layout

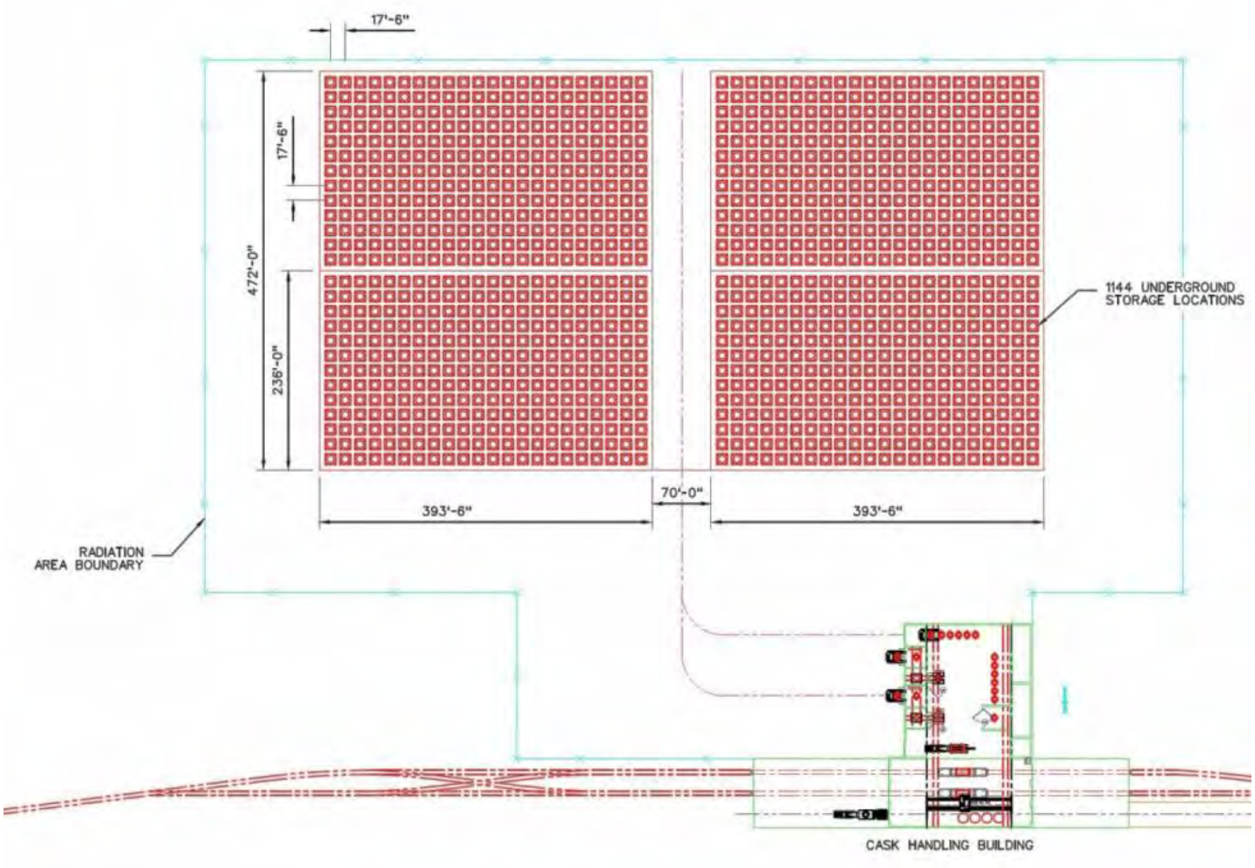
S-UGS is a straightforward application of the Holtec HI-STORM UMAX system for SNF storage. This is a new SNF storage technology but it has only been proposed for vertical storage canisters. The S-UGS alternative will propose an approach that will broaden the applicability of this concept to any size STAD canisters. However, it assumes that only one STAD becomes the standard. **Figures C2-8 through Figure C2-10** show the S-UGS overall site layout.

The transport casks are delivered to the site by rail. Most likely, the railroad carrier will put the unit car at a siding off site and the ISF dedicated tug will be dispatched to retrieve the train. This small locomotive brings the railcars from the mainline siding to the Rail Interchange Siding Yard. At this point, the unit cars are disconnected and the security detachment who accompanied the ship is relieved. There is a powered derailer preventing unauthorized rolling stock onto the siding yard without clearance.

The individual transport cask bearing railcars are moved to the Railcar Security Inspection Area located at the entrance of the ISF protected area. There, site security officers will review the shipping paperwork and perform a thorough check of the rolling stock and the packaging to ensure that there is no contraband on the shipment. The railroad tracks have a powered derailer that is positioned at the gate to prevent unauthorized access into the protected area via rail. After the security inspection, the transport cask railcars are move into the SNF Delivery Rail Yard / Staging Area until the Cask Handling Crew is ready for them in the CHB.

Figure C2-8
Conceptual Site Plan of the S-UGS Using Small STAD Canisters

Figure C2-9
Conceptual Site Plan of the S-UGS Using Medium STAD Canisters



The CHB is where the transition from the rolling stock to the storage area is begun. As a result, it is located at the intersection of the rail yard and the concrete storage area. It is accessible by two sets of rails, one for each railbay, and has cask transporter heavy haul routes to the storage area. The storage area is centrally located and laid out to provide easy access for the cask transport machines and the survey and security teams.

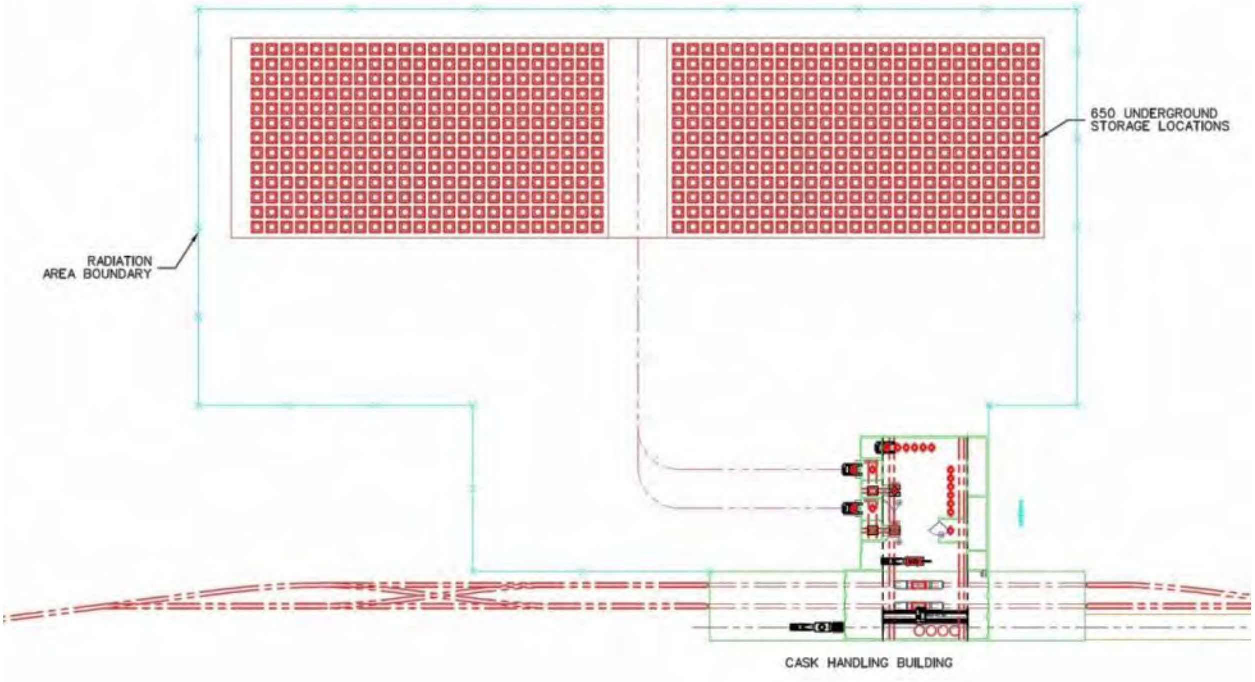
Transport casks are brought into the CHB from the staging area via the rollup doors on either the west or the east end of the railbay[2]. Material and supplies are brought in via the loading dock on the east side of the CHB. Lifting frames and other necessary adaptors to accommodate odd sized legacy SNF canisters are brought in by truck from the fabrication yard and handled via the railbays.

The SNF storage locations are north of the CHB and provide a large area for storage and for future expansion. The Expanded facility storage location would be constructed to the west of the

[2] For this presentation, North is at the top of the figure. The ISF can be in any orientation, but for clarity of this description, North is up; East is right; etc.

ISF storage location. Major civil/structural work for the Expanded area for the S-UGS would need to be constructed at the same time as the ISF storage area to avoid potential damage to SNF stored in the ISF storage area.

Figure C2-10
Conceptual Site Plan of the S-UGS Using Large STAD Canisters



Personnel entrances and support facilities are located to the southeast of the CHB and include the ISF Office Building, Warehouse, Security Entrance, parking lots, electrical substation, fire water tanks and pump house, emergency diesel generators and fuel storage tanks, and the ISF Visitor's Center.

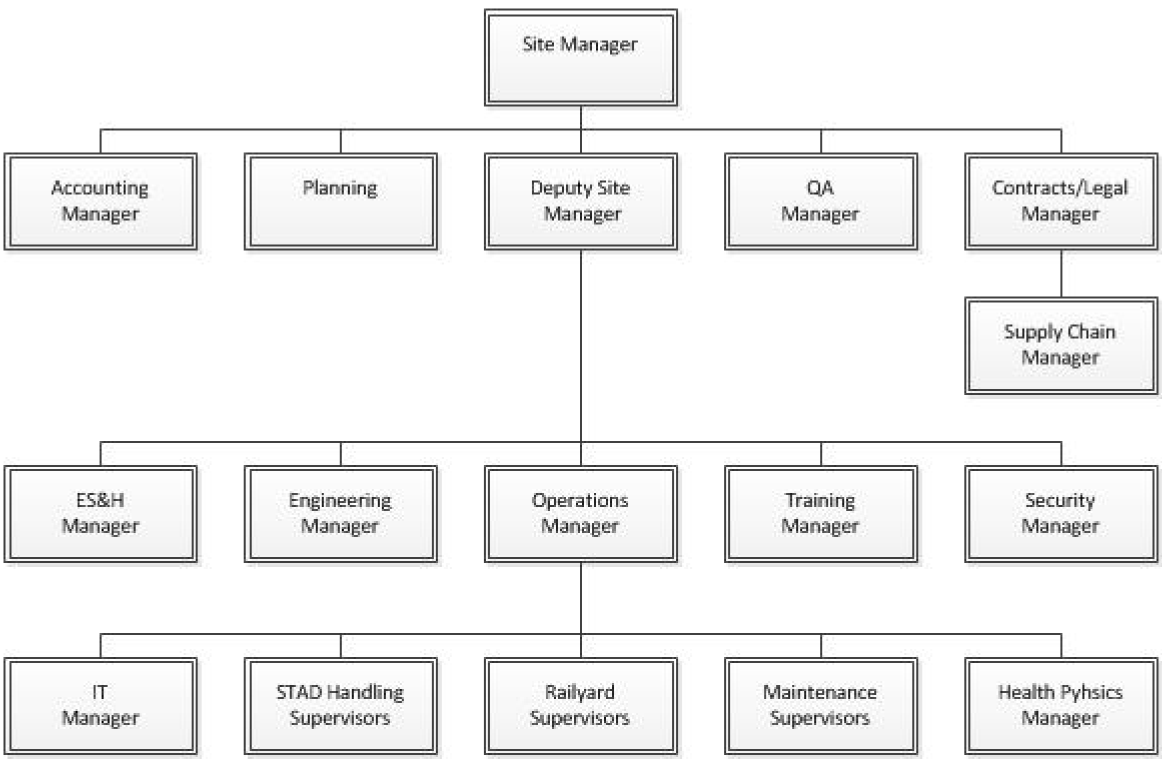
C2-2.2 ISF Operations

The ISF operates 24-hour, 7-days a week basis, but cask handling operations are limited to a single 8-hour shift, 40-hour work week. This has been done because the logistics issues associated with delivering a large number of transport casks to the site do not warrant around-the-clock cask handling operations. It also provides the ability to accommodate surges of work that might be necessary by the simple expedient of adding additional cask handling crew shifts. It is assumed that the ISF is operated by an independent contractor so that many of the administrative and Human Resource functions of an organization are not required within the site organization. The costs for these off-site services are covered in the overhead calculation for labor. **Figure C2-11** is the chart of the site organization.

There are two phases to ISF operations: Cask Handling Operations and Storage Facility Surveillance and Maintenance Operations. The Cask Handling Operations are the activities necessary to accept SNF packaged in STAD canisters from nuclear generators and to place the SNF into interim storage on site. This is a temporary activity lasting only as long as necessary to accept the design basis amount of SNF considered in this study. This activity lasts only a few years and involves the most labor intensive activities experienced at the ISF. Additional Cask Handling Operations will be necessary at the end of ISF life when the stored SNF is repackaged and shipped to its final destination.

The Storage Facility Surveillance and Maintenance Operation is the ongoing activity that spans the entire operational lifetime of the ISF. It consists of all the activities necessary to plan, to monitor the performance and aging of the storage systems used to house and cool the SNF, and to provide for the safeguards and security necessary to protect the facility from unwanted intrusions and/or damage. The Surveillance and Maintenance Operations begin immediately upon the commissioning of the ISF and continue until the last STAD has been removed.

Figure C2-11
Typical ISF Organization Chart



A major activity at the ISF during the Cask Handling Operations is maintenance of the equipment necessary to perform the heavy lifts and heavy load movements necessary to fulfill the SNF handling function. While Cask Handling Operations are underway, the major equipment necessary to move the heavy loads around the ISF must be available and in working order. Cranes, carts and wheeled vehicles that handle STAD canisters need to be single failure proof and inspected and maintained rigorously to ensure operability and safety. The commercially available machines may need to be modified to make them more capable of sustaining the sustained work load during the early stages of the ISF life cycle.

In addition to physical labor, the ISF requires planning and engineering to support operations. As already described, engineering, procurement and insert/adaptor/lifting frame assembly activities need to be well ahead of actual SNF acceptance activities. The timescale of the work necessary to prepare the inserts/adaptors/lifting frames for the storage of SNF requires that the planning and engineering activities be performed nearly a year ahead of the SNF acceptance activities.

Engineering activities are required for safety analyses and modifications to processes and materials to support SNF storage. Also, record keeping is required to identify where each STAD canister originates from, what it contains, the SNF characteristics and where it has been stored. In addition, all material certifications for SNF storage containers and other materials used for SNF handling need to be meticulously maintained for easy retrieval in the future.

Finally, the largest functional activity at the ISF is physical security. The security group needs to actively maintain the security of the site in addition to inspecting all materials coming onto the site. This security function is the largest single group of the organization and is a 24-7 operation. The S-UGS has a significant advantage over other pad-based storage alternatives in this area. Since the STAD canisters are stored below grade, it is easier for two lines of sight to be established over the SNF storage area in order to locate and to identify intruders. So, while a traditional overpack system might require as many as four security locations to establish the necessary security coverage, the S-UGS can achieve it with only two. This results in a smaller security force than is needed for other pad-based storage systems.

In addition, the IAEA oversight systems would be simplified since a single camera would be able to survey the entire storage area to assure inspectors that no diversion was of potentially strategic materials occurs.

Table C2-2 is a listing of the site organization staff. The organizational staff would be adequate to support the activities at the ISF necessary to support the cask handling activities. This staff totals 126 but does not include the cask handling crew. Many of the staff personnel are cross trained to enable them to support cask handling activities if necessary.

Table C2-2
Site Organization

Position	Staff	Position	Staff
Site Manager	1	Health Physicists	2
Deputy Site Manager	1	Mechanical Engineers	4
Accounting Manager	1	I&C Engineers	1
Planning Manager	1	Electrical Engineers	2
QA – Manager	1	Civil/Structural Engineers	4
Contracts/Legal Manager	1	Quality Engineers	3
Supply Chain Manager	1	Buyers	2
Operations Manager	1	Planners	3
ES&H Manager	1	Security	46
Engineering Manager	1	Trainers	2
Training Manager	1	Railyard Operators	2
Security Manager	1	Supervisors	4
IT Manager	1	Mechanics	6
DPC Handling Supervisors	1	Electricians	4
Fabrication Supervisors	1	CHB Facility Operators	10
Railyard Supervisors	2	IT Technicians	2
Maintenance Supervisors	2	Administration Assistants	2
Health Physics Manager	1	EMT	1
Nuclear Safety Engineers	2	RR Tug Engineers/Brakemen	4
		Total	126

C2-2.3 Cask Handling Crew Size

The Cask Handling Operations staff is dedicated to the movement of STAD canisters around the site. These operations are carried out by dedicated crews who focus on certain areas of the operation. This way, when multiple STAD canisters are processed each week, a crew learns specialized skills that will improve efficiency. The crews are: 1. the Railbay Crew, 2. the Cask Transfer Crew and 3. the Transporter Crew.

The Railbay Crew consists of the skilled crafts necessary to prepare the transport cask to be unloaded and later to be reassembled to be shipped back to the generator. These activities include receipt inspection of the as-received package, removal and storage of the impact limiters, removal and storage of the transport cask cover, and removal and storage of the tie-down straps. Then, the Railbay crew rigs the transport cask for lift by the overhead traveling bridge crane and places it on the transfer cart in the CHB.

The Cask Transfer Crews preform the transfer of the STAD canisters from the transport cask transfer cask. The transfer of STAD canisters takes place in the vertical transfer cells. Once the STAD canister is loaded into the transfer cask, the cask is handed off to the Transporter Crew. In addition, the Cask Transfer Crew also prepares the storage VVM at the pad and works with the Transporter Crew to place the STAD canister into storage.

The Transporter Crews operate the Vertical Cask Transporters (VCTs) to move the storage transfer casks. The Transporter Crew positions the storage transfer cask in the receiving transfer cell or on the transfer fixture, and after it is loaded, picks the storage transfer cask and transports it to the storage location. Once at the storage location, the Transporter Crew operates the VCT in coordination with the Cask Transfer Crew to place the STAD into storage.

Table C2-3 shows the staffing for each major activity necessary to move STAD canisters from the transport cask to the storage area. These values are based on current experience with moving STAD canisters around operating nuclear sites to store the SNF at generator ISFSIs. Each STAD canister has a dedicated supervisor who is responsible for all activities associated with that package from receipt until replacement. In addition, a supervisor is assigned to each transport cask as it is serviced and packaged for reshipment. The mechanics are responsible for removing the mechanical fasteners that hold the various cask lids on and the lifting lugs.

The Riggers are responsible for attaching the lifting devices to casks and for visually monitoring the lifts.

The Electricians are instrumentation specialists who visually inspect the tamper proof seals on the transport casks and reinstalling them for the reshipment. They also have a role in installing the instrumentation packages to the storage containers in the fabrication crew and attaching the instrumentation to the monitoring systems once the SNF is placed in the storage area.

Health Physics teams are associated with all STAD canister handling activities as are QA/QC inspectors. The Crane Operators are needed for three different types of cranes. The Railbay cranes are overhead traveling 200 ton bridge cranes. The vertical transport cask crane is a jib crane and a collection of other lifting devices and hoists associated with specialized transfer devices. The Heavy Equipment operators are the operators of the VCTs and specialized fixed machines such as powered carts and transfer fixtures.

Table C2-3, Basis of Staffing

STAD - Unshielded STADs in Individual Vaults		Supervisor	Mechanics	Electricians	Riggers	Operations*	HP	QA/QC	Crane	RR Ops*	Heavy Eq. Operator	Security*	Total Staff	Duration (hrs)
0)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	0	0	11	0.5
1)	Receive transport cask on railcar at Cask Handling Building	1	2	2	0	1	2	1	0	2	0	2	13	1
2)	Remove impact limiters and place in temporary storage	1	2	0	2	0	2	0	1	0	0	0	8	3
3)	Upend and lift transport cask off of railcar and place on unloading cell transfer cart	1	0	0	2	0	2	0	1	0	0	0	6	2
3a)	Remove railcar from railbay	0	0	0	0	1	0	0	0	2	0	2	5	1
4)	Unbolt and remove transport cask lid using jib crane	1	2	0	1	0	2	0	1	0	0	1	8	1
4a)	Secure the transport cask and transfer cart seismically	1	2	0	2	0	0	1	1	0	0	0	7	0.5
4b)	Plan of the day and safety meeting	1	2	0	2	0	2	1	1	0	1	0	10	0.5
5)	Attach lifting lug to top of STAD	1	2	0	2	0	2	1	1	0	0	0	9	1
6)	Position transport cask transfer cart into unloading cell and close shield doors	1	0	0	1	0	0	0	0	0	1	0	3	1
7)	Stage transfer cask in receiving cell using VCT	1	2	0	0	0	0	1	0	0	1	0	5	1
8)	Close receiving cell shield doors	1	0	0	2	0	0	0	0	0	0	0	3	0.5
9)	Position shielded transfer sleeve cart over unloading cell	1	0	0	2	0	0	1	0	0	1	0	5	0.5
10)	Lower shield sleeve hoist and grapple STAD lifting lug	1	0	0	2	0	0	0	0	0	1	0	4	0.5
11)	Raise STAD into shield sleeve	1	0	0	2	0	2	1	0	0	1	0	7	1
12)	Position shielded transfer sleeve cart over transfer cask in receiving cell	1	0	0	2	0	0	1	0	0	1	0	5	0.5
13)	Lower STAD into transfer cask, release grapple, and retract hoist	1	0	0	2	0	2	0	0	0	1	0	6	1
14)	Remove lifting lug from STAD	1	2	0	2	0	0	0	1	0	0	0	6	0.5
14a)	Secure the STAD and the transfer cask seismically	1	2	0	2	0	0	1	1	0	0	0	7	0.5
14b)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	1	0	12	0.5
15)	Pick up transfer cask and transfer to underground storage cell using VCT	1	0	0	2	0	0	0	0	0	1	0	4	2
16)	Install docking collar at underground storage cell	1	2	0	2	0	0	1	1	0	1	0	8	2
17)	Dock transfer cask to underground storage cell and remove rigging	1	0	0	2	0	2	0	0	0	1	0	6	0.5
18)	Rig STAD to VCT for vertical lift and hoist	1	0	0	2	0	0	0	0	0	1	0	4	0.5
19)	Remove transfer cask base using docking collar	1	2	0	2	0	0	0	1	0	1	0	7	0.5
20)	Lower STAD into underground storage cell	1	0	0	2	0	0	1	0	0	1	0	5	1
21)	Access top of STAD (by ladder inside transfer cask) and remove rigging	1	2	0	2	0	2	0	0	0	0	0	7	0.5
22)	Withdraw STAD rigging and replace transfer cask base	1	2	0	2	0	0	0	0	0	0	0	5	0.5
23)	Re-rig transfer cask to VCT and undock from underground storage cell	1	2	0	2	0	0	0	0	0	0	0	5	1
24)	Install closure lid on CEC	1	2	0	2	0	0	1	1	0	0	0	7	1
24a)	Turnover to operations	0	0	2	0	2	2	1	0	0	0	0	7	24
24b)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	1	0	12	0.5
25)	Return VCT to CHB	1	0	0	0	0	0	0	0	0	1	0	2	1
26)	Open unloading cell shield doors and position transfer cart under jib crane	1	0	0	2	0	0	0	0	0	0	0	3	1
27)	Install transport cask lid	1	2	0	2	0	0	1	1	0	1	1	9	1
28)	Lift transport cask and transfer to maintenance	1	0	0	2	0	0	0	1	0	1	0	5	1
28a)	Survey and wipedown transport cask	1	0	0	0	0	2	0	0	0	0	0	3	1
28b)	Reposition empty railcar to railbay	0	0	0	0	1	0	0	0	2	0	2	5	1
29)	Lift transport cask and place on railcar	1	2	2	2	0	0	0	1	0	1	0	9	1
30)	Install impact limiters on transport cask	1	2	0	2	0	0	1	1	0	0	0	7	2
31)	Release railcar for shipment	1	0	0	0	1	2	1	0	2	0	2	9	1

* These categories are loaned to the Cask Handling Crew

The results of this effort are summarized in **Table C2-4** below. This staffing estimate is approximate since not all crafts are required for an entire shift. Also, some intermediate steps do not require a certain craft, but in reality, they do not disappear. These interruptions are ignored because they provide opportunities for breaks for the workers and do not materially impact the assessment. The ISF labor pool will be a matrix structure where necessary craft and managers will be drawn from the site organization staff as necessary to achieve the desired operations. This is an obvious requirement because of the variability in the Cask Handling Crew size by shift in **Table C2-4**. Based on this study, the site organization staff will need to be increased by 47 workers to achieve the desired ISF throughput during the cask handling phase of the facility's life cycle. This results in a total ISF staff of 173.

Table C2-4
Cask Handling Crew Makeup

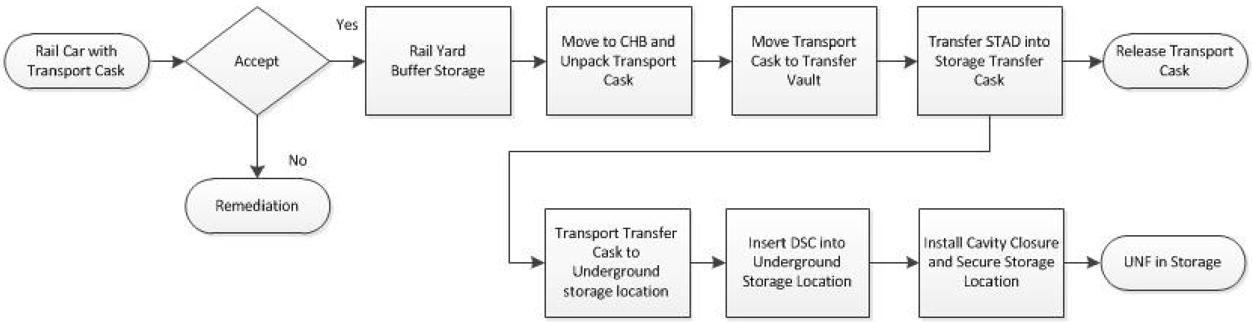
Craft	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Maximum*
Supervisor	4	4	4	4	4	4
Mechanics	8	8	8	8	8	8
Electricians	6	6	6	6	6	6
Riggers	10	10	10	10	10	10
HP	8	8	8	8	8	8
QA/QC	4	4	4	4	4	4
Crane Operator	4	4	4	4	4	4
Heavy Eq. Operator	3	3	3	3	3	3
Totals	47	47	47	47	47	47

* To the nearest whole person

C2-2.4 Material Handling Flow Diagram

Figure C2-12 is a representation of the material handling flow for the S-UGS alternative for the ISF. It describes the material flows of the operation. The central flow is the movement of STAD canisters containing SNF to the site. But equally important to the operations of the ISF are the material flow necessary to support the production of suitable storage insert/adaptor/lifting frames to place the STAD canisters into after being accepted by the site for storage. The vertical storage adaptors are prefabricated by the vendors and shipped to the site as steel structures packaged to protect them during transit. These adaptors are only required for legacy STAD canisters that are much smaller than the current STAD canisters. The need for the adaptor will be part of the licensing basis for the S-UGS design. The site crew will inspect these packages to accept them as undamaged and then will complete the fabrication in accordance with the vendor's specification.

Figure C2-12
Cask Handling Material Handling Flow Diagram[3]



C2-2.5 Operations

C2-2.5.1 Operational Sequence

Cask handling operations are a series of heavy lifts and heavy equipment movements that move the SNF in sealed STAD canisters from the rail head to the storage area. The operational sequence was benchmarked against ISFSI operations at operating nuclear plants. Although no one has actually performed all of the operations at an ISF, each operation has a precedent established in the nuclear industry. The crew sizes and the durations necessary to perform each activity therefore has basis. This benchmarking provides the underpinning supporting this operational sequence and the Time and Motion analysis the follows in **Section C2-2.6**.

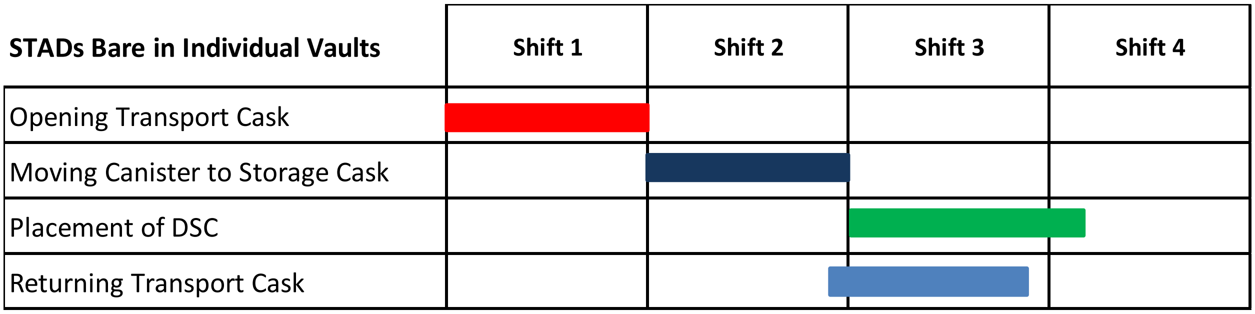
Figure C2-13 shows the high-level schedule for the two storage concepts in S-UGS assuming 8-hour shifts. The operational sequence once the transport cask is accepted into the CHB can be divided into four large operations:

1. Opening the transport cask
2. Moving the STAD into the Transfer device or system
3. Placement of the STAD in the cavity enclosure container and
4. Preparing for the turnaround of the transport cask.

It should be noted that this is essentially a three shift exercise regardless of the STAD size used. (The slight overlap into the fourth shift is the return of the empty VCT to the CHB; a non-critical path activity.) Once the transport cask is received in the CHB, the most time consuming operation is unpacking the transport cask from the railcar. This is a very labor intensive process that requires the removal of the impact limiters, the cask cover and the hold down straps. This process takes an entire 8-hour shift to accomplish. It also monopolizes the use of the OTB crane in each railbay.

[3] Remediation is not part of this study's work scope and is not addressed other than to note that the packages are not accepted on site regardless of their condition.

Figure C2-13
High-Level Operational Sequences



The STAD canister is transferred into the necessary insert/adaptor required to secure the legacy STAD canister in the cavity enclosure container in the concrete array inside the transfer cask. This is accomplished in the CHB by use of a transfer cells. A lifting lug is affixed to the top of the STAD canister while it is still in the transport cask. Then the transport cask is placed in the transfer cell via a transfer cart. The shield doors are closed and the mating adaptor is prepositioned on the transfer cask and the transfer cask is placed on top of the transport cast.by the overhead crane. The STAD canister is withdrawn from the transport cask up into the transfer cask. Once the STAD is in the transfer cask, the transfer cask is removed from the transport cask and placed in the receiving cell and retrieved by the VCT.

The transport cask is returned to the railbay where it is surveyed and inspected for damage. On the following shift, the transport cask is mated with its original railcar and the shipping package is reassembled: tie-down straps are installed, the transport cask cover is secured and the impact limiters are reinstalled. This process takes about one shift to accomplish.

At the beginning of the next shift, the VCT begins the trip to the storage location. At the same time, the Cask Transfer Crew begins to prepare the VVM to receive the STAD canister. The VCT removes the closure lid from the VVM.

Once the closure lid has been removed, the internals of the VVM will be inspected to ensure that there is no debris or water in the cavity. Depending on the final geometries of the site, the crew may need to remove the exhaust stacks from the closure lids between the storage location and the haul road to prevent damage.

A mating collar is placed on the top of the CEC. It provides both shielding and the mating device that captures the transfer cask's bottom lid. The VCT retrieves the transfer cask from the CHB, takes it to the storage location and places the transfer cask on top of the mating device. It is bolted to the mating device while the VCT hoist is rerigged to grapple the lifting lug on the

STAD canister. The hoist lifts the STAD canister slightly to unload the bottom lid. The lid is unbolted from the top and lowered into the drawer of the mating device. The drawer is hydraulically actuated to move the lower lid out of the way allowing the STAD canister free access to the VVM. The VCT hoist lowers the STAD canister into the VVM and verifies that it is fully seated in the VVM.

The hoist un-grapples the lifting lug and returns to the full up position. The transfer cask is rigged to the VCT hoist. The mating device closes its drawer and the lower lid is reattached to the bottom of the storage transfer cask. The VCT backs out of the storage array using the same path as it used to approach the storage location. The mating device is partially opened allowing workers to remove the lifting lug and to plug any empty bolt holes on the top of the canister/lifting frame. When all of the rigging has been removed from the VVM, the mating device's drawer is removed by the VCT and moved back to storage. The closure lid is then replaced on the storage location and the STAD is turned over to operations for a 24-hour observation period. The area is returned to its original condition and the VCT is returned to the CHB to pick up its next STAD canister.

C2-2.5.2 Limits to Operation

Railbay

S-UGS Cask Handling Operations are essentially a three shift process. Two of those shifts take place in the railbay. Therefore, the railbay is central to ISF operation and its design limits the ISF throughput. The only one railcar can fit under the OTB crane at a time, so this forces the railbay crew to arrange for the rail yard workers to move the empty railcar out of the way and to place another loaded railcar in the railbay as soon as the transport cask has been lifted free of the rolling stock. This permits the crew to start work unpacking the next transport cask at the start of the second shift of the week. Since there are two rail lines in the railbay, the CHB is able to place five STAD canisters into storage every week.

Adding another rail line to the railbay would eliminate the shuffling of railcars but would have no impact on the site throughput.

Overhead Traveling Bridge Cranes

The railbay requires a heavy lift crane in order to maneuver the transport cask off of the railcar and onto the transfer cart in the CHB. It also requires a crane to reverse this process and to replace the transport cask onto the railcar. While these activities are underway, they dominate the OTB crane and it is unavailable for any other activity. The CHB has only one OTB crane per railbay. This is adequate to support the existing design assuming no failures and permits a potential throughput to 5 STAD canisters per week.

The OTB cranes operate on the same set of rails to minimize the building height. If an outage occurs, one crane can cover either railbay albeit at a reduction in throughput. It would be necessary to ensure that the next crane to transfer a load to or from the railbay would be shuffled to ensure that the cranes would not interfere with each other during operations.

Transporters

The vertical cask transporters (VCTs) are very complex, heavy haul machines. They move slowly at approximately 1 mph and take a long time to move their loads to the storage locations. It takes one and a half shifts from being loaded in the CHB until a transporter returns ready for a second load. There needs to be four operable VCTs to handle the maximum ISF throughput. In addition, two spare VCTs are likely to be required to permit routine maintenance of the complex machinery to ensure continued throughput.

C2-2.6 Time and Motion Analysis

C2-2.6.1 Methodology

No one has operated a national scale ISF for the dry storage of SNF and STAD canisters have not been used. For this reason, this study is based on a theoretical construct based on a high-level operational sequence developed by the concept designers. These high-level activities were decomposed down to their constituent activities. At this level, the activities were generally ones that had been performed by operators at existing nuclear facilities, or that could be estimated by small extrapolations of existing operational experience. Interviews were conducted with several individuals with real, hands-on operational experience with moving SNF to achieve a consensus on the completeness, the durations and the staff size necessary to achieve each of these constituent activities. These were then pieced together to develop a bottom up estimate of durations and crew sizes for each step.

Additional steps were added to recognize the practice of having a "Plan of the Day" meeting and a safety meeting at the start of each shift. Also, steps not envisioned by the facility designers such as HP surveys of the emptied transport casks, and adding seismic restraints to packages containing SNF at the end of a shift were added to allow time for these necessary steps.

Once the operational sequence was developed, the sequences were considered in parallel to determine how many STAD canisters could be placed per week. Several basic assumptions were made. The first was that a large supply of transport casks on railcars was staged on the site ready for processing. If the ISF railyard is empty or contains only two railcars during a week, this time and motion study does not apply. The two railcars will be processed and the Cask Handling Crews will be given other duties to fill up the week. So, the first inherent assumption is that the logistics supply chain is adequate to fully challenge the capacity of the ISF.

Secondly, this study only considers operations that are already developed and in operation at existing operating nuclear plant experience. No unusual enhancements were considered.

Finally, no operation involving the movement of a STAD canister would be started during a shift if it could not be completed by the end of that shift. This is necessary because the CHB does not operate continuously, so no load would be left hanging or in some other unstable condition that would jeopardize the integrity of the SNF or its confining structures in the event of a design basis event. Therefore, the STAD canister is not allowed to be abandoned in any operation at the end of a shift without first securing the STAD canister.

As stated earlier, this study considers only a single 8-hour shift per week with no overtime. Clearly, the throughput could easily be increased by adding workers and shifts, and indeed that would be a cost effective expedient if additional capacity is desired. However, a working assumption of this study is only a single, 40-hour shift is necessary per week. Based on the certain problems with the logistics of moving SNF to the site, it is considered that this is a reasonable approach.

C2-2.6.2 Conclusion

It was determined that the S-UGS throughput with all of the assumptions is five STAD canisters (or five 4-pack small STAD canisters) placed into storage each week. This conclusion is independent of what size STAD canisters were considered. So, while the movement of STAD canisters is the same, the placement of SNF into storage is very different**.** **Table C2-5** captures the differences among the STAD canister options available.

Table C2-5
ISF Throughput Using STAD canisters

Option	STAD Canister	STAD Capacity		MTHM per Year (260 STADs/yr)	5000 MTHM Time
		PWR	BWR		
S-UGSa	Small	16	36	1898	2.6 years
S-UGSb	Medium	12	32	1404	3.6 years
S-UGSc	Large	21	44	2470	2.0 years

With the CHB having two rail lines, it is the OTB cranes that determine the maximum throughput of the CHB. The single OTB crane is the limiting element in the throughput of this alternative. It precludes increasing the throughput of the facility and should it fail or experience an outage, it would effectively prevent the CHB from functioning.

There needs to be two single-failure-proof transporters on site to develop and maintain full ISF throughput. These are extremely slow moving machines. Their size and mass make them destructive of the road bed if they move too rapidly. Moreover, they are restrained from moving too rapidly when carrying STAD canisters in order to limit the potential impact should there be a failure of any kind. They become critical path constraints if any one of them is out of service. In addition, they are currently designed for a limited amount of duty. The ISF would use these machines far more than their design. This could force a great deal of maintenance to keep them available. One or two spares are considered necessary for the long-term functionality of the ISF. If the "pillbox" design overpack is used, the transporter is less important in that it will have adequate down time between movements for maintenance. One transporter is probably adequate.

Figure C2-14 below shows the schedule for the S-UGS alternative. It should be noted that the schedules for all STAD sizes are the same.

The activities on the Y-axis are the steps necessary to process the STAD canisters from when they enter the CHB until the empty transport cask has been reinstalled on the railcar and removed from the CHB. The time across the top of the schedule is in hours. The red bars are critical path activities; the blue are near critical path activities. It has been assumed that it will take 24-hours of observations of the STAD canister once stored to accept the package. This activity is show as a green dashed line on this chart but is not really part of the cask handling crew's scope. It is the hand-off to ISF Operations for long-term surveillance and safeguards. It will consist of a series of temperature, air flow and radiation measurements over the initial 24-hour period to validate that the expected performance has been achieved.

The repackaging of the emptied transport cask was stretched out as a result of the Time Motion study to permit the OTB crane to finish unloading a new transport cask. Unloading new transport casks is given priority over repackaging the emptied transport cask.

The schedules in **Figure C2-14** were then placed in series and in parallel to establish the maximum throughput of the ISF.

Figure C2-15 is a week of this operational sequence schedule. It shows how the work flows from one transport cask to the next. The bars are color coded based on the major equipment needed for the activity. Look vertically down a scheduled hour to verify that the same piece of equipment is not being used for two activities at the same time. **Figure C2-15** is an extract of a four week schedule. It takes four weeks for the sequence to repeat. In four weeks, this system is able to place 10 STAD canisters into storage.

Figure C2-14 - Time Motion Schedule for S-UGS

	STAD - Bare STADs in Individual Vaults
0)	Plan of the day and safety meeting
1)	Dock transfer cask to underground storage cell and remove rigging
2)	Remove impact limiters and place in temporary storage
3)	Upend and lift transport cask off of railcar and place on unloading cell transfer cart
3a)	Remove railcar from railbay
4)	Unbolt and remove transport cask lid using jib crane
4a)	Secure the transport cask and transfer cart seismically
4b)	Plan of the day and safety meeting
5)	Attach lifting lug to top of STAD
6)	Position transport cask transfer cart into unloading cell and close shield doors
7)	Stage transfer cask in receiving cell using VCT
8)	Close receiving cell shield doors
9)	Position shielded transfer sleeve cart over unloading cell
10)	Lower shield sleeve hoist and grapple STAD lifting lug
11)	Raise STAD into shield sleeve
12)	Position shielded transfer sleeve cart over transfer cask in receiving cell
13)	Lower STAD into transfer cask, release grapple, and retract hoist
14)	Remove lifting lug from STAD
14a)	Secure the STAD and the transfer cask seismically
14b)	Plan of the day and safety meeting
15)	Pick up transfer cask and transfer to underground storage cell using VCT
16)	Install docking collar at underground storage cell
17)	Dock transfer cask to underground storage cell and remove rigging
18)	Rig STAD to VCT for vertical lift and hoist
19)	Remove transfer cask base using docking collar
20)	Lower STAD into underground storage cell
21)	Access top of STAD (by ladder inside transfer cask) and remove rigging
22)	Withdraw STAD rigging and replace transfer cask base
23)	Re-rig transfer cask to VCT and undock from underground storage cell
24)	Install underground storage cell cover
24a)	Turnover to operations
24b)	Plan of the day and safety meeting
25)	Return VCT to CHB
26)	Open unloading cell shield doors and position transfer cart under jib crane
27)	Install transport cask lid
28)	Lift transport cask and transfer to maintenance
28a)	Survey and wipedown transport cask
28b)	Reposition empty railcar to railbay
29)	Lift transport cask and place on railcar
30)	Install impact limiters on transport cask
31)	Release railcar for shipment

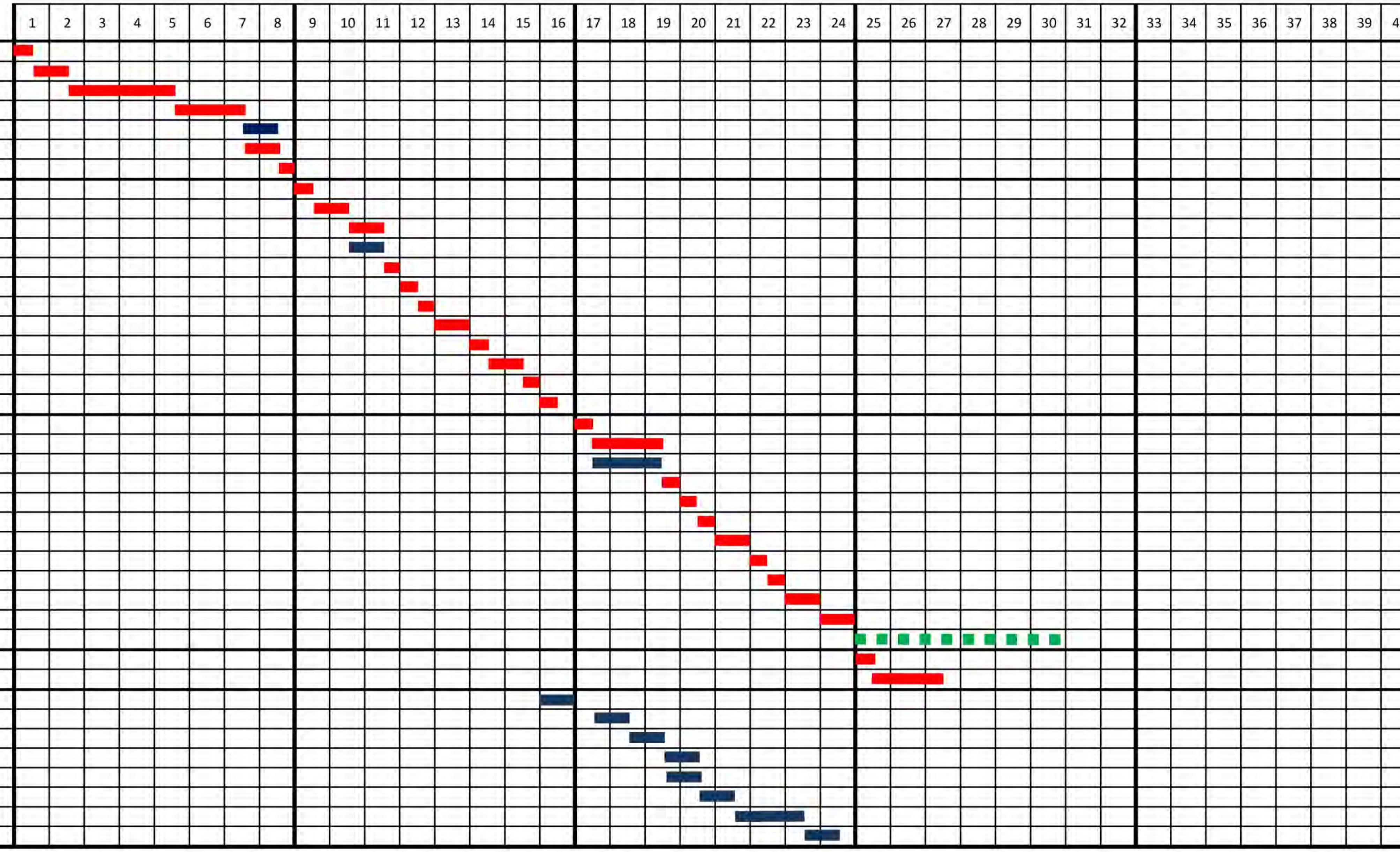


Figure C2-15
Typical Work Plan for S-UGS

	Week 1					Week 2				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Railbay #1	Transport Cask #1 Unload	STAD #1 Transfer to Pad	Transport Cask #1 Reload		Transport Cask #5 Unload	STAD #5 Transfer to Pad	Transport Cask #5 Reload		Transport Cask #9 Unload	STAD #9 Transfer to Pad
Railbay #1		Transport Cask #2 Unload	STAD #2 Transfer to Pad	Transport Cask #2 Reload		Transport Cask #6 Unload	STAD #6 Transfer to Pad	Transport Cask #6 Reload		Transport Cask #10 Unload
Railbay #2	Transport Cask #19 Reload		Transport Cask #3 Unload	STAD #3 Transfer to Pad	Transport Cask #3 Reload		Transport Cask #7 Unload	STAD #7 Transfer to Pad	Transport Cask #7 Reload	
Railbay #2	STAD #20 Transfer to Pad	Transport Cask #20 Reload		Transport Cask #4 Unload	STAD #4 Transfer to Pad	Transport Cask #4 Reload		Transport Cask #8 Unload	STAD #8 Transfer to Pad	Transport Cask #8 Reload

	Week 3					Week 4				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Railbay #1	Transport Cask #9 Reload		Transport Cask #13 Unload	STAD #13 Transfer to Pad	Transport Cask #13 Reload		Transport Cask #17 Unload	STAD #17 Transfer to Pad	Transport Cask #17 Reload	
Railbay #1	STAD #10 Transfer to Pad	Transport Cask #10 Reload		Transport Cask #14 Unload	STAD #14 Transfer to Pad	Transport Cask #14 Reload		Transport Cask #18 Unload	STAD #18 Transfer to Pad	Transport Cask #18 Reload
Railbay #2	Transport Cask #11 Unload	STAD #11 Transfer to Pad	Transport Cask #11 Reload		Transport Cask #15 Unload	STAD #15 Transfer to Pad	Transport Cask #15 Reload		Transport Cask #19 Unload	STAD #19 Transfer to Pad
Railbay #2		Transport Cask #12 Unload	STAD #12 Transfer to Pad	Transport Cask #12 Reload		Transport Cask #16 Unload	STAD #16 Transfer to Pad	Transport Cask #16 Reload		Transport Cask #20 Unload

NOTES*:*

1. The highlighted boxes show the critical path activity in the railbays. Note that work is always on going in the railbays.
2. The railcars are removed after the work crews are done with them and replaced by the next railcar to be processed.
3. The cycle is four shifts long.
4. This process is the same for all STAD canister sizes.
5. The Standalone CHB design can process 20 STAD canisters in four weeks; averaging 5 a week

C2-3.0 ISF Construction

The ISF will consist of a number of features and structures that will need to be constructed for the facility to operate. They include:

- ISF Site (with access road and utilities)
- Railroad spur and yard
- Storage area
- Cask Handling Building
- Protected Area (security boundary, cameras, intrusion detection and lighting)
- Overpack fabrication area
- Concrete batch plant
- Administration building
- Security/access control building
- Warehouse/maintenance facilities

C2-3.1 ISF Site

The ISF site is assumed to be placed on approximately one square mile of property. Not all of the land will require construction, only the area for the initial storage area. An access road and electrical utilities will need to be constructed into the property. The site access road will consist of an asphalt paved 2 lane road from the nearest highway into the ISF. The location of the site will determine if mechanical utilities (domestic water, wastewater, natural gas) can be supplied from local means or if these will need to be self-contained. A remote site requiring self-contained utilities can use water wells or trucked-in tanks of water depending on the underground water capability. Wastewater can be discharged through drain fields. Propane gas can be supplied if no natural gas lines are near the site.

The site will require an Owner Controlled Area (OCA) fence which will likely consist of a chain link fence to discourage trespassers from entering the site and keep animals out. The fence requires minimal construction and establishes a good facility boundary. Just inside the fence a gravel security road can be constructed to enable guard patrols around the site. This fence must be placed at some distance from the actual storage area in order to meet regulatory requirements which maintain a safe distance from the storage area to minimize radiation doses to the public.

The purpose of the OCA is to establish the portion of the property that maintains a level of secured control. Within this boundary, security maintains control and patrols for unauthorized individuals. In addition, 10CFR72.106 requires that all SNF storage and handling operations be maintained at least 100 meters from the OCA boundary. All CSF functions are contained within this boundary.

C2-3.2 Railroad Spur and Yard

The ISF will need railroad tracks from the mainline to receive incoming train consists and prepare for outgoing train consists. A rail portal at the PA boundary and a rail yard near the storage area will also be required.

The purpose for the rail yard is to provide adequate railcar storage for incoming and outgoing SNF train consists, and access to the CHB. The rail yard must be designed to allow flexibility for maneuvering yard switchers, railcars, buffer cars, and escort cars.

It is assumed that the rail yard will consist of at least 4 tracks – 2 tracks to receive inbound trains and 2 tracks for staging outbound trains. The yard includes a runaround track to permit the yard switchers access around the tracks. The yard also includes a lead line and a spur off the lead line accessing the CHB.

Construction of the rail yards will involve excavation, structural fill, potential geotextile materials to maintain soil stability, gradation to establish various elevations to ease railcar movements, heavy steel rail, ties, several rail turnouts, ballast placement, lighting, and other minor railroad related features.

C2-3.3 Storage Area

For the S-UGS storage alternative, the storage area will consist of a reinforced concrete storage pad, CECs surrounded by low strength cemented material, and topped by a second reinforced concrete pad. The underground storage system is designed to ensure adequate safety and to mitigate the effects of site environmental conditions, natural phenomena, and accidents including stability and liquefaction caused by earthquake conditions and settling over the life of the facility.

The size of a UMAX storage area depends on the number of storage units and the shape and limitations of the physical space where the storage area is to be placed.

To store up to 5,000 MTHM of SNF, the ISF will need to store approximately 926 small STAD canisters (4-pack canister), 926 medium STAD canisters, or 463 large STAD canisters in the UMAX system. This will likely consume more than the 250 acres used for the commercial pad ISF arrangement.

C2-3.4 Cask Handling Building

The S-UGS storage alternative would require some facility in order to offload transport casks from the railcars and perform canister transfer operations for all DPCs. The CHB provides these functions. The CHB for this report has been designed with 2 rail bays, 2 truck bays, 4 vertical canister transfer cells, 2 - 200 ton single-failure-proof overhead bridge cranes, laydown area for impact limiters, staging area for transport casks and office area. The CHB would be a reinforced concrete structure with thick walls to protect all SNF casks, canisters, overpacks, and cask-handling equipment from the effects of earthquakes, tornado winds, tornado-generated missiles, fire, and explosions. The throughput would be 3,000 MTHM/yr with one shift per day, 5 days per week.

C2-3.5 Protected Area

The PA is an area within the OCA large enough to encompass the ISF rail yards, CHB, and underground system storage area. The PA consists of two physical barriers: (1) a security fence and (2) a nuisance fence separated by a 20-foot wide isolation zone. Within the isolation zone is an intrusion detection system that provides ground surveillance to detect any unauthorized entry into the PA. Assessment of unauthorized intruders is provided by illumination along the PA perimeter and throughout the storage area and a CCTV system, consisting of both fixed and pan-tilt-zoom cameras to monitor activities around the PA boundary from the security building.

The PA is surrounded by a passive vehicle barrier system (VBS) that is constructed of large concrete blocks to prevent any vehicles from getting near the PA boundary. The VBS is physically placed at a distance so that a pressure wave from a vehicle-born improvised explosive device cannot affect the storage containers or cask handling activities. Active VBSs are placed at large gates that accommodate railcars loaded with SNF transport casks or vehicles to prevent any unauthorized entry. These VBSs can be lowered once the railcar or vehicles are inspected and cleared for entry.

Security equipment is typically powered from normal off-site power supplies. However, in the event of a loss of off-site power, an Uninterruptable Power System (UPS) consisting of batteries would be used to provide seamless power to all electronic security equipment. The UPS and site lighting would be backed up by an emergency diesel-powered generator located within the PA.

Bullet resistant enclosures (BRE) would be situated at strategic locations within the PA to provide protected locations for security force personnel during a security event.

C2-3.6 Concrete Batch Plant

A large amount of concrete will be required during construction of the underground system. This concrete can be supplied from a local concrete supplier or from a site concrete batch plant. Once the construction is complete, little use of the batch plant may needed until the next underground storage module is constructed.

If a site concrete batch plant is used, additional equipment associated with concrete supply operations such as concrete trucks, concrete pumper trucks, mobile cranes, backhoes for excavation, front-end loaders and dump trucks for moving soil, compaction equipment, powered concrete tools and small concrete finishing tools will be required.

C2-3.8 Site Support Buildings

The ISF will need to include a number of support buildings. An administration building will need to be constructed to house managers, admin staff, engineers, document storage, licensing records, health physics personnel, radiological records, training rooms, etc.

A security/access control building will need to be constructed to house security personnel, security managers, the Central Alarm Station (CAS), safeguards information, etc. The building can be sited at the PA boundary to provide access control for personnel entering the storage area. This most likely would include a badging station, explosion detectors, metal detector to monitor persons entering the secured area, x-ray machines to monitor materials brought onsite, and turnstiles delineating the PA boundary.

A warehouse/maintenance building will need to be constructed to stockpile materials shipped to the ISF for inspection equipment, general supplies, etc. This structure could also double as a maintenance building for general maintenance activities as well as transporter and canister handling equipment maintenance.

The ISF would also include a number of other features such as fire protection, potable water, sanitary drains, electrical power and distribution, and communications.

C2-4.0 Expansion to an Expanded ISF

C2-4.1 Storage Area Impact

ISF expansion of another 5,000 MTHM would require doubling the storage area size. Construction of the second 5,000 MTHM storage area should be performed outside of the ISF PA to facilitate construction activities without stressing security. Once the underground system is constructed, the PA would be expanded to encompass the additional storage area. Of course, this type of construction would mean that a significant corridor would need to be placed between storage areas, and large separation corridors to ensure that construction workers receive as low as reasonably achievable (ALARA) radiation dose from the existing loaded storage units.

The PA would be expanded in size as required to accommodate the new underground storage area including fencing, intrusion detection system equipment, number of CCTV cameras and yard illumination.

Electrical power would need to increase to accommodate a larger ISF to account for the additional security, lighting and temperature monitoring equipment. The Uninterruptable Power

System (UPS) and security backup emergency diesel-powered generator would need to be able to accommodate the new loads of the larger site.

C2-4.2 Increased Throughput Impact

The CHB constructed for the ISF has a throughput capacity of 3,000 MTHM/yr which may be adequate for an Expanded ISF. Even if the throughput requirements are increased to 4,500 MTHM/yr, the CHB would not need to be enlarged. Rather, adding a second shift would effectively double the throughput of the building to 6,000 MTHM.

To expand the ISF, the rail yards, Administration Building Warehouse/Maintenance Building, Security/Access Control Building and other site infrastructure utilities may not require many modifications. Backup electrical power service for illumination and security of the larger storage area, additional security guards, increased CCTV and intrusion detection equipment are a few modifications that may be required to accommodate the expanded ISF. For example, these additions may require a larger Security/Access Control Building for the additional security personnel as well as a larger CAS for the increased CCTV and intrusion detection systems. However, if the ISF is designed with the understanding of the expanded ISF that doubles the storage area, then these items could easily be included in the initial design.

After the expansion, the ISF may need to procure additional vertical cask transporters (VCTs) to accommodate the expansion of the site. Although two VCTs may be able to handle the throughput, it is recommended that the ISF should employ at least three transporters. With the continual work, it is very likely one transporter (on average) could be in maintenance status at all times and the third transporter could alleviate any backups that may occur.

C2-4.3 Modular Expansion Impact

For underground storage, the only modular construction is the second underground storage area. This modular unit is fairly large and requires construction activities be conducted in concentrated phases. Although this requires heavy capital costs upfront, once constructed no other construction activities are required until the next storage module is required.

C2-5.0 Performance of Structures, Systems and Components

C2-5.1 Structural and Seismic Evaluation

Seismic evaluations for the U-MAX storage system are performed to ensure that the storage system is capable of withstanding the accelerations generated by the design earthquake, that the system is sized to maintain structural integrity under loading applied by the DPC, that the system will transfer the inertia loading from the DPC to the earth around the storage system and that the storage system has sufficient engagement in the soil to prevent soil failure.

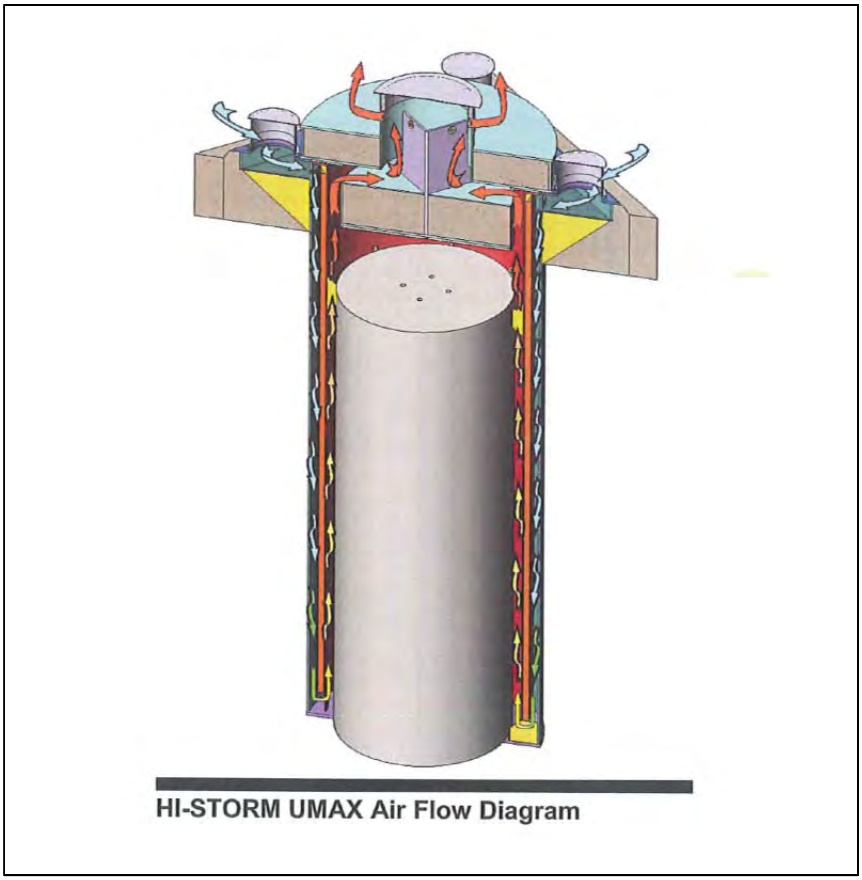
Seismic evaluations of the storage systems documented in vendor SAR determine the capacity to resist accelerations applied by the U-MAX system. The results of this comparison indicate that for the 0.25G earthquake, the capacities of the U-MAX storage system are within 20% of the maximum responses calculated at the grade elevation. In general, there is enough margin between the seismic capacity credited in the vendor SAR and the actual maximum seismic capacity at the material design limits to consider the storage systems qualified for the 0.25G earthquake demands.

For the 0.75G earthquake, the capacities of the U-MAX storage system will remain within the maximum responses calculated at grade elevation. Even with this higher acceleration, there is enough margin between the seismic capacity credited in the vendor SAR and the actual maximum seismic capacity at the material design limits to consider the storage systems qualified for the 0.75G earthquake demands. Note that the U-MAX design will use low-strength fill for seismic demands up to 1.00 G. For a 1.5 G seismic input, the U-MAX design will utilize higher-strength concrete fill.

C2-5.2 Thermal Evaluation

The underground storage system primarily relies upon free convection passive cooling to reject the heat generated by the STAD it contains (see **Figure C2-16**). In order to introduce the flow of cooling air at the base of the STAD, the underground system utilizes a cylindrical sleeve which encircles the STAD mid-way between the interior surface of the CEC and the exterior surface of the STAD. The sleeve extends from the surface of the ground almost all the way down to the bottom of the CEC. The air flows from the ground surface down the gap between the CEC wall and the outside of the sleeve, through the narrow opening at the bottom of the CEC, and up the gap between the STAD exterior surface and the sleeve interior surface. The air exhausts through vents in the concrete cap which sits on top of the CEC. The gaps are sized to provide sufficient flow to remove both the heat coming off of the exterior surface of the STAD and the heat coming off the sleeve which transfers from the STAD to the sleeve by radiation.

Figure C2-16
Passive Cooling in a Holtec HI-STORM U-MAX Storage System



The thermal evaluation determined that the heat transfer capabilities of the underground silos will need to be analyzed to show that they will meet the allowable temperature limits since the gaps and the height of the air column between the STAD and the CEC which drives the air flow for whichever STAD is selected for use. However, since the heat generated by the fuel is below the design heat load for the STAD due to aging, the risk associated with the underground storage system design not meeting thermal performance requirements with SNF is considered low.

A detailed discussion of the thermal evaluation is provided in **Section 6.2** of the report.

C2-5.3 Radiological Evaluation

The exposures to radiation for the workers in this study are based on historical radiological source terms from dry storage systems at commercial nuclear plants. They demonstrate differences among the various options rather predict actual doses. STAD canisters would be licensed for newer spent fuel with different source terms that are yet to be determined. Therefore, doses from STAD canisters were not calculated for this study. However, some factors are noteworthy:

1. Due to self-shielding within the STAD canister, the contact dose rate for any size STAD should be within a few percent of the contact dose rate for other size STAD canister containing the same SNF. Since worker dose rates are determined by a few activities that involve close contact with the canister, the worker exposures for the different STAD canisters are based primarily on the handling activities required not the STAD type.
2. The activities necessary to transfer a STAD canister from a rail car to the storage location are assumed in this report to be similar to the commercial DPC processes in order to provide a comparison of the different storage alternatives. STAD canisters and their associated transport, transfer casks or storage units can be designed to remove or reduce dose intensive activities. For example, attaching and removing lifting lugs to DPCs is major contributor to dose rates. An integral lifting means on the STAD will remove considerable worker dose.
3. STAD transport casks, transfer casks and storage units can be designed with improved shielding. STAD canisters are smaller and lighter than commercial DPCs, so the various shielding casks can be heavier without impact shipping or lifting infrastructure. This can reduce worker dose without changes to rolling stock or cask handling equipment.
4. STAD handling systems can be designed with more automated features reducing manual activities next to the canister. Commercial systems were developed as temporary expedients to address fuel pool capacity and life extension issues. STAD canisters can be designed to improve performance based on industry experience.
5. Study #1 determined that worker doses are fairly consistent for all alternative storage methods. Study #2 determined that the method used to process incoming SNF shipments has a greater effect on worker dose than the storage method – more automation can substantially reduce worker doses versus manual handling. Similar results are likely to be the same with STAD canisters.
6. Offsite doses to the public are expected to be very similar to commercial systems. Offsite dose is a function of shielding and distance. Doses to the public can be reduced with additional system or building shielding and/or by increasing the distance from the storage area to the Owner Controlled Area boundary. The exposures to radiation for the workers due to STAD canister processing at the ISF cannot be assessed at this time since they are still conceptual. It is very difficult to predict what overall dose would be received for each canister transfer let alone the dose each worker receives.

C2-5.4 Design Life, Aging and Maintenance Evaluation

Currently, storage systems may be designed for 40 to 100 years but are only permitted to be licensed for a period of up to 40 years. Prior to February 16, 2011, when 10 CFR 72.42, Duration of License; Renewal (for specific licenses) and 10 CFR 72.240, Conditions for Spent Fuel Storage Cask Renewal (for CoCs for general licenses) were revised to permit 40 year license durations, licenses and CoCs for storage systems had a duration of 20 years. Therefore, most of the storage systems currently in place at ISFSIs are only licensed for 20 years. In order to renew the license and extend the storage license, NUREG-1927, Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance (Reference C2-7) requires that an applicant demonstrate that the effects of aging will be adequately managed so that the intended safety function(s) of SSCs identified in the scope of license renewal will be maintained consistent with the current licensing basis for the period of extended operation. The NRC requires that an Aging Management Review (AMR) be performed that consists of identifying ISFSI components relied on for safety, susceptible materials in those components, environments to which susceptible materials are exposed, aging effects, and development of an aging management program to manage aging effects and protect against degradation of age-sensitive components (such as by performing inspections of age-sensitive components and replacing components that have a life expectancy of less than the license renewal period being requested in the anticipated environment). For purposes of this section, it is assumed that the original license has a duration of 20 years and a 40 year license extension is requested, so the licensee will need to demonstrate the in-scope component materials will withstand the anticipated environment for a total of 60 years, or provide a plan for replacing age-sensitive components at acceptable analyzed intervals. If the initial license was for a 40 year duration, and a 40 year license extension is requested, then the licensee would need to demonstrate the in-scope components are acceptable for 80 years in the storage environment.

The AMR identifies susceptible materials of subcomponents in the in-scope SSCs that are exposed to environments that could cause age-related degradation. The functions required to be performed by the individual subcomponents of these in-scope SCCs (determined in previous section) are identified in applicable tables in this AMR section of the application for ISFSI license renewal.

The NRC's Draft Revision 1 of NUREG-1927, Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel (Reference C2-8 explains the purpose of the AMR as follows:

> "The purpose of the aging management review (AMR) is to assess the proposed aging management activities (AMAs) for structures, systems, and components (SSCs) determined to be within the scope of renewal. The AMR addresses aging mechanisms and effects[1] that could adversely affect the ability of the SSCs (and associated subcomponents) from performing their intended functions during the period of extended operation. The reviewer should verify that the renewal application includes specific information that clearly describes the AMR performed on SSCs within the scope of renewal."
>
> Footnote 1 in this quotation states: "In order to effectively manage an aging effect, it is necessary to determine the aging mechanisms that are potentially at work for a given

material and environment application. Therefore, the aging management review process identifies both the aging effects and the associated aging mechanisms that cause them."

The license application needs to include an Aging Management Review (AMR) that is comprised of four major steps that are summarized as follows:

1) <u>Identification of In-Scope Subcomponents Requiring AMR</u>

Structures, Systems and Components (SSCs) within scope of the aging evaluation are identified as those that are 1) classified as important to safety (ITS), and 2) classified as not important to safety but whose failure could prevent an ITS function from being fulfilled. SSCs within scope are determined based on review of the ISFSI Materials License, ISFSI SAR, ISFSI Tech Specs, NRC's SER for the ISFSI and docketed licensing correspondence related to the ISFSI.

2) <u>Identification of Susceptible Materials and Applicable Environmental Conditions</u>

For the subcomponents of in-scope SSCs that require AMR, the next step is identification of materials of construction susceptible to aging and the environments (e.g., temperature, pressure, radiation, wet vs. dry, etc.) that these materials normally experience.

3) <u>Identification of Aging Mechanisms and Effects Requiring Management</u>

Aging mechanisms potentially at work on susceptible materials in given environments (corrosion, cyclic stress fatigue, radiation embrittlement, etc.) are determined. Aging effects (manifestation of aging mechanisms) of material / environment combinations are compiled from industry and plant operating experience through use of industry standards and reference materials, including metallurgical literary references. During this process, the question is asked, are the potential aging effects credible given the identified materials and environmental conditions of storage?

4) <u>Determination of Activities Required to Manage Aging Effects (Aging Management Program)</u>

The final step in the AMR process involves the determination of activities necessary to manage the effects of aging. If the aging review determines that certain materials may not be able to support a 60 year life in the environment that they are normally exposed to, then an Aging Management Program needs to be established for those subcomponents to extend the life of the storage system to 60 years (such as by performing inspections of vulnerable subcomponents to determine their continued adequacy, or replacing the associated subcomponent at specified intervals).

Each of the four above steps of the AMR process are discussed in more detail in the following paragraphs.

C2-5.4.1 Aging Management Review (AMR)

Identification of In-Scope Components Requiring AMR

During this first step in the AMR process, the in-scope SSCs are further reviewed to identify and describe the subcomponents that support the SSC intended function. Intended functions of interest in the AMR are sub-criticality control, pressure boundary integrity (confinement of fission products), heat transfer, structural support (protection against environmental phenomena) and shielding. The subcomponents and associated intended functions are identified by reviewing the applicable current licensing basis (CLB) documentation sources.

SSCs and associated subcomponents within the scope of renewal fall into the following scoping categories:

(1) They are classified as important to safety (ITS), as they are relied on to do one of the following functions:

i. Maintain the conditions required by the regulations, specific license, or CoC to store spent fuel safely;

ii. Prevent damage to the spent fuel during handling and storage; or

iii. Provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

These SSCs ensure that important safety functions are met for (1) confinement, (2) radiation shielding, (3) sub-criticality control, (4) heat-removal capability, (5) structural integrity, and (6) retrievability of the spent fuel.

(2) They are classified as not important to safety but, according to the design bases, their failure could prevent fulfillment of a function that is important to safety.

Subcomponents that perform or support any one of the identified intended functions will require an AMR. Those components that do not support an intended function can be excluded from further evaluation in the AMR with supporting justification. The SSCs within the scope of renewal are screened to identify and describe the subcomponents with intended functions. It should be recognized that SSC subcomponents may degrade by different modes, or have different criteria for evaluation from the overall component (i.e., different materials or environments). SSC subcomponents may also have different performance requirements for support of safety functions.

Typically, the application for ISFSI license renewal tabulates the results of the AMR, including a listing of subcomponents and the intended function provided by each subcomponent, material group, environment, aging effects requiring management and aging management activity required. The AMR results tables also identify subcomponents that did not support the SSC intended function and are not subject to AMR, with justification for their exclusion.

Identification of Materials and Environments

The second step of the AMR process requires the identification of materials of construction and the environments to which these materials are exposed, for the in-scope ISFSI subcomponents that require an AMR. Environmental data may include: temperature, wind, relative humidity, relevant atmospheric pollutants and deposits, exposure to precipitation, marine fog, salt, or water exposure, radiation field (gamma and neutron), the service environment (e.g., embedded, sheltered, or outdoor), and gas compositions (e.g., external: air; internal: inert gas such as helium).

The environments to which components are exposed play a critical role in the determination of potential aging mechanisms and effects. A documentation review is required to quantify the environmental conditions to which the in-scope ISFSI SSCs are continuously or frequently exposed (conditions known to exist on a recurring basis). As noted in the next section, normal operating conditions are evaluated and not accident conditions.

The storage system FSAR is typically used to determine the intended functions and materials of construction for cask subcomponents that are in-scope of ISFSI license renewal. Additional documentation, drawings and technical reports should also be reviewed during the AMR process as required to obtain clarifications of the intended materials of construction and functions performed by in-scope ISFSI subcomponents.

The specific materials of construction for the cask and fuel assembly subcomponents requiring aging management review are identified and evaluated for the renewal period.

Identification of Aging Mechanisms and Effects Requiring Management

The third step in the AMR process is to identify the aging mechanisms and effects requiring management. A Material Aging Effects Report (MAER) is typically prepared for the storage system in question. This report needs to include aging mechanisms and effects that theoretically occur as well those that have actually occurred based on industry operating experience and the ISF operating experience for the appropriate material and environmental conditions. Aging effects are presented in this report in terms of material / environment combinations.

The environments considered in the evaluation are the environments that the subcomponents normally experience. Environmental stressors that are conditions not normally experienced, such as accident conditions, or that may be caused by a design problem, are considered event-driven situations and are not characterized as sources of aging. Such event-driven situations would be evaluated at the time of event, with corrective actions taken as necessary.

To effectively manage an aging effect, it is necessary to determine the aging mechanisms that are potentially at work for a given material and environment application. Therefore, the AMR process needs to address both the aging mechanisms as well as the aging effects. Selective mechanisms are only applicable under certain environmental conditions, such as high temperature or moisture. The identified aging mechanisms need to be characterized by a set of applicable conditions that must be met for the mechanism to occur and/or propagate. The application for ISFSI license renewal should identify aging effects based on the aging mechanisms potentially at work in given environments on susceptible subcomponent materials (e.g., general corrosion of carbon steel, stress corrosion cracking and crevice and pitting corrosion of stainless steel, cyclic stress fatigue, radiation embrittlement, boron depletion of neutron absorber due to neutron flux, etc.). Aging effects (manifestation of aging mechanisms) of material / environment combinations are compiled from industry and plant operating experience through use of industry standards and reference materials, including metallurgical literary references. The majority of aging mechanisms will be extracted from industry documents (including NRC and EPRI) for the applicable material/environmental combinations. For instance, the EPRI Dry Cask Characterization Project final report (Reference C2-9) is a primary source for fuel assembly and dual purpose canister internals aging mechanism evaluations. During the process of identifying aging effects the question is asked, are the potential aging effects credible given the identified materials and environmental conditions of storage?

Appendix D, Table D-1, of NUREG-1927 lists potential aging effects and possible aging mechanisms that should be considered. This information is also available from a table in Appendix C to NUREG-1557 (Reference C2-10). Section 3.4 of the NRC's Draft Revision 1 of

NUREG-1927 lists the following sources of information that should be used to identify applicable aging mechanisms and effects:

- site maintenance, repair, and modification records;
- corrective action reports, including root cause evaluations;
- lead system inspection results ;
- maintenance and inspection records from ISFSI sites with similar SSC materials and operating environments;
- industry records;
- applicable operating experience outside the nuclear industry;
- applicable consensus codes and standards;
- NRC reports;
- other applicable guidance for determining if an aging mechanism or effect should be managed for the period of extended operation.

Section 3.4 of the NRC's Draft Revision 1 of NUREG-1927 gives the following examples of potential aging mechanisms and effects that may be identified by reviewing the above sources of information:

> "(1) cracking or loss of strength as a result of cement aggregate reactions in the concrete, (2) cracking or loss of material as a result of freeze-thaw degradation of the concrete (requires the presence of moisture combined with temperatures below freezing), (3) reinforcement corrosion and concrete cracking as a result of chloride ingress, (4) accelerated corrosion of steel structures and components and stress corrosion cracking of austenitic stainless steels as a result of atmospheric deposition of chloride salts."

Other possible aging effects are settlement, change in dimension and change in material properties. The applicant for renewal of an ISFSI specific license is not required to take further action if an SSC is determined to be within the scope of renewal but is found to have no potential aging effects for the period of extended operation.

The AMR defines two methods for addressing potential aging mechanisms and effects: TLAA and AMP, both of which are discussed below.

Time-Limited Aging Analyses to Identify Aging Effects

Time-Limited Aging Analyses (TLAAs) are calculations performed to evaluate the life of subcomponents of interest. TLAAs are defined in Section 3.5 of the NRC's Draft Revision 1 of NUREG 1927, as those licensee calculations and analyses that meet all of the following criteria:

1. Involve SSCs important to safety within the scope of the specific-license renewal, as delineated in Subpart F of 10 CFR Part 72;

2. Consider the effects of aging;

3. Involve time-limited assumptions defined by the current operating term;

4. Were determined to be relevant by the specific licensee or certificate holder in making a safety determination;

5. Involve conclusions or provide the basis of conclusions related to the capability of SSCs to perform their intended safety functions (analyses that do not affect the intended functions of the SSCs are not considered TLAAs); and

6. Are contained or incorporated by reference in the design bases.

The defined operating term should be explicit in the analyses. Simply asserting that the SSC is designed for a service life or ISFSI life is not sufficient. The assertions must be supported by a calculation, analyses, or testing that explicitly include a time limit.

Examples of TLAAs described in the past applications for license renewal are: 1) cracking of the dual purpose canister (DPC) shell due to fatigue from thermal cycling; 2) change in material properties of epoxy seal in DPC penetration (for temperature monitoring) due to exposure to ionizing radiation; and 3) canister basket poison plate depletion of boron due to increase in neutron exposure for 60 year life of ISFSI; change in properties of boron-polyethylene front access cover plate due to increased radiation exposure over 60 year life of ISFSI.

Operating Experience Review for Process Confirmation

Typically, the potential aging effects for the ISFSI material and environment combinations are compiled from common industry and plant operating experience through the use of accepted industry standards and reference materials, including various metallurgical literary references relating specific materials and environments to aging effects and mechanisms.

A further review of industry and plant specific operating experience for the ISFSI should also be performed in order to confirm the applicability of previously identified potential aging mechanisms/effects and to identify any aging effects not previously addressed.

The application for ISFSI license renewal will need to address the various observations resulting from ISFSI operating experience with the storage systems. This information should address items specific to the subcomponents. As an example; Dominion identified corrosion of lid bolts and outer metallic lid seals on some of the TN-32 casks stored at the Surrey ISFSI. The corrosion was most prevalent on the down-slope side of the cask lid. As part of the investigation, the bolt torque was checked and it was determined that there had been no torque relaxation. The corrosion of the lid bolts and outer metallic seal was the result of external water intrusion in the vicinity of the lid bolts and outer metallic seal. It was determined that the connector seal for the electrical connector in the cask protective cover was leaking due to improper installation of the connectors. Therefore, this degradation was not related to aging.

Activities Required to Manage Aging Effects (Aging Management Program)

The fourth and final step in the AMR process involves the determination of the aging management activities or Aging Management Programs (AMPs) to be credited or developed for managing the effects of aging. Section 3.6 of Draft Revision 1 of NUREG-1927 states the following regarding AMPs:

> "Aging management programs (AMPs) monitor and control the degradation of SSCs within the scope of renewal so that aging effects will not result in a loss of intended functions during the period of extended operation. An AMP includes all activities that are credited for managing aging mechanisms or effects for specific SSCs. An effective AMP prevents, mitigates, or detects the aging effects and provides for the prediction of the extent of the effects of aging and timely corrective actions before there is a loss of intended function."

> "Aging management programs should be informed, and enhanced when necessary, based on the ongoing review of both site-specific and industry-wide operating experience. Operating experience provides direct confirmation of the effectiveness of an AMP and critical feedback for the need for improvement. As new knowledge and data become available from new analyses, experiments, and operating experience, licensees and CoC holders should revise existing AMPs (or pertinent procedures for AMP implementation) to address program improvements or aging issues."

Section 3.6.1 of the NRC's Draft Revision 1 of NUREG-1927 indicates that an AMP should contain the following elements:

1. Scope of Program,
2. Preventive actions,
3. Parameters monitored or inspected,
4. Detection of aging effects,
5. Monitoring and trending,
6. Acceptance criteria,
7. Corrective actions,
8. Confirmation process,

9. Administrative controls, and
10. Operating experience.

To the extent practical, existing ISFSI programs and/or activities are credited for the management of aging effects that could cause a loss of component intended function during the license renewal period. If the aging review determines that certain materials cannot support the required life in the environment that they are normally exposed to, then an AMP needs to be established for those subcomponents to extend the life of the storage system for the duration of the license renewal period (such as by performing inspections of vulnerable subcomponents to determine their continued adequacy, or replacing the associated subcomponent at specified intervals). The application for ISFSI license renewal will need to discuss development of AMPs to address subcomponents whose materials are susceptible to age-related degradation. AMPs for ISFSIs typically include visual inspections of cask external surfaces to look for signs of deterioration due to corrosion (general corrosion for carbon steel subcomponents due to moist atmospheric environments, and crevice and/or pitting corrosion for stainless steel surfaces that are subject to wetting), and monitoring area radiation levels, airborne and smearable contamination levels at selected areas of the ISFSI. Increased radiation / radioactivity levels could indicate reduction in shielding, breach of the SFA cladding or loss of cask confinement. Inspection intervals are established at frequencies that provide confidence the subcomponents of interest will not experience age-related adverse effects that could prevent them from performing their intended functions.

C2-5.5 Postulated Accident Evaluation

The accident descriptions to follow refer to "Design Event" levels given in ANSI/ANS 57.9, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)" (Reference C2-11). As explained in NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" (Reference C2-12): "Off-normal events are those expected to occur with moderate frequency or once per calendar year. ANSI/ANS 57.9 refers to these events as Design Event II. Accident events are considered to occur infrequently, if ever, during the lifetime of the facility. ANSI/ANS 57.9 subdivides this class of accidents into Design Event III, a set of infrequent events that could be expected to occur during the lifetime of the ISFSI, and Design Event IV, events that are postulated because they establish a conservative design basis for SSCs important to safety. The effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches, are considered to be accident events."

Section 15.4 of NUREG-1567 identifies acceptance criteria for accidents, including the following:

> Criticality: 10 CFR 72.124(a) requires that the spent fuel must be maintained in a subcritical condition (i.e., $k_{eff} \leq 0.95$), and at least two unlikely, independent and

concurrent or sequential changes must be postulated to occur in the conditions essential to nuclear criticality safety before a nuclear criticality accident is possible (double contingency).

Confinement: 10 CFR 72.128(a)(3) requires that the systems important to safety must be evaluated, using appropriate tests or by other means acceptable to the Commission, to demonstrate that they will reasonably keep radioactive material confined under credible accident conditions. NUREG-1567 states that “A breach of a confinement barrier is not acceptable for any accident event.”

Retrievability: 10 CFR 72.122(l) requires that “Storage systems must be designed to allow ready retrieval of spent fuel, high-level radioactive waste, and reactor-related GTCC waste for further processing or disposal.” The definition for Important to Safety SSCs in 10 CFR 72.3 includes those features whose function is to “provide reasonable assurance that spent fuel, high-level radioactive waste, or reactor-related GTCC waste can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.”

Instrumentation: 10 CFR 72.122(i) states in part: “Instrumentation systems for dry storage casks must be provided in accordance with cask design requirements to monitor conditions that are important to safety over anticipated ranges for normal conditions and off-normal conditions. Systems that are required under accident conditions must be identified in the Safety Analysis Report.”

Radiological Dose: 10 CFR 72.104 requires that for off-normal events, annual dose equivalent to any individual located beyond the controlled area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as a result of exposure to planned discharges to the general environment, direct radiation from operations of the ISFSI, and cumulative radiation from uranium fuel cycle operations in the area. 10 CFR 72.106(b) requires that any individual located at or beyond the nearest controlled area boundary must not receive a dose greater than 5 rem to the whole body or any organ from any design basis accident.

C2-5.5.1 Earthquake

An earthquake is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. Earthquakes are associated with faults in the upper crust of the earth’s surface. SSCs classified as Important to Safety are required to be designed to resist the effects of the design basis ground motion in accordance with the requirements of 10 CFR 72.122(b).

10 CFR Part 72.103, "Geological and Seismological Characteristics for Applications for Dry Cask Modes of Storage on or after October 16, 2003," gives requirements for determining Design Earthquake Ground Motion (DE) at sites for spent fuel storage, and NRC Regulatory Guide 3.73 "Site Evaluations and Design Earthquake Ground Motion for Dry Cask Independent Spent Fuel Storage and Monitored Retrievable Storage Installations" (Reference C2-13) provides guidance on applying the rules in Part 72.103 to arrive at an acceptable DE that satisfies the requirements of Part 72. In general, Part 72.103 allows use of a standardized DE described by an appropriate response spectrum anchored at 0.25 g for sites in non-seismically-active areas east of the Rocky Mountain Front and requires a seismic evaluation elsewhere. For the ISF, a probabilistically-derived horizontal ground acceleration design value of 0.75 g is used to provide a bounding value for all potential ISF sites.

Depending on the specific storage system, the acceptance criteria for seismic design may include some or all of the following:

i. The loaded overpacks will not impact each other during the DE event.

ii. The loaded overpack will not slide excessively.

iii. The loaded overpack will not tip over.

iv. The confinement boundary will not be breached.

C2-5.5.2 Tornado Winds and Missiles

The storage system is designed to withstand loads associated with the most severe meteorological conditions, including extreme winds, pressure differentials, and missiles generated by a tornado. The extreme design basis wind is derived from the design basis tornado. Extreme wind is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. The design basis tornado loading is defined for a given region (identified in NRC Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants" (Reference C2-14). It is conservatively assumed that Region I design basis tornado loading applies to the ISF. The design basis tornado wind loading for this region is defined as a tornado with a maximum wind speed of 230 mph and a 1.2 psi pressure drop occurring at a rate of 0.5 psi/sec.

In addition, the ISF is designed to withstand the effects of tornado-generated missiles that could be created by the passage of the tornado as identified in Regulatory Guide 1.76, Rev. 1, and discussed in Sections 3.3.2 (Tornado Loadings) and 3.5.1.4 (Missiles Generated by Extreme Winds) of NUREG 0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, (Reference C2-15). Tornado-driven missiles, identified in the following table, are assumed to impact a storage system in a manner that produces maximum damage. Regulatory Guide 1.76, Rev. 1, identifies the following design basis missiles for Region I:

Missile Description	Total Mass (lbs)	Velocity (mph)
Automobile	4000	92
Schedule 40 Pipe (6. 625 inch-diameter), 15 ft long	287	92
Solid Sphere (1-inch-diameter)	0.147	17.7

Alternatively, there are other spectrums of tornado missiles that have been accepted by the NRC (for which spent fuel storage systems have been qualified) that could be reviewed for potential use at the ISF.

The combination of tornado winds with the most massive missile, a 4,000 lb automobile traveling at 92 mph, needs to be evaluated in accordance with Section 3 of NUREG-0800, since it tests storage system stability. The wind tip-over moment is applied to the cask at its maximum rotation position following the worst-case missile strike. The schedule 40 pipe missile tests the capacity of the storage system to resist penetration, and the small solid steel sphere missile tests barrier openings. Canister tip-over potential and reduction in shielding from tornado-borne projectile strikes are evaluated.

C2-5.5.3 Flood

Flooding is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. 10 CFR 72.122(b)(2) requires that SSCs Important to Safety must be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lighting, hurricanes, floods, tsunami, and seiches, without impairing their capability to perform safety functions.

The probable maximum flood (PMF) is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions.

Other potential sources of flooding considered include effects from an upstream dam breach, seismically induced flooding due to landslides in the site area, occurrence of the PMF with superposition of wind-wave activity on nearby water bodies, flooding due to tsunamis and ice conditions, and flooding from local intense precipitation.

The storage system is designed to withstand severe flooding, including pressure and water forces associated with deep and moving flood waters. Resultant loads on the storage system consist of buoyancy effects, static pressure loads, and velocity pressure due to water velocity. The flood is assumed to deeply submerge the storage system without the canisters collapsing, buckling, or allowing water in-leakage under the hydrostatic pressure from the flood; and, where applicable, without sliding and cask tip-over occurring. Full blockage of the air inlets by submergence in water is addressed by emergency action planning based on the individual storage device's capabilities. For more information on blockage of air inlets, refer to "Loss of Cooling Accident."

C2-5.5.4 Fire

Fire is classified as a human-induced Design Event IV as defined in ANSI/ANS-57.9. The storage system must withstand elevated temperatures due to a fire event. Credible fires from various sources such as buildings, fuel spills, and other combustible materials are analyzed for heat flux using standard analysis techniques from NFPA and compared with acceptance criteria for the storage system. Possible effects from wildfires are also evaluated, addressing fire magnitude, duration, propagation, and heat generation.

Fires analyzed include those that could occur during transfer operations and those affecting stored fuel. Canister integrity during smaller fire events is qualified by heat flux comparison with a bounding fire for which an approved canister analysis has been performed. Fires affecting structures in which transfer operations and storage of fuel occur have been analyzed to ensure continued reliability.

Based on the analyses, the canister storage and transfer systems meet the general design criteria of 10 CFR 72.122(c), which states that SSCs Important to Safety must be designed and located so that they can continue to perform their safety functions effectively under credible fire exposure conditions. A fire at the ISF (or a wildfire adjacent to the ISF Protected Area) would not cause a radioactive release, even if no credit were taken for firefighting by personnel or for automatic fire detection/suppression systems.

C2-5.5.5 Explosion

Explosion is classified as a human-induced Design Event IV as defined in ANSI/ANS-57.9. The ISF storage system must withstand loads due to an explosion. Potential onsite (internal and external) and offsite explosions are investigated.

NRC Regulatory Guide 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plants" (Reference C2-16) provides guidance for calculating safe distances from transportation routes, based on calculated overpressures at various distances created by postulated explosions from accidents. The Regulatory Guide indicates that overpressures which do not exceed 1 psi at the storage site would not cause significant damage and states:

> under these conditions, a detailed review of the transport of explosives on these transportation routes would not be required.

In lieu of the 1 psi overpressure selected in the Regulatory Guide, the overpressure for which the storage system is qualified (e.g., 3 psi, 5 psi, 10 psi) is used to determine the safe standoff distance from the source of the potential explosion.

There are no credible internal explosive events since the canister is comprised of non-explosive materials, it is filled with an inert gas, and materials are compatible with the operating environment. Likewise, the mandatory use of the protective measures at the ISF site to prevent fires and explosions and the absence of any need for an explosive material during canister loading, transfer, and unloading operations eliminates the scenario of an onsite explosion as a credible event, except during canister movement, which requires investigation of any nearby onsite-specific potential explosive sources.

Any design basis overpressure from an offsite explosion (e.g., from a truck, rail car, barge, fuel storage tank, munition depot, chemical processing plant, petroleum refinery, natural gas facility, etc.) must be investigated and, if credible, analyzed.

Based on the analyses, the canister storage and transfer systems meet the general design criteria of 10 CFR 72.122(c), which states that SSCs Important to Safety must be designed and located so that they can continue to perform their safety functions effectively under credible explosion exposure conditions.

C2-5.5.6 Canister Drop Accident

NUREG-1567 considers both off-normal cask drops and more severe cask drop accidents. With regards to an off-normal event involving a cask drop that is less than the design allowable lift height, Section 15.5.1.1 of NUREG-1567 states:

> The drop of the confinement cask at less than design allowable height is one of the hypothetical off-normal scenarios that the applicant must evaluate. The evaluation must show that the cask integrity and fuel spacing geometry are not compromised if the cask is dropped from a relatively low height. It must also show that the cask will continue to store fuel safely after such a drop.

For accident conditions, the hypothetical drop of a storage canister is classified as Design Event IV as defined by ANSI/ANS-57.9.

With regards to a cask drop accident, Section 15.5.2.2 of NUREG-1567 identifies the key items to be evaluated assuming a cask drop, including decelerations, evaluation of calculated stress intensities against the allowable stresses identified in the applicable code, evaluation of buckling stability for each component of the cask confinement subjected to compressive loading, and evaluation of deformation of cask internal members that could contribute to fuel assembly spacing geometry (for criticality concerns). While this guidance may apply to transport casks that do provide a confinement boundary, it may not be directly applicable to the transfer casks that are used to transfer canisters from transport casks to storage overpacks. In addition, in the event the spent fuel cask handling systems meet the NRC criteria for “single-failure-proof” (discussed in Section 9.1.5 of NUREG-0800, "Overhead Heavy Load Handling Systems”), the NRC does not require a cask drop accident to be postulated nor its consequences to be analyzed.

Within the alternative storage systems, there are two basic drop situations, with certain potential drop accidents that necessitate analysis and/or operational restrictions, as identified below:

(1) Handling inside the transport cask receiving structure and canister transfer facility:

- A drop of the transport cask with its impact limiters removed prior to being handled by the single-failure-proof crane requires analysis and operational restrictions.
- Transport cask drop accidents (other than above) and transfer cask drop accidents are precluded by the use of a single-failure-proof handling system, consisting of an overhead crane whose main hoist meets the NRC criteria for a single-failure-proof crane (i.e., NUREG-0554, "Single-Failure-Proof Cranes for Nuclear Power Plants," (Reference C2-17) or ASME NOG-1, "Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)" (Reference C2-18)).

(2) Handling outside the transport cask receiving structure and canister transfer facility (i.e., during cask transfer to the storage area):

- For some transport systems, it is required to assume a cask drop and, therefore, the lift height is limited to a height that has been fully analyzed for the assumed cask drop accident (e.g., TransNuclear transfer casks and NAC storage casks).
- For other systems (e.g., Holtec Vertical Cask Transporter), the lifting apparatus is required to meet ANSI N14.6 "American National Standard for Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10 000 Pounds (4500 kg) or More" (Reference C2-19) criteria for allowable stresses and to have redundant drop protection features. For these systems, no height restriction is required for cask transfer.
- For potential drops when a canister is being handled, lifts of canisters loaded with spent nuclear fuel are performed using single-failure-proof equipment and lifting devices that comply with the stress limits of ANSI N14.6 and have redundant drop protection to render an uncontrolled lowering of the payload non-credible, so a canister drop accident need not be postulated.

C2-5.5.7 Loss of Cooling Accident (LOCA)

The various spent fuel storage system alternatives all use passive air cooling of the dry storage canisters. The cooling air flow is driven by natural convection with cool air at ambient temperature entering the canister storage area near the bottom of the canister(s), rising as it is heated by the relatively hot outer surface of the canister(s), and exiting the canister storage area by outlet vents above the canisters.

It is credible that various types of debris or materials such as plastic sheets could blow into the canister storage area and block some of the air vents, thus reducing air flow and causing canister temperatures and spent fuel cladding temperatures to increase. Complete blockage of the air inlet ducts is classified as a Design Event IV accident condition as defined by ANSI/ANS-57.9. In addition, partial blockage of the cooling air vents is also analyzed as an off-normal condition, such as by assuming that one-half of the area of the air inlet vents is blocked. Thermal analyses are required to be performed to determine storage system temperatures, including canister and spent fuel cladding temperatures. The resulting temperatures are compared with the applicable temperature limits for off-normal (partial vent blockage) and accident or faulted conditions (complete blockage of air inlets).

Typically, the thermal analysis of partial blockage determines final steady-state temperatures of the storage system that result from the reduced air flow rates and these are compared to the maximum allowable temperatures of the various components to demonstrate the storage system can acceptably withstand this partial blockage with no operator actions.

For the accident condition involving postulated complete blockage of the air inlet vents, a transient thermal analysis is performed that determines the time at which temperatures of storage system components that are classified as Important to Safety exceed their maximum allowable temperatures for accident conditions, such as spent fuel cladding, canister confinement or canister basket material temperatures. This time is then used to establish a conservative required frequency of inspection or temperature monitoring of the storage system that ensures temperature limits will not be exceeded. This inspection frequency is then incorporated into the Technical Specifications that govern operations of the spent fuel storage facility. With regard to this inspection frequency requirement, Section 6.5.1.1 of NUREG-1567 recommends the following paragraph be incorporated into the Technical Specifications, based on results of the accident analysis that assumes complete blockage of air inlet vents:

> Surveillance requirement: Periodic surveillance will be performed to ensure that there is no blockage of cooling air flow in the heat removal system. This surveillance [typically based on the minimum time for stored material cladding or other material Important to Safety (e.g., shielding) to reach a threshold temperature in the event of a complete blockage occurring immediately following the prior surveillance.

Surveillance of cooling air vents for blockage can either be performed by visual inspection of the air inlet and outlet vents or by checking temperature readings of the temperature monitoring system to verify temperatures for each storage system are within allowable limits. ISFSIs frequently use temperature detectors mounted in the outlet vents to assess the performance of the natural convection air cooling system, since blockage of cooling air vents will result in reduced airflow with consequent increased air outlet temperatures. For ISFSIs with a relatively large number of storage systems, temperature monitoring is used to ensure worker doses are ALARA, since significant dose can be accrued by workers performing routine inspections of storage system air vents (typically, daily inspections are required), which requires the inspector to be in the near vicinity of the spent fuel storage systems.

C2-5.5.8 Off-Normal and Extreme Environmental Temperature

Ambient environmental temperatures must be evaluated for periods during which handling operations take place and also for the long time period over which spent fuel storage will occur. The various cask vendors have analyzed their products for intended use typically to cover all ISFSI sites in the continental U.S.

Minimum short-term temperature limitations are specified to ensure a sufficient safety margin against brittle fracture during handling. A typical operational limitation would be around 0°F, so it is likely that operational temperature restrictions imposed for other reasons may be more stringent (e.g., the minimum allowable temperature for crane operation). The lower bound off-normal temperature limit, applicable to long-term storage, is typically about -40°F.

Storage systems are designed for upper bound off-normal temperatures in the range of about 100°F, which is assumed to persist for a sufficient duration to allow the system to reach thermal equilibrium. The accident condition extreme ambient environmental temperature is typically around 125°F. Upper bound limitations are based on analyses that determine the storage system's ability to properly convey heat away from the spent fuel. Extreme environmental temperature is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9.

C2-5.5.9 Lightning

Lightning is classified as a natural phenomenon Design Event III as defined in ANSI/ANS-57.9. Because a direct lightning strike of a storage SSC is a credible occurrence, the ISF storage system must withstand loads due to lightning, with the canister retaining its confinement integrity, and thereby preventing release of radioactivity. The lightning path to ground will vary, depending on the storage system alternative; but for each alternative, the canister will be protected from the effects of a lightning strike. (For example, for above-ground vertical cask storage, the steel shell of the overpack will convey the lightning to ground and the lightning will not pass through the canister, which is surrounded by the cask steel, so the strike will not affect the canister integrity.) Therefore, no offsite doses would result from this accident.

C2-5.5.10 C2 Alternative Applicability

Each of the previously discussed design basis accidents for each alternative will be slightly different since each of the alternatives' design handles each of the accidents differently. The below list summarizes the applicability of the accidents with regard to S-UGS:

1. Seismic (C2-5.5.1)

   The C-UGS will be designed to adhere fully to the requirements discussed in C2-5.5.1. A site-specific seismic analysis will be performed to ensure all components of the S-UGS are qualified for the chosen ISF site's seismic input.

2. Tornado Winds / Missiles (C2-5.5.2)

   The existing C-UGS has been qualified to the NRC's tornado winds and missile criteria as discussed in C2-5.5.2. The proposed ISF design basis is less severe than the design basis tornado for existing nuclear power plants and ISFSIs in Region I since they were designed and licensed to the requirements in the initial Regulatory Guide 1.76, issued in April 1974, for which the maximum tornado wind speed was substantially higher at 360 mph. This would give the ISF additional inherent conservatism in this respect without additional analyses or cost.

3. Flooding (C2-5.5.3)

   The S-UGS will comply with all flooding requirements discussed in C2-5.5.3.

4. Fire (C2-5.5.4)

   The S-UGS will comply with all fire protection requirements discussed in C2-5.5.4, including fire sources from nearby buildings, fuel spills, combustibles, and wildfires.

5. Explosion (C2-5.5.5)

   The S-UGS will comply with all explosion requirements from NRC Reg Guide 1.91 as discussed in C2-5.5.5.

6. Canister Drop Accident (C2-5.5.6)

   The S-UGS system will comply with all canister drop requirements from NUREG-1567 as discussed in C2-5.5.6. All material handling systems will be classified as Single-Failure-Proof as and thus not require postulation of a dropped canister.

7. Loss of Cooling Accident (LOCA) (C2-5.5.7)

   The S-UGS will comply with all LOCA requirements discussed in C2-5.5.7. The S-UGS alternative will use passive air cooling of the dry storage canisters within underground vertical ventilated modules (VVM). The cooling air flow is driven by natural convection with cool air at ambient temperature entering the VVM near the bottom of the canister(s), rising as it is heated by the relatively hot outer surface of the canister, and exiting the VVM by outlet vents above the canister.

8. Off-Normal and Extreme Environmental Temperature (C2-5.5.8)

   The S-UGS will comply with all off-normal and extreme environment temperature requirements discussed in C2-5.5.8 based on the environmental maximum temperatures at the ISF site. Since the S-UGS is a currently utilized and licensed system, considerations for off-normal and extreme environmental temperature has been analyzed for all areas within the US.

9. Lightning (C2-5.5.9)

   The S-UGS will comply with all lightning requirements discussed in C2-5.5.9. Since the S-UGS is a currently utilized and licensed system, considerations for lightning have already been analyzed for all areas within the US.

C2-5.6 Licensing Evaluation

C2-5.6.1 Overview

10 CFR Part 72 governs ISFSI licensing. There are two options for licensing an ISFSI: (1) a specific license and (2) a general license. However, 10 CFR 72.210 only authorizes the use of a general license at a power reactor site with a 10 CFR Part 50 or 10 CFR Part 52 license. Since it is not anticipated that the ISF would be located at the site of a nuclear power plant, the ISF would be governed by a 10 CFR Part 72 specific license.

The process for obtaining a specific ISFSI license is similar to that for obtaining a license for a fuel cycle facility under 10 CFR Part 70 (Reference C2-20). The applicant submits a License Application (LA) in accordance with 10 CFR 72.16 that includes the information required by 10 CFR 72.22 through 10 CFR 72.28. The primary documents comprising the LA are as follows:

- Safety Analysis Report (SAR) that assesses safety of the storage system and the ISFSI facility (used as basis for NRC preparation of the Safety Evaluation Report)
- Environmental Report (used as basis for NRC preparation of the Environment Impact Statement)
- Proposed Technical Specifications
- Quality Assurance (QA) program
- Decommissioning Plan
- Emergency Plan
- Security Plan

C2-5.6.2 Licensing Process

Upon receipt of the application, the NRC establishes a docket number and reviews the application for completeness. If the application is deemed complete, the NRC prepares and publishes a notice of docketing in the Federal Register (FR). The notice of docketing identifies the site of the ISF and includes either a notice of hearing or a notice of proposed action and opportunity for hearing pursuant to 10 CFR 72.46. 10 CFR 72.46 provides the regulations governing the hearing process with references to 10 CFR Part 2 (Reference C2-21), as appropriate.

The NRC will request a hearing upon the notice of docketing if a statute specifically requires it, or if they believe it to be in the public interest, notwithstanding any requests for hearing submitted by parties who believe they having standing in the licensing action. 10 CFR 2.105(a)(7) specifies that if the NRC is not required by statute to conduct a hearing and does not find that a hearing is in the public interest, a notice of proposed action is instead published in the FR.

The notice of proposed action includes the time frame for any person whose interest may be affected by the proceeding to file a request for a hearing or a petition for leave to intervene if a hearing has already been requested. A request for hearing on a 10 CFR Part 72 License Application must be submitted, with the contentions upon which the hearing would be litigated, within 60 days of the notice of docketing. It is worth noting that if the 10 CFR Part 72 specific license applicant is incorporating design information pertaining to a previously NRC-certified spent fuel storage cask design by reference into the application, any hearing held to consider the application will not include any cask design issues pursuant to 10 CFR 72.46(e).

If any requests for hearing are received on the notice or proposed action, the NRC will establish an Atomic Safety Licensing Board (ASLB) to review the hearing requests and contentions for admittance. For the ASLB to admit a contention and grant a hearing, the requestor needs to have standing in the proceeding per 10 CFR 2.309(d), and at least one contention must meet the criteria in 10 CFR 2.309(f). The NRC may also permit discretionary intervention of someone not having standing under the strict requirements of 10 CFR 2.309(e).

Admitted contentions are litigated through a review of documents submitted by the petitioner and may require court testimony and/or documents to be submitted by the applicant, at the discretion of the ASLB. Hearings would take place after issuance of the Final Environmental Impact Statement (EIS). The ASLB may decide to start the hearings prior to completion of the NRC staff Safety Evaluation Report (SER). A license would not be granted until all hearings are completed and the contentions resolved in favor of the applicant. At that point, the Director of the Office of Nuclear Material Safety and Safeguards would request Commission authorization to issue the license pursuant to 10 CFR 72.46(d). While petitioners may appeal the resolution of contentions in the courts, the license would likely be issued without awaiting resolution of those court appeals.

The NRC reviews the application for a specific license, and generally there are several rounds of requests for additional information.

10 CFR 72.42, Duration of License; Renewal, paragraph (a) states the following:

> Each license issued under this part must be for a fixed period of time to be specified in the license. The license term for an ISFSI must not exceed 40 years from the date of issuance. The license term for an MRS must not exceed 40 years from the date of issuance. Licenses for either type of installation may be renewed by the Commission at the expiration of the license term upon application by the licensee for a period not to exceed 40 years and under the requirements of this rule.

C2-5.6.3 License Application

NUREG-1571, "NRC Information Handbook on Independent Spent Fuel Storage Installations," (Reference C2-22) summarizes key requirements for a specific license application, as follows:

- Siting Evaluation Factors (10 CFR 72 Subpart E)—The site characteristics, including external, natural, and manmade events, that may directly affect the safety or the environmental impact of the ISFSI.
- General Design Criteria (10 CFR 72 Subpart F)—Applies to the design, fabrication, construction, testing, maintenance, and performance requirements for structures, systems, and components important to safety.
- Quality Assurance (10 CFR 72 Subpart G)—The planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will

perform satisfactorily in service as applied to design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, modification, and decommissioning.

- Physical Protection (10 CFR 72 Subpart H)—The detailed plans for ISFSI security.
- Personnel Training (10 CFR 72 Subpart I)—The program for training, proficiency testing, and certification of ISFSI personnel who operate equipment or controls important to safety.

The NRC will review the specific license application and complete an evaluation of potential environmental impacts of the ISFSI in accordance with the National Environmental Policy Act of 1969 (NEPA), as amended (Reference C2-23). The NRC will prepare an EIS in accordance with 10 CFR Part 51 (Reference C2-24). Following its safety review and resolution of comments, the NRC issues a Materials License along with its SER and final EIS. The SER describes the conclusions of the staff's safety review based on the applicant's SAR and assesses the technical adequacy of the ISFSI and the spent fuel storage system(s).

Safety Analysis Report

The level of effort associated with preparation of the ISFSI SAR for a specific license can be reduced considerably by taking advantage of the permission granted in 10 CFR 72.46(e) to select storage systems with SARs that have been reviewed and approved by the NRC (with Certificate of Compliances [CoC] having been issued for the storage systems), or storage systems that are currently undergoing NRC review per 10 CFR 72, Subpart L. 10 CFR 72.46(e) states: "If an application for (or an amendment to) a specific license issued under this part incorporates by reference information on the design of a spent fuel storage cask for which NRC approval pursuant to subpart L of this part has been issued or is being sought, the scope of any public hearing held to consider the application will not include any cask design issues." With this approach, the NRC will focus its review on site-specific issues and storage system/site interface issues. This helps streamline the specific licensing process. Should the applicant select a storage system that has neither been reviewed and approved by the NRC nor is currently undergoing NRC review, the NRC must review information associated with the proposed spent fuel storage system as part of the specific license application, which would extend the review time.

Detailed guidance as to information that needs to be included in the ISFSI SAR that is submitted with the license application is provided by Regulatory Guide 3.48, "Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage)" (Reference C2-25). Additional information to enable the NRC staff review in accordance with NUREG-1567 should also be included in the SAR, along with information from any applicable NRC Interim Staff Guidance (ISG). The SAR for the ISF will need to identify and evaluate each of the storage systems that will be used at the ISF to store SNF. For each individual system, the ISF SAR will need to address the following key topics specified in the NUREG-1567 Standard Review Plan:

- General description of the storage system
- Design criteria
- Structural evaluation
- Thermal evaluation
- Shielding evaluation
- Criticality evaluation
- Confinement evaluation
- Material evaluation
- Operating procedures
- Acceptance tests and maintenance program
- Radiation protection (occupational exposures, public exposures, ALARA measures)
- Accident analyses
- Operating controls (technical specifications)
- Quality assurance
- Decommissioning

The previous topics are addressed in the storage system vendors' SARs that have been approved by the NRC for general and specific ISFSI licenses; these documents can be incorporated by reference into the ISF SAR. It is envisioned that the ISF SAR will have a main body that describes and analyzes the ISF design and generic operations, with a separate appendix that serves as the SAR for each individual storage system. The ISF SAR will benefit in that it will primarily use SNF storage systems that have already been licensed under the provisions of 10 CFR Part 72, Subpart K, and have existing Final Safety Analysis Reports (FSARs) that have been approved by the NRC and can be referenced. A specific revision of the vendors' FSARs would need to be chosen for incorporation into the ISF ISFSI SAR. Changes to the vendors' FSARs thereafter would not automatically be incorporated by reference into the ISF SAR, but would require evaluation by the ISF license applicant for incorporation.

The SAR would include descriptions of the safety analyses and other technical evaluations for the ISFSI in each SAR chapter, incorporating by reference any required information for the storage system designs. The format and content would coincide with the chapters of the SRP in NUREG-1567 and any applicable Interim Staff Guidance documents amending that guidance. Formatting the ISFSI SAR in this manner sets the stage for a more efficient NRC technical review because the SRP establishes the format and content template for the NRC's SER.

Environmental Report

The Environmental Report (ER) that is submitted with the License Application is prepared to address the requirements of Subpart E of 10 CFR Part 72, Siting Evaluation Factors, and Subpart A of 10 CFR Part 51, National Environmental Policy Act - Regulations Implementing Section 102(2), using the guidance provided in NRC NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs," (Reference C2-26). The ER contains the following key topics:

- General description of the proposed activities and discussion of need for the facility
- Site interfaces with the environment, including geography, demography, land use, ecology, climatology, hydrology, geology and seismology, historical and cultural features, and background radiation levels.
- Description of the facility, including appearance, construction, operations and effluent control
- Environmental effects of facility construction and operation, including transportation of radioactive material, and effects of decontamination and decommissioning
- Environmental effects of accidents involving radioactive materials, including transportation accidents
- Proposed environmental monitoring programs
- Economic and social effects of facility construction and operation, including cost benefit analysis
- Facility siting (site selection process) and design alternatives
- Environmental approvals including federal, state, and local regulations and permits

As noted above, the NRC will need to prepare a complete EIS for the ISF based on the ER submitted by the licensee, in accordance with 10 CFR Part 51 requirements.

C2-5.6.4 Licensing of Alternative Systems

The approach to licensing of the different alternative systems would be the same as that described above. Key differences involve the information that would be required in the License Application are discussed in the following paragraphs.

Alternative 2, Stad Canister Storage in an Underground Storage System

S-UGS does away with pad storage altogether and places each DPC into an underground "silo" referred to as a Vertical Ventilated Modules (VVMs). The Holtec HI-STORM UMAX system utilizes this type of storage method and is in the process of being licensed by the NRC, with issuance of Certificate of Compliance (CoC) No. 1040 scheduled for Spring, 2015. Callaway plans to load fuel into their UMAX ISFSI in Summer, 2015. The HI-STORM UMAX is similar to the HI-STORM 100U underground storage system that was previously licensed by the NRC under CoC No. 1014, except the UMAX is larger to accommodate the 37 PWR and 89 BWR assembly Multi-Purpose Canisters (MPCs) that were certified in the HI-STORM FW docket (NRC CoC No. 1032). The FSAR for the HI-STORM UMAX system has been reviewed by the NRC and will be approved for use at an ISFSI under a general license, but could also be referenced in the ISF SAR that would be submitted in the License Application for the ISF specific license.

While the HI-STORM UMAX storage system will be licensed initially to store Holtec MPC-37 canisters for PWR fuel and MPC-89 canisters for BWR fuel under a general license, Holtec has plans to amend the CoC No. 1040 to include all Holtec MPC designs, with further expansion of the type of MPCs beyond that as appropriate. The HI-STORM UMAX cavity is one size, which is large enough to store the largest certified canister with radial guides inside the Cavity Enclosure Container (CEC) to secure smaller diameter canisters. Similar to Alternative 2, above, this storage alternative effectively creates a single overpack that stores all the DPCs. Use of the UMAX storage system at the ISF would require analyses to demonstrate compatibility of the various DPCs with this storage system, similar to the analyses that would be required to store these various DPCs in the standardized overpack as described for Alternative 2.

The UMAX design removes the possibility of overpack tipover or sliding caused by an earthquake since the DPC is locked into position in the ground. The VVMs (which function as canister overpacks) are stabilized by surrounding soil so that overpack sliding or tipping during an earthquake is not a credible condition and is not required to be analyzed in the SAR. Another advantage of the UMAX design from a licensing standpoint is that the surrounding soil greatly reduces direct radiation from the sides of stored DPCs, with the earth providing extensive shielding.

As discussed in the section on Security, the UMAX design minimizes security concerns (which are a licensing consideration) since the DPCs are underground, and are more protected from design basis explosions or unauthorized intrusions than above-ground overpacks. In addition, security staff can observe the entire storage area since the system lids with their vents protrude only several feet above the ground.

Placing horizontal DPCs in a vertical position would require additional analyses. New structural, thermal, and shielding analyses would need to be performed to show the horizontal DPCs could be placed in the vertical position without adverse effects. As was the case for Alternative 2, this storage method would need to obtain a single license for canister systems developed and owned by four different vendors, who may be unwilling to share proprietary information that would enable the different canisters to be analyzed for storage in the UMAX VVMs. However, this is a patented design that does not lend itself to having each vendor develop and license their own storage silo (overpack). Therefore, the use of this method could incur proprietary conflicts that could be difficult to resolve possibly involving legal issues.

Horizontal DPCs cannot be lifted from the lid and would require some type of lifting cage to lift and move them into a vertical position so they could be lowered into the underground VVMs. The lifting cage for handling horizontal DPCs in a vertical orientation would need to be addressed in the licensing documentation (i.e., ISF SAR).

In the UMAX storage system, transfer casks with a removable bottom lid are used along with the Vertical Cask Transporter to transfer DPCs from the transfer cask into the underground VVM. The Vertical Cask Transporter has specially designed DPC lifting features that meet requirements such that a canister drop accident need not be postulated. The transfer cask is placed on a Mating Device on a VVM (with its lid removed) in preparation for a canister transfer, avoiding a “stacked cask” configuration for the canister transfer into or out of the VVM. However, it is considered that a stacked cask configuration may be required to transfer an incoming canister from the transport cask to the transfer cask and this would require design and licensing of a canister transfer facility similar to that discussed in Alternative 1.

C2-5.7 Security Evaluation

The purpose of security at an interim storage facility is to protect the SNF against acts of radiological sabotage and theft or diversion that could lead to an unreasonable risk to the health and safety of the public. The ISF must meet the requirements of 10 CFR 73 (Reference C2-27). In order to accomplish this task the ISF will need to establish and maintain a physical protection system which consists of the following:

- Controlled access
- Visual surveillance
- Detection and assessment of unauthorized individuals
- Adversary response
- Measures to resistance explosive devices

The physical security systems must be designed to protect against loss of control of the ISF.

Controlled Access

Controlled access is maintaining control of a clearly demarcated area and isolation of the material or persons within it. The features at the ISF that afford controlled access include a fenced Owner Controlled Area (OCA) typically established at the property boundaries, vehicular access gates into the property where security personnel can verify the identification and authorization of all persons and vehicles entering the site, a Protected Area (PA) with two physical barriers (fences or structures) designed to thwart physical intrusion, and personnel and vehicle access barriers into the PA. All of these features are required of the ISF regardless of the storage system utilized. However, the area required may vary depending on the storage alternative used thus affecting the OCA and PA boundary distances.

For underground storage, the PA will need to be approximately 250 acres in size which would require a perimeter fence roughly 2- 3 miles in length.

Visual Surveillance

Visual surveillance is establishing security guards around the PA who maintain an unobstructed view of the PA at all times. This may be performed from bullet resistant enclosures (BREs) placed around the PA which are occupied by security guards, closed circuit TV (CCTV) cameras that are viewed by security guards at the Central Alarm Station (CAS) or secondary Alarm Station (SAS) or security guards patrolling the site. BREs are situated at strategic locations within the PA to provide protected locations for security force personnel during a security event.

Underground storage has a major advantage in that few BREs or cameras are required to maintain line of sight around the storage area. Since the lids of the storage units are very low to the ground, an intruder would be unable to easily hide. Having a wide space between the storage areas and the PA fence would also assist in providing adequate assessment should an intruder penetrate the PA boundary.

Detection and assessment of unauthorized individuals

Detection of unauthorized individuals is maintained by establishing an intrusion detection system that can detect unauthorized penetration through the isolation zone located between the PA boundary fences and tamper devices on doors and equipment that send an alarm to alert security staff when the PA or security equipment is breached. Assessment of unauthorized individual is established by illuminating the PA with sufficient lighting that security guards can adequately determine the nature of the intrusion either visually or by the CCTV system. The intrusion and CCTV systems are monitored continually by security staff at the CAS and SAS.

Underground storage will only affect the detection and assessment capabilities based on the size of the PA discussed above. A longer PA boundary means more intrusion detection equipment and more cameras.

Adversary Response

Adversary response is the ability to prevent or delay the attempted theft of SNF or radiological sabotage by armed response personnel. Adversary response also includes the ability to provide timely communication to a designated response force such as the local law enforcement agency whenever necessary.

Underground storage will not affect adversary response since this is primarily a function of security staff and communication equipment.

Measures to resistance to explosive devices

Resistance to explosive devices intended to disable security personnel or radiological sabotage is maintained by establishing engineered barriers that prevent such explosions from damaging SNF storage containers or disabling security personnel. Engineered barriers consist of access points designed to slow the speed of approaching vehicles by turns, speed humps, or a serpentine design and a vehicle barrier system (VBS) made of thick reinforce concrete walls or heavy steel portal gates that are installed at a prescribed distance from the SNF or cask handling activities. The VBS prevents entry of vehicle-borne explosive devices. Its distance from the storage area minimizes the impact of an explosion if one were to occur.

Resistance to explosive devices is also maintained by passing persons through explosive and metal detectors, checking all hand-carried items by X-ray machines and inspecting all vehicles and deliveries by security personnel.

Since the entire system except the lids are underground, the underground storage system has excellent resistance to high explosion pressure waves. This ability enables the VBS to be placed much closer to the PA which effectively reduces the overall footprint of the PA.

C2-6.0 Summary

In general, the use of STAD canisters offers a standardized method of SNF storage. Use of a single storage system simplifies handling equipment and operations. Only one storage overpack and concrete storage pad design is required which reduces analyses, design and licensing time.

There are also dry cask storage industry issues that can be resolved with STAD canisters. Elimination of the need to affix a temporary lifting lug to the top of the STAD canister would significantly reduce dose rates. Also the transport cask could be designed with lids on either end so that traditional canister transfer is eliminated and the canister could be directly transferred into a storage unit from the transport cask.

STAD canisters represent a marked increase in the number of units required due to the reduced capacity from current commercial storage systems. This increase will affect the cost as a whole. The size of the STAD canister also factors into the cost – the more canisters required, the higher the costs. The use of a 4-pack container for the small STAD canisters helps defray some of the storage issues as well as cost. STAD canisters contain fewer assemblies than a current DPCs being used in the industry. This means that for a given amount of effort less MTHM will be placed into storage. Instead of 450 overpacks as in other commercial alternatives, the STAD canister forces the use of between 500 and 1000 overpacks, depending on the size STAD canister ultimately selected. The storage pad would need to be substantially larger for STAD alternatives and the cost could be a significant penalty.

STAD canisters do not currently exist and no design standard has been accepted. Moreover, the NRC has not reviewed STAD canisters yet in any licensing application, so it is not clear what the final configuration of STAD canisters will be. Likewise, there eventually will need to be a transfer system developed that takes SNF assemblies out of their NRC-licensed canisters and to repackage them in STAD canisters. The process for doing this is undefined, it is not licensed, and there are no facilities available to make this exchange.

In summary, the pros and cons of this alternative in comparison with the other alternative using STAD canisters is listed from the highest most significant impact to the lowest least significant impact are as follows:

<u>Pros</u>

- The Underground Storage of STAD canisters in silos represent no departure from current practice. Holtec's UMAX system is licensed and soon will be in use at operating nuclear plants. All of the processes, licensing expectations, and equipment needed will be available and in use. There will still need to be a new licensing effort but it is likely to be minimal.

- Underground storage offers a low seismic response spectra and makes the storage of SNF in underground silos attractive in high seismic zones. It removes the possibility of overpack tipover or sliding caused by an earthquake since the DPC is locked into position within the ground.
- Underground storage greatly reduces direct radiation from the sides of the STAD canister by using the earth as a shield.
- Underground storage minimizes security concerns since the STAD canisters are underground, and are more protected from design basis explosions or unauthorized intrusions. In addition, security staff can observe the entire storage area since the system lids protrude only a few inches above the ground.

Cons

- The underground storage system replaces ongoing overpack fabrication activities at the ISF (a good thing) with construction of large sections of the storage area at one time. But unlike pads that can be poured as the ISF grows, the large sections of the underground storage system must be constructed prior to any storage. The system is designed with a large reinforced base pad, steel silos, soil or low strength concrete around each silo, an upper reinforced concrete pad and the silo lids making it more expensive than the Pad Storage concept.

C2-7.0 References

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24. 10 CFR 51, Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.

25. NRC Regulatory Guide 3.48, Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage), Rev. 1, 1989.

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27. 10 CFR 73, Physical Protection of Plants and Materials.

APPENDIX C3

STUDY 3 – ALTERNATIVE DRY STORAGE METHODS FOR STANDARD SNF CANISTERS

Alternative 3 – Below Grade Vault Using STAD Canisters (S-BGV)

Alternative 3 – Below Grade Vault Using STAD Canisters (S-BGV)

C3-1.0 Description of Storage Alternative

Alternative 3 evaluates the use of below grade, air-cooled vaults to store Standardized Transportation, Aging and Disposal (STAD) canisters. Internationally, air-cooled vaults have been used to store spent nuclear fuel (SNF) and high level wastes from reprocessing plants. In the USA, air-cooled vaults have been used or proposed to store non-LWR SNF. An air-cooled vault design was chosen to house the SNF from the decommissioned Fort St. Vrain (FSV) High Temperature Gas Cooled Reactor.

The concept of STAD canister was developed by the U.S. Department of Energy (DOE) as a means of addressing the variability of the spent nuclear fuel (SNF) storage issues that confronted the Department when faced with consolidating the SNF at a single location. In addition to the multitude of dual-purpose canister dry storage designs that have been deployed at reactor sites, several dry canister-based storage systems were not designed for transportation and may not be able to be certified for transport, even if packaged in a transport cask.

The DOE has decided to consider three STAD canister designs which are shown in **Figure C3-1**. Small STAD canisters (4 PWR/9 BWR) and medium STAD canisters (12 PWR/32 BWR) are specified by the DOE "Performance Specification for Small and Medium Standardized Transportation, Aging and Disposal Canister Systems," (Reference C2-1). Large STAD canisters (21 PWR/44 BWR) are specified by DOE "Transportation, Aging, and Disposal Canister System Performance Specification," (Reference C2-2).

All three of these STAD canister sizes are considered together in this alternative at the Interim Storage Facility (ISF). The variations in size will be called S-BGVa for the small STAD canister, S-BGVb for the medium STAD canister, and S-BGVc for the large STAD canister.

The small STAD canisters can be handled individually but that would greatly increase the amount of canister transfers required at the ISF. The small STAD canisters can also be packed in a 4-pack STAD canister multi-can storage container so that they can be handled as a single package, resulting in 16 PWR assemblies or 36 BWR assemblies being shipped in the multi-can storage container.

Figure C3-1
Proposed STAD Canister Sizes

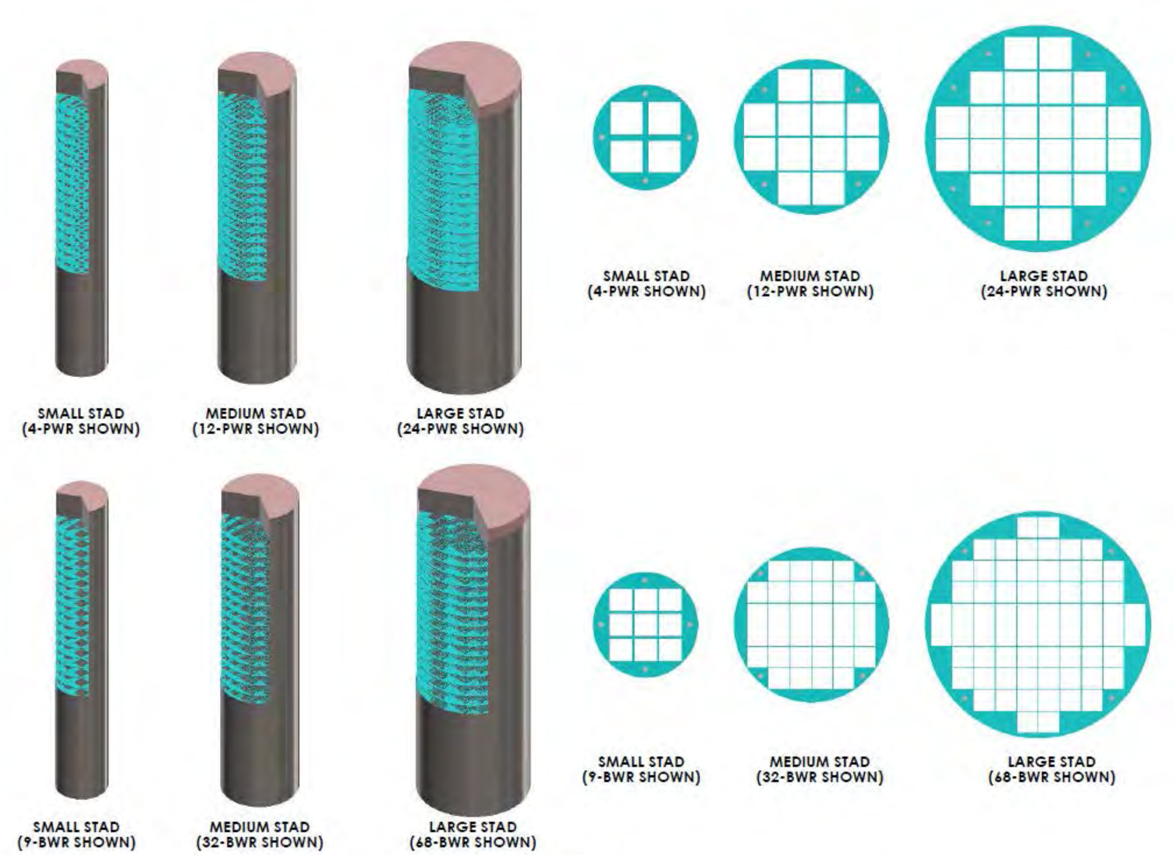


Table C3-1 summarizes the three STAD canister capacities.

Table C3-1
STAD Canister Capacities

Option	STAD Canister Size	Shipment	PWR	BWR	MTHM per Overpack
S-BGVa	Small	4 each	16	36	7.3
S-BGVb	Medium	1 each	12	32	5.4
S-BGVc	Large	1 each	21	44	9.5

This study has assumed that a 32 PWR assembly commercial DPC received at the ISF contains approximately 14.5 MTHM.[1] The large STAD canister contains only 66% of the number of PWR assemblies as the 32-assembly PWR DPC in current use. Part of the

[1] Some of the legacy DPCs contain fewer fuel assemblies so that the average mass per DPC is actually 11.1 MTHM for the ISF.

reasoning for this is that the lower-capacity STAD canister may be used to transport SNF with higher decay heat than could occur using a 32-assembly DPC. Smaller capacity packages generally can transport SNF with higher decay heat due to more efficient heat transfer in the smaller packages.

During transportation, the STAD canisters are loaded into a transport cask that provides shielding and structural protection to the STAD canister. Impact limiting devices are attached to the ends of the transport cask for additional protection during transit. The shipping package must comply with the requirements of 10CFR71 (Reference C3-3). Four small STAD canisters will be shipped in a Multi-can storage container that uses a common handling mechanism to enable handling all of four small STAD canisters as a single entity. For storage, the STAD canisters must comply with the requirements of 10CFR72 (Reference C2-4).

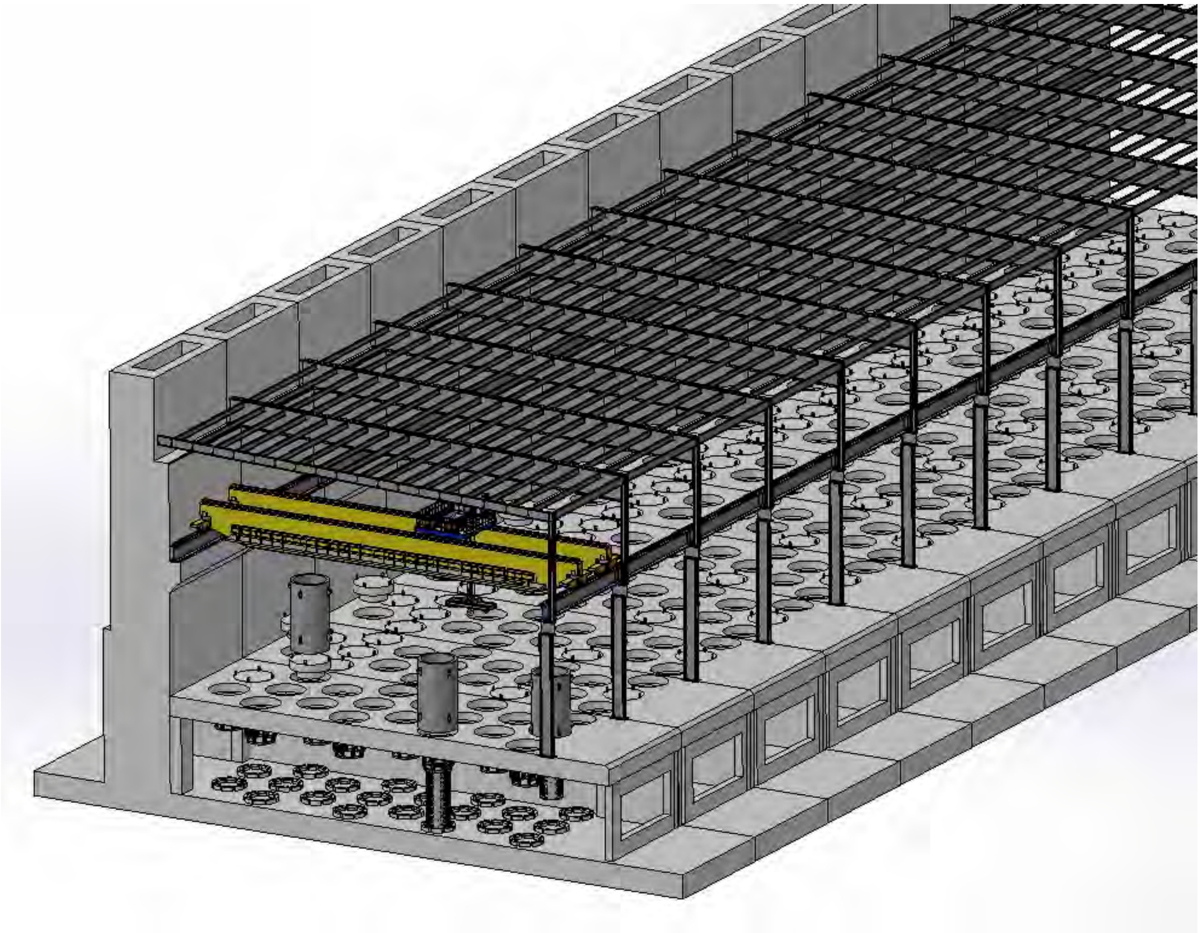
In this concept, a large shielded structure is constructed that houses an array of storage locations into which STAD canisters can be placed. It has a large service hall covered by an overhead traveling bridge crane. The floor of this hall is the shield structure covering the air-cooled vault. A shield plug is fitted into the floor over each storage location. Below this shield plug is a seismic restraint system that secures the STAD canisters in a way that prevents movement in the event of a seismic event.

The vault area beneath this shield floor is designed to encourage passive air flow around the STAD canisters. Exhaust stacks on one side of the vault allow the air warmed by the STAD canisters to escape while air inlets on the other side of the vault draw cool outside air into the building. This natural draft system provides bulk cooling to remove the decay heat from the SNF. **Figure C3-2** shows a 3D rendering of a conceptual vault design that could store commercial SNF.

Typically, air-cooled vaults used for the storage of nuclear wastes have stored individual fuel assemblies in vertical storage locations. The ISF air-cooled vaults will need to accommodate STAD canisters that house many fuel assemblies and it will need to accommodate STAD canisters designed to be stored vertically.

The STAD canisters will be loaded with SNF and transported to the ISF site by rail. The STAD canisters will be fitted with the necessary adaptor frames to compensate for any size variations relative to the standard used to size the vault storage seismic restraint system.

Figure C3-2
3D Rendering of a Conceptual Vault



C3-2.0 Concept of Operations

C3-2.1 Facility Layout

Figure C3-3 through **Figure C3-5** shows the Below Grade Vault overall site layout for all three sizes of STAD canisters. The transport casks are delivered to the site by rail. Most likely, the railroad carrier will park the unit train at a siding off site and the ISF dedicated tug will be dispatched to retrieve the unit train. This small locomotive brings the railcars from the mainline siding to the Rail Interchange Siding Yard at the northwest corner of the ISF site.[2] At this point, the unit cars are disconnected and the security detachment who accompanied the shipment is relieved. There is a powered derailer preventing unauthorized rolling stock onto the siding yard without clearance.

[2] For this study, North is at the top of the figure. The ISF can in fact be situated in any orientation, but for clarity of this description, North is up; East is right; etc.

The individual transport railcars are moved to the Railcar Security Inspection Area located at the entrance of the ISF protected area. There, site security officers complete the review of the shipping paperwork and perform a thorough check of the rolling stock and the packaging to ensure that there is no contraband on the shipment. The railroad tracks have a powered derailer that is positioned at the gate to the protected area to prevent unauthorized access into the protected area via rail. After the security inspection, the transport cask railcars are moved into the SNF Delivery Rail Yard / Staging Area until being moved into the CHB.

The CHB is where the transition from the rolling stock to the storage vault begins. As a result, it is located near the Rail Yard / Staging Area. It is accessible by two sets of rails, into a single railbay. The CHB is centrally located to access different vaults.

Transport casks are brought into the CHB from the staging area via the rollup doors on either the west or the east end of the railbay. Materials and supplies are brought in via the loading dock/truckbay on the east side of the CHB.

Personnel entrances and support facilities are located at the southeast corner of the ISF site. These facilities include the ISF Office Building, Warehouse, Security Entrance, parking lots, electrical substation, fire water tanks and pump house, emergency diesel generators and fuel storage tanks, and the ISF Visitor's Center.

The designs of the S-BGV variants are impacted by the size of the STAD canister. Small STAD canisters require more storage space to store the same amount of SNF. **Figure C3-3** shows S-BGVa, **Figure C3-4** shows S-BGVb and **Figure C3-5** shows S-BGVc.

Figure C3-3
Conceptual Site Plan of the S-BGV Using Small STAD Canisters

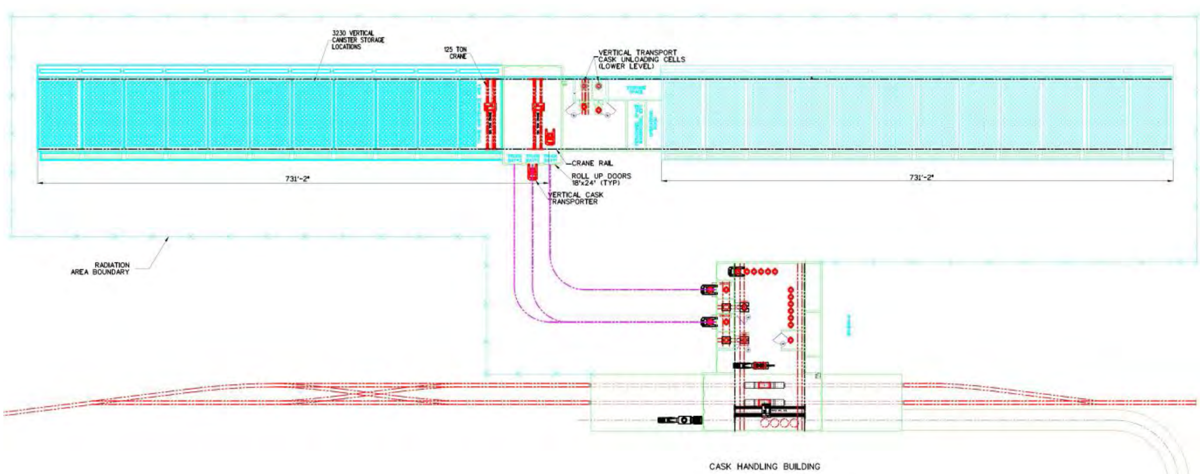
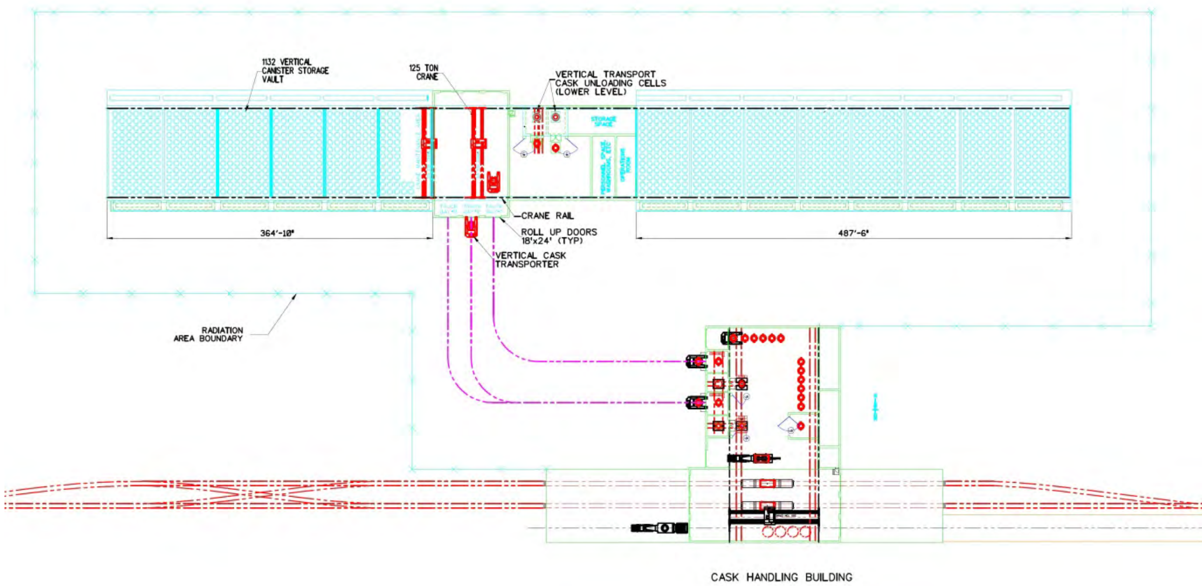
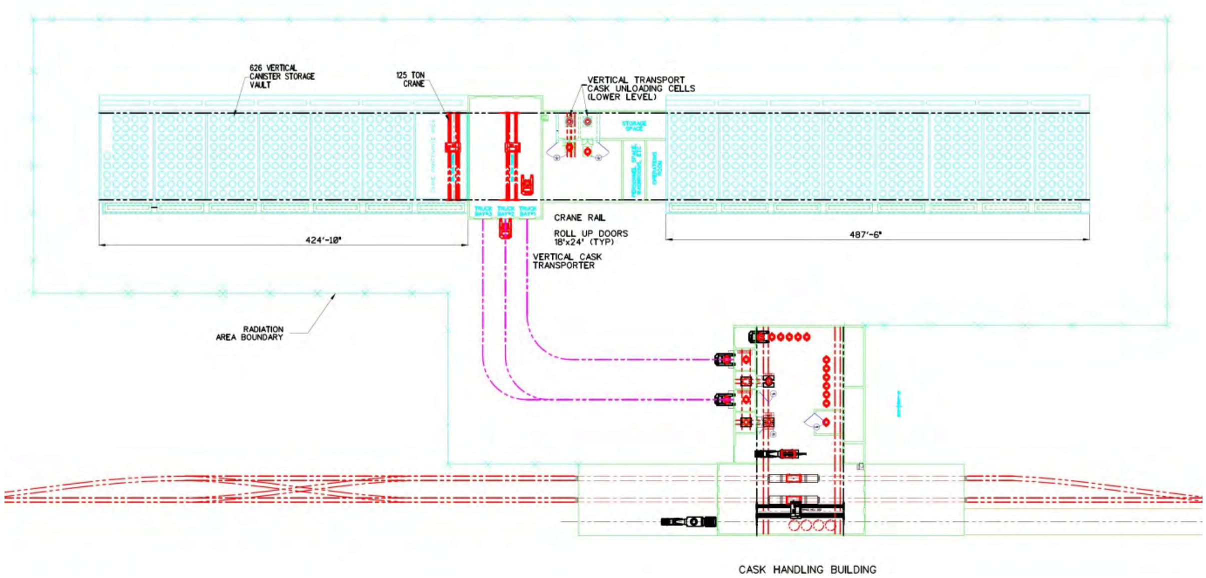


Figure C3-4
Conceptual Site Plan of the S-BGV Using Medium STAD Canisters



The STAD canister is transferred from the transport cask into a shielded transfer cask in the CHB. The shielded transfer cask is picked up by a Vertical Cask Transporter (VCT) and transported to the vault building operating floor. This is done to separate the placement of the STAD canister in the vault from the recycling of the transport cask.

Figure C3-5
Conceptual Site Plan of the S-BGV Using Large STAD Canisters



The total cycle time for a cask handling evolution is determined by how rapidly the crew can turn around the transport cask. Using the shielded transfer cask enables the crew to begin recycling the transport cask in parallel with the placement of the STAD canister. This adds several complex and heavy components to the ISF inventory but it significantly increases the throughput. It also concentrates most of the STAD canister preparation activities in the CHB. This allows for better utilization of the work crews by segregating the types of work into the appropriate buildings.

Once inside the vault building, the STAD canister is removed from the shielded transfer cask into a shielded transfer sleeve in a dedicated vertical transfer vault. The shielded transfer sleeve is attached to the overhead traveling bridge crane that moves the STAD canister to the storage location in the vault.

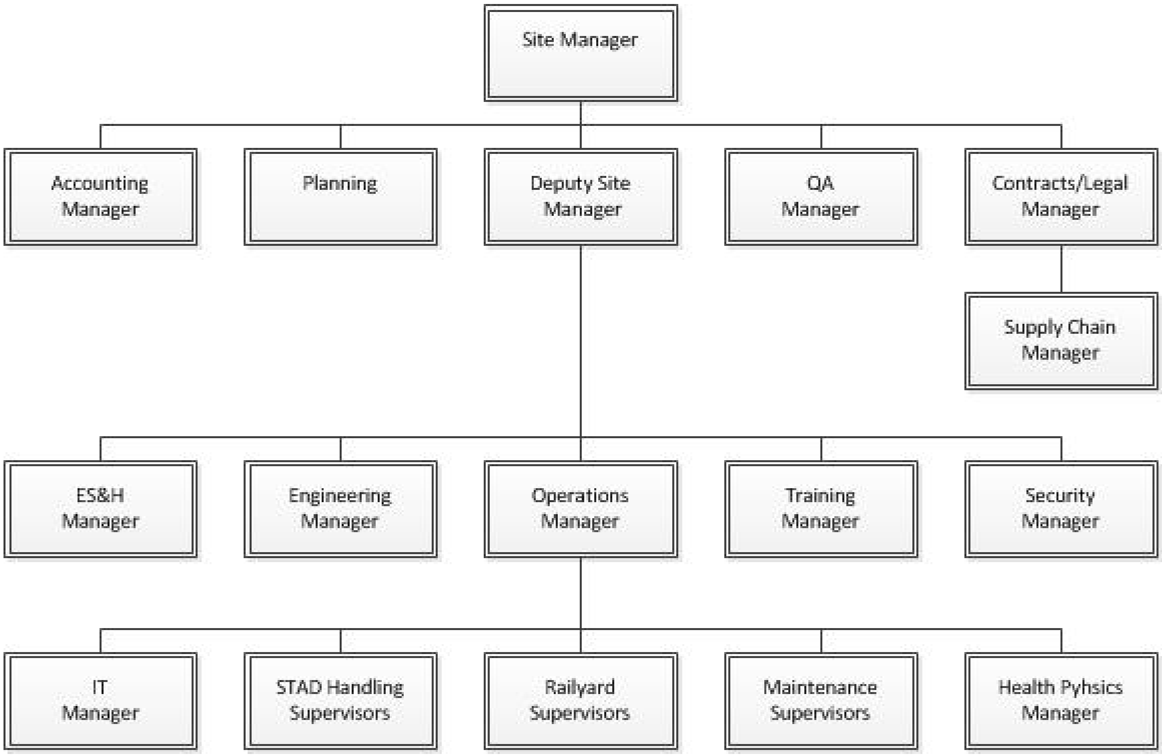
C3-2.2 ISF Operations

The ISF operates on a 24-hour, 7-days a week basis, but Canister Handling operations are limited to a single 8-hour shift, 40-hour work week. This has been done because the logistics issues associated with delivering a large number of transport casks to the site do not warrant around-the-clock Canister Handling operations. It also provides the ability to accommodate surges of work that might be necessary by the simple expedient of adding additional Canister Handling crew shifts. It is assumed that the ISF is operated by an independent contractor so that many of the administrative and Human Resource functions of an organization are not required within the site organization. The costs for these off-site services are covered in the overhead calculation for labor. **Figure C3-6** is the chart of the site organization.

There are two phases to ISF operations: Canister Handling Operations and Storage Facility Surveillance and Maintenance Operations. The Canister Handling Operations are the activities necessary to accept SNF packaged in STAD canisters from nuclear generators and to place the SNF into interim storage on site. This is a temporary activity lasting only as long as necessary to accept the design basis amount of SNF considered in this study. This activity lasts only a few years and involves the most labor intensive activities experienced at the ISF. Additional Canister Handling Operations will be necessary at the end of ISF life when the stored SNF is repackaged and shipped to its final destination.

Storage Facility Surveillance and Maintenance Operations are the ongoing activity that spans the entire operational lifetime of the ISF. This consists of all the activities necessary to plan, to monitor the performance and aging of the storage systems used to house and cool the SNF, and to provide for the safeguards and security necessary to protect the facility from unwanted intrusions and/or damage. The Surveillance and Maintenance Operations begin immediately upon the commissioning of the ISF and continue until the last STAD canister has been removed.

Figure C3-6
Typical ISF Organization Chart



The ISF has a fairly active rail yard system with a dedicated crew of train experts managing the rolling stock and ensuring that the unit trains are rapidly brought onto site after being put on a nearby siding by the railroad company. This is a full-time support activity that includes two tugs and a maintenance facility for servicing them as well as the railcars associated with the delivery of the SNF to the ISF.

Regular plant maintenance required for the equipment necessary to perform the heavy lifts and heavy load movements necessary to fulfill the SNF handling function. This includes the overhead travelling bridge (OTB) crane servicing the railbay, the Vault Building cranes, the transfer carts in the CHB and the Vault Building, and the shield sleeve. Cranes, carts and specialty components that handle STAD canisters need to have single-failure-proof designs and be inspected and maintained rigorously to ensure operability and safety.

In addition to physical labor, the ISF requires planning and engineering to support operations. The planning function needs to encompass not only the activities on the ISF site proper, but must be well informed about the SNF transportation system and recovery and repackaging of SNF from the nuclear generators. Engineering activities are required for safety analyses and modifications to processes and materials to support SNF storage. Also, record keeping is required to identify the origin of each STAD canister in storage at the ISF, its contents, the SNF characteristics and its storage location at the ISF. In addition, all material certifications for each STAD canister and other materials used for cask and STAD handling need to be meticulously maintained for easy retrieval in the future.

The lifting lug assemblies that are bolted to the top of the STAD canisters to enable them to be lifted by cranes and hoists are unretreivable in the vaults. There is not shielding in the air-cooled vault between STAD canisters. Work crews cannot go into the vault to retrieve the lifting lug assemblies due to the high dose rates. Therefore, the lifting lug assemblies are considered consumables. They are fabricated off-site by contract shops. The procurement group is responsible for assuring that enough lifting lug assemblies are available in the warehouse to support ISF activities.

Finally, the largest functional activity at the ISF is physical security. The security group's functions will include daily, routine site security activities as well as inspection of all materials coming onto the site. This security function is the largest single group of the organization and is a 24-7 operation. The vault concepts have a significant advantage over other pad-based storage alternatives in this area. Since the STAD canisters are stored within a reinforced concrete vault that requires special equipment to access, the rest of the site can easily afford two lines of sight over the ISF site in order to locate and to identify intruders. So, while a traditional overpack system might require as many as four security locations to establish the necessary security coverage, the vault concepts can achieve this same requirement with only two. This results in a smaller security force than is needed for other pad-based storage systems. In addition, the IAEA oversight systems would be simplified since a couple of dedicated cameras would be able to survey the entire storage area to assure inspectors that no diversion of potentially strategic materials occurs.

Table C3-2 is a listing of the site organization staff. The organizational staff would be adequate to support the activities at the ISF necessary to support the Canister Handling activities. This staff totals 128 but does not include the Canister Handling crew. Many of the staff personnel are cross trained to enable them to support cask handling activities if necessary. If the alternate for the S-BGV includes a standalone CHB, then the number of Security personnel would increase by 10 (two per shift) and the number of Facility Operators would increase by 5 (one per shift). So, the total for a S-BGV with standalone CHB would be 143.

Table C3-2
Site Organization

Position	Staff	Position	Staff
Site Manager	1	Mechanical Engineers	4
Deputy Site Manager	1	I&C Engineers	1
Security Manager	1	Quality Engineers	2
Operations Manager	1	Buyers	2
ES&H Manager	1	Planners	4
QA – Manager	1	Security	45
Accounting Manager	1	Trainers	4
Purchasing Manager	1	Rail yard Operators	2
Contracts/Legal Manager	1	Facility Operators	16
Manager of Engineering	1	Supervisors	4
Training Manager	1	Mechanics	4
Health Physics Manager	1	Electricians	4
HR Manager	1	IT Technicians	3
HR Specialists	2	IT Manager	1
Health Physicists	2	Administration Assistants	4
Nuclear Safety Engineers	2	EMT	1
Electrical Engineers	2	RR Tug Engineers/Brakemen	4
Civil/Structural Engineers	2		
		Total	128

C3-2.3 Canister Handling Crew Size

The Canister Handling Operations staff is dedicated to the movement of STAD canisters around the site. These operations are carried out by dedicated crews who focus on certain areas of the operation. This way, when multiple STAD canisters are processed each week, a crew learns specialized skills that will improve efficiency. The crews are: 1. the Railbay Crew, 2. the Cask Transfer Crew, and 3. the Vault Building Crew.

The Railbay Crew consists of the skilled crafts necessary to prepare the transport cask to be unloaded and later to be reassembled to be shipped back to the generator. These activities include receipt inspection of the as-received package, removal and storage of the impact limiters, removal and storage of the transport cask cover, and removal and storage of the tie-down straps. Then, the Railbay Crew rigs the transport cask to be lifted by the OTB crane and places it on the transfer cart in the CHB.

The Cask Transfer Crew then positions the transport cask in the transfer cell and transfers the STAD canister into the shielded transfer cask. The crew then repositions the shielded transfer cask so that it can be picked by the vertical cask transporter. The Cask Transfer Crew also removes the transport cask from the shielded transfer cell and prepares it for the lift that will return it to the railway.

The Vault Building Crew is responsible for the placement of the STAD canister into the vault. If the design employs an integral CHB, these workers operate the vault crane and the shielded transfer sleeve to place the STAD canister into the vault. If the design employs a standalone CHB, these workers have the additional responsibility of using the cask transporter to pick the shielded transfer cask and transport the STAD canister to the Vault Building via the heavy haul road.

The Vault Building Crew positions the shielded transfer cask on a powered transfer cart. The cart is then positioned in a vertical transfer vault and the STAD canister is extracted into the shielded transfer sleeve attached to the overhead traveling bridge crane. The shielded transfer sleeve is then positioned in the vault area to affect the placement of the STAD canister.

Tables C3-3 and C3-4 show the staffing for each major activity necessary to move a STAD canister from the transport cask to the storage vault for an integral CHB and a standalone CHB. It can be seen in **Tables C3-3 and C3-4** that the vaults with standalone CHBs require a significantly larger staff.

The Heavy Equipment operators are the operators of the cask transporters that transport the STAD canisters in their shielded transfer casks from the CHB to the Vault Building(s). Because the distance between the CHB and the Vault Buildings is short, and because the cask transporters are only used to deliver the shielded transfer casks between buildings, the ISF only needs two VCTs for operations. Due to the complexity of these machines, one spare cask transporters is required.

In order to establish the size of the crews, **Tables C3-3 and C3-4** below needs to be used in conjunction with the time motion studies presented in **Section C3-2.6**. Depending on the location of the the CHB, several shifts a week do not require a full complement of workers for the entire shift. The idled workers will be rotated back to the matrixed workforce for other assignments as necessary. Certain workers such as the crane operator, the Health Physics techs and the QA/QC inspectors are area workers in that they are assigned an area and service the SNF canister only when it is that area. The crane operators use radio remote controllers for the OTB cranes, the shielded transfer sleeve hoists and for jib cranes so that one person could, in fact, operate all of the cranes in a certain area. The mechanics and riggers are task focused and only work on the STAD canister to accomplish certain activities.

Table C3-3, Basis of Staffing – S-BGVa

STAD Canisters Stored Vertically in Vault with Integral CHB		Supervisor	Mechanics	Electricians	Riggers	Operations*	HP	QA/QC	Crane	RR Ops*	Heavy Eq. Operator	Security*	Total Staff	Duration (hrs)
0)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	0	0	11	0.5
1)	Receive transport cask at BGV/AGV	1	2	2	0	1	2	1	0	2	0	2	13	1
2)	Remove impact limiters and place in temporary storage	1	2	0	2	0	2	0	1	0	0	0	8	3
3)	Upend and lift transport cask off of railcar and place on transfer cart	1	0	0	2	0	0	0	1	0	0	0	4	2
4)	Remove transport cask cover using jib crane and set down	1	2	0	2	0	2	0	1	0	0	1	9	1
4a)	Secure the transport cask and the transfer cart seismically	1	2	0	2	0	0	1	1	0	0	0	7	0.5
4b)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	0	0	11	0.5
5)	Hoist lifting lug to top of STAD canister and bolt in place	1	2	0	1	0	0	0	0	0	0	0	4	1
6)	Position transfer cart in transfer cell and close shield doors	1	0	0	2	0	0	0	0	0	0	0	3	1
7)	Position shielded transfer sleeve on bridge crane above transfer cell	1	0	0	2	0	0	0	1	0	0	0	4	0.5
8)	Lower hoist, grapple lifting lug, and raise STAD canister into shield sleeve	1	0	0	2	0	0	1	1	0	0	0	5	1.25
9)	Transfer STAD canister to vault storage location	1	0	0	2	0	0	0	1	0	0	0	4	2
10)	Remove shield plug above vault storage location	1	0	0	2	0	0	0	1	0	0	0	4	1
11)	Lower STAD canister into storage position on vault floor	1	0	0	2	0	0	1	1	0	0	0	5	1
12)	Replace shield plug above vault storage location	1	0	0	2	0	2	1	1	0	0	0	7	1
12a)	Turnover to operations	1	0	2	0	2	2	1	0	0	0	0	8	24
13)	Return crane to operating floor	1	0	0	0	0	0	0	1	0	0	0	2	1
14)	Remove transport cask from transfer cell	1	0	0	2	0	0	0	1	0	0	0	4	1
15)	Install transport cask lid	1	2	0	2	0	2	1	1	0	0	1	10	1
16)	Lift transport cask and transfer to maintenance	1	0	0	2	0	0	0	1	0	0	0	4	1
16a)	Survey and wipedown transport cask	1	0	0	0	0	2	0	0	0	0	0	3	1
17)	Lift transport cask, place on railcar, and downend	1	2	2	2	0	0	0	1	0	0	2	10	1
17b)	Plan of the day and safety meeting	1	2	0	2	0	2	1	1	0	0	0	9	0.5
18)	Install impact limiters on transport cask	1	2	0	2	0	0	1	1	0	0	0	7	2
18a)	Plan of the day and safety meeting	1	0	0	0	0	2	1	0	0	0	0	4	0.5
19)	Release railcar for shipment	1	0	0	0	1	2	1	0	2	0	2	9	1

* These categories are loaned to the Cask Handling Crew

Table C3-4, Basis of Staffing – S-BGVb

STAD Canisters Stored Vertically in Vault with Standalone CHB		Supervisor	Mechanics	Electricians	Riggers	Operations*	HP	QA/QC	Crane	RR Ops*	Heavy Eq. Operator	Security*	Total Staff	Duration (hrs)
0)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	0	0	11	0.5
1)	Receive transport cask on railcar at Cask Handling Building	1	0	2	0	1	2	1	0	2	0	2	11	1
2)	Remove impact limiters and place in temporary storage	1	2	0	2	0	0	1	1	0	0	0	7	3
3)	Upend and lift transport cask off of railcar and place on unloading cell transfer cart	1	0	0	2	0	0	0	1	0	0	0	4	2
3a)	Remove railcar from railbay	0	0	0	0	1	0	0	0	2	0	2	5	1
4)	Unbolt and remove transport cask lid using jib crane	1	2	0	2	0	0	0	1	0	0	0	6	1.3
4a)	Secure transport cask on unloading cell transfer cart	1	2	0	2	0	0	1	1	0	0	0	7	0.5
4b)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	1	0	12	0.5
5)	Attach lifting lug to top of STAD canister	1	2	0	2	0	0	0	1	0	0	0	6	1
6)	Position transport cask transfer cart in unloading cell and close shield doors	1	0	0	2	0	0	1	1	0	0	1	6	1
7)	Stage empty shielded transfer cask in receiving cell using a transfer cart	1	0	0	2	0	0	0	1	0	0	0	4	0.5
8)	Position shielded transfer sleeve cart over unloading cell	1	0	0	2	0	0	0	1	0	0	0	4	0.5
9)	Lower shield sleeve hoist and grapple STAD canister lifting lug	1	0	0	2	0	2	0	1	0	0	0	6	0.5
10)	Raise STAD canister into shield sleeve	1	0	0	2	0	2	1	1	0	0	0	7	1
11)	Position shielded transfer sleeve cart over shielded transfer cask in receiving cell	1	0	2	2	0	2	1	1	0	1	0	10	1
12)	Lower STAD canister into shielded transfer cask, release grapple, and retract hoist	1	0	0	2	0	0	1	1	0	0	0	5	1
13)	Install shielded transfer cask lid using jib crane	1	2	0	2	0	0	0	1	0	0	0	6	1
13a)	Secure the transfer cask and the transfer cart seismically	1	2	0	2	0	2	1	1	0	0	0	9	1
13b)	Plan of the day and safety meeting	1	0	0	2	0	2	1	1	0	0	0	7	1
14)	Place transfer cask on CHB floor pick point	1	0	0	2	0	0	0	1	0	0	0	4	1
15)	Pick up transfer cask and transfer to BGV using omni-loader	1	0	0	2	1	2	1	0	0	1	2	10	1
16)	Place shielded transfer cart onto transfer cart	1	0	0	2	0	0	0	1	0	0	0	4	0.5
17)	Remove shielded transfer cask Lid	1	2	0	2	0	2	0	1	0	0	0	8	1
18)	Position transfer cart in unloading cell and close shield doors	1	0	0	2	0	0	0	1	0	0	0	4	0.5
19)	Position shielded transfer sleeve above transfer cell	1	0	0	2	0	0	0	1	0	0	0	4	0.5
20)	Lower hoist, grapple lifting lug and raise STAD into shield sleeve	1	0	0	2	0	0	1	1	0	0	1	6	1
20a)	Secure the transport cask and the transfer cart seismically	1	0	0	2	0	0	0	1	0	0	0	4	1
20b)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	1	0	12	0.5
21)	Transfer STAD to vault storage location	1	0	0	0	1	0	0	0	2	0	2	6	2
22)	Remove shield plug above vault storage location	1	2	0	2	0	0	0	1	0	0	0	6	1
23)	Lower STAD into storage position on vault floor	1	2	0	2	0	0	1	1	0	0	0	7	1
24)	Replace shield plug above vault storage location	1	0	0	0	1	1	1	0	2	0	2	8	1
24a)	Turnover to operations	0	0	2	0	2	2	1	0	0	0	0	7	24
25)	Return crane to Operating Floor	1	0	0	2	0	0	0	1	0	0	0	4	1
26)	Remove shielded transfer cask from transfer cell	1	0	0	2	0	0	0	0	0	0	0	3	1
27)	Install shielded transfer cask lid using jib crane	1	2	0	2	0	0	0	1	0	0	0	6	1
28)	Place shielded transfer cask at vault floor pick point	1	0	0	2	0	0	0	1	0	0	0	4	1
29)	Return shielded transfer cask to CHB using omni-loader	1	0	0	2	0	0	0	0	0	1	0	4	1
30)	Open unloading cell shield doors and position transfer cart under jib crane	1	0	0	2	0	0	0	1	0	0	0	4	1
31)	Install transport cask lid	1	2	0	2	0	0	1	1	0	0	0	7	1
32)	Lift transport cask and transfer to maintenance	1	0	0	2	0	0	0	1	0	0	0	4	1
32a)	Survey and wipedown transport cask	1	0	0	0	0	2	0	0	0	0	0	3	1
33)	Lift transport cask, place on railcar, and downend	1	2	2	2	0	0	0	1	0	0	0	8	1
34)	Install impact limiters on transport cask	1	2	0	2	0	0	1	1	0	0	0	7	2
35)	Release railcar for shipment	1	0	0	0	1	2	1	0	2	0	2	9	1

* These categories are loaned to the Cask Handling Crew

The results of this effort are summarized in **Table C3-5** below. This staffing estimate is approximate since not all crafts are required for an entire shift. Also, some intermediate steps do not require a certain craft, but in reality, they do not disappear. These interruptions do not materially impact the assessment. The ISF labor pool will be a matrix structure where necessary craft and managers will be drawn from the site organization staff as necessary to achieve the desired operations. This is an obvious requirement because of the variability in the Canister Handling Crew size by shift in **Table C3-5**. Based on this study, the site organization staff will need to be increased by 23 workers to achieve the desired ISF throughput during the Canister Handling phase of the facility's life cycle for the S-BGV design. This results in a total ISF staff of 151 for the BGV with Integral CHB. The Cask Handling crew size for the S-BGV with standalone CHB is more than double at 50, but the benefit of the dual railbay can be seen quite clearly as the crew for the S-BGV with standalone CHB is uniform. This is why the throughput of this design is double the throughput of the S-BGV with Integral CHB. This efficiency of labor utilization is significant benefit of the standalone CHB concept.

Table C3-5
Canister Handling Crew Makeup (Integral CHB)

	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Average*
Supervisor	1	2	2	1	1	2
Mechanics	2	4	4	2	2	3
Electricians	2	2	2	2	2	2
Riggers	2	6	6	2	2	4
HP	2	4	4	2	2	3
QA/QC	1	2	2	1	1	2
Crane Operator	1	3	3	1	1	2
Heavy Eq. Operator	0	0	0	0	0	0
Total	11	23	23	11	11	18

* To the nearest whole person

Canister Handling Crew Makeup (Standalone CHB)

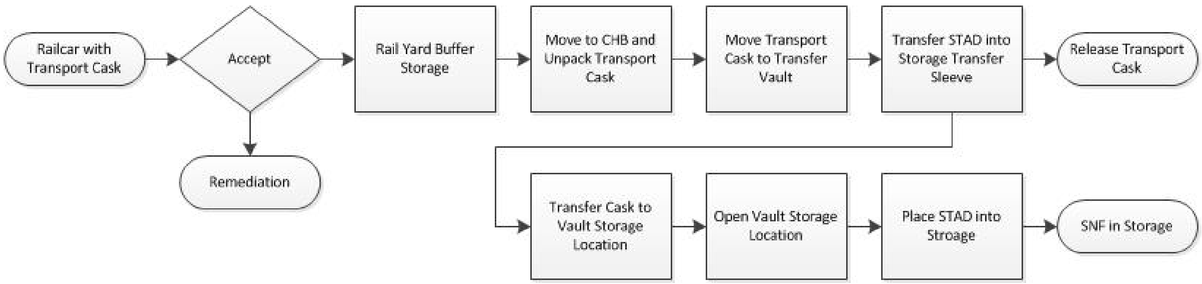
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Average*
Supervisor	4	4	4	4	4	4
Mechanics	8	8	8	8	8	8
Electricians	6	6	6	6	6	6
Riggers	10	10	10	10	10	10
HP	10	10	10	10	10	10
QA/QC	5	5	5	5	5	5
Crane Operator	5	5	5	5	5	5
Heavy Eq. Operator	2	2	2	2	2	2
Total	50	50	50	50	50	48

* To the nearest whole person

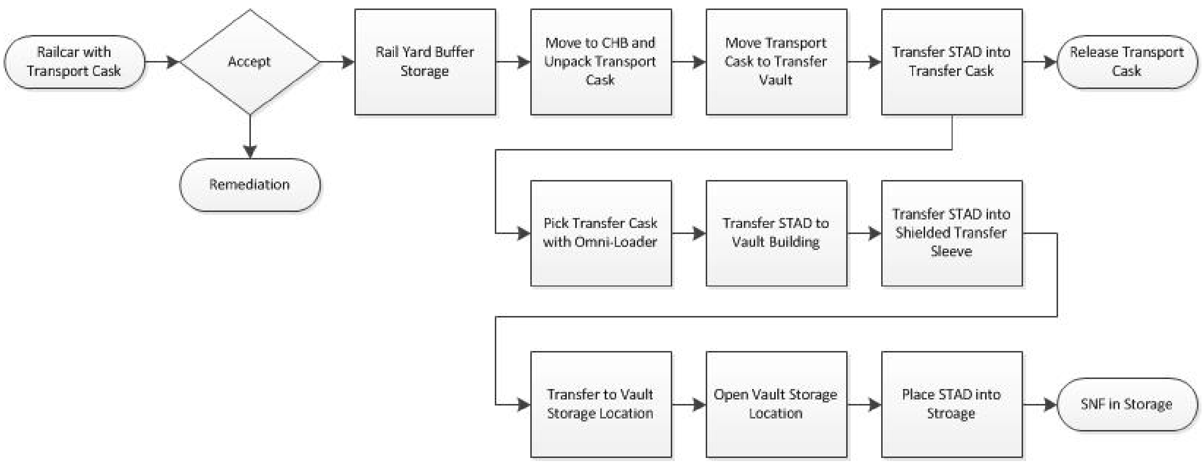
C3-2.4 Material Handling Flow Diagram

Figure C3-7 is a representation of the material handling flow for the Below Grade Vault alternative for the ISF with integral CHB. It describes the material flows of the operation.

Figure C3-7
Canister Handling Material Handling Flow Diagram S-BGV (Integral CHB)[3]



Canister Handling Material Handling Flow Diagram S-BGV (Standalone CHB)[3]



It should be noted that there are no significant differences in the processing times necessary for STAD canisters regardless of their size. Since they all contain SNF that is just as susceptible to damage regardless of how many assemblies are in each container and since the dose rates and weights are all substantial, all lifts and other movements must be carefully planned and executed to avoid damage to the fuel or injury to the workers. The difference is that the number of STAD canisters necessary to achieve the ISF quantity of 5,000 MTHM is larger for STAD canisters than for conventional DPCs.

[3] Remediation is not part of this study's work scope and is not addressed other than to note that the packages are not accepted on site regardless of their condition.

C3-2.5 Operations

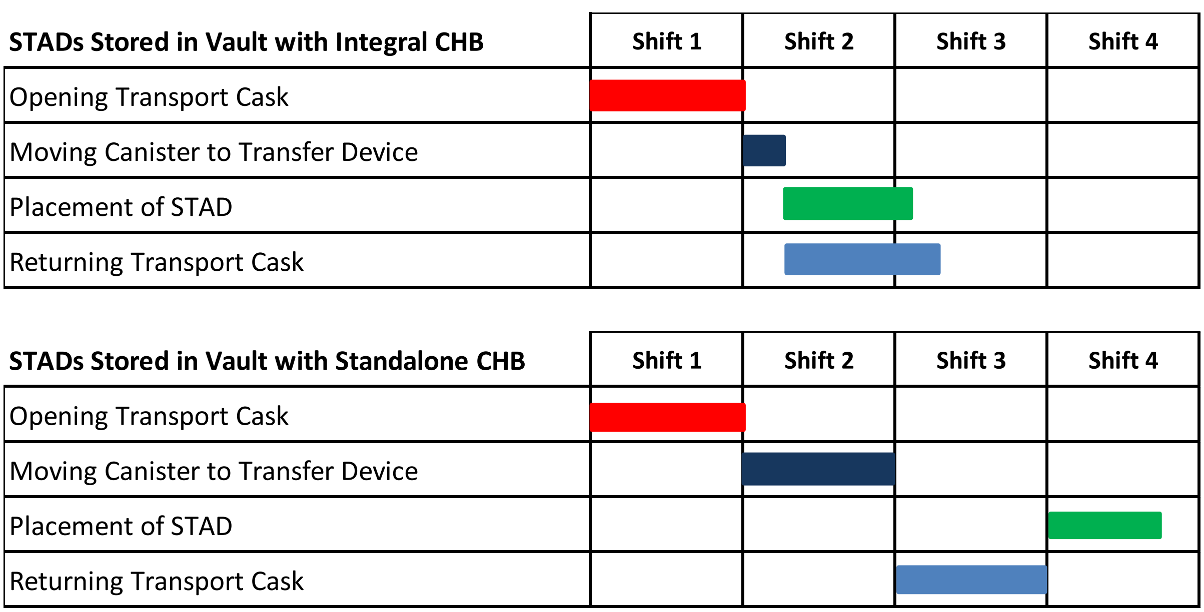
C3-2.5.1 Operational Sequence

Canister Handling operations are a series of heavy lifts and crane movements that move the SNF in sealed STAD canisters from the rail head to the storage vault. The operational sequence was benchmarked against ISFSI operations at operating nuclear plants. Although no one has actually performed all of the operations at an ISF, each operation has a precedent established in the nuclear industry. The crew sizes and the durations necessary to perform each activity therefore has basis. This benchmarking provides the underpinning supporting this operational sequence and the Time and Motion analysis which follows in **Section C3-2.6**.

Figure C3-8 shows the high-level schedule for the two storage concepts in Below Grade Vault assuming 8-hour shifts. The operational sequence once the transport cask is accepted into the CHB can be divided into four large blocks:

1. Opening the transport cask
2. Moving the STAD canister into the transfer device or system
3. Transfer of the STAD canister to the storage location and
4. Preparing for the turnaround of the transport cask.

Figure C3-8
High-Level Operational Sequence A-BGV



The key to cycling STAD canisters through this sequence is the time it takes to recycle the transport cask. Is can be seen that the time it takes to move the STAD canister from the transport cask into the shielded transfer cask and then into the shielded transfer sleeve in the Vault Building is essentially a two shift exercise. However, the transport cask is released from its duty half way through that process, enabling it to be recycled in three shifts. The actual placement of the STAD canister into storage takes place on the fourth shift but it takes place in a separate building from the transport cask activities so it has no impact on the cycle time. So, the use of the shielded transfer cask enables a three-shift process rather than a four shift process.

Ironically, when one integrates the operational sequence for the S-BGV with Integral CHB, it becomes necessary to delay the repackaging the transport cask until the third shift to enable the maximum throughput. If one relies on the 2½ shifts shown above, the throughput is two STAD canisters per week. If the repackaging is delayed to enable the unpacking of a second transport cask, the throughput can be improved to 2½ STAD canisters per week.

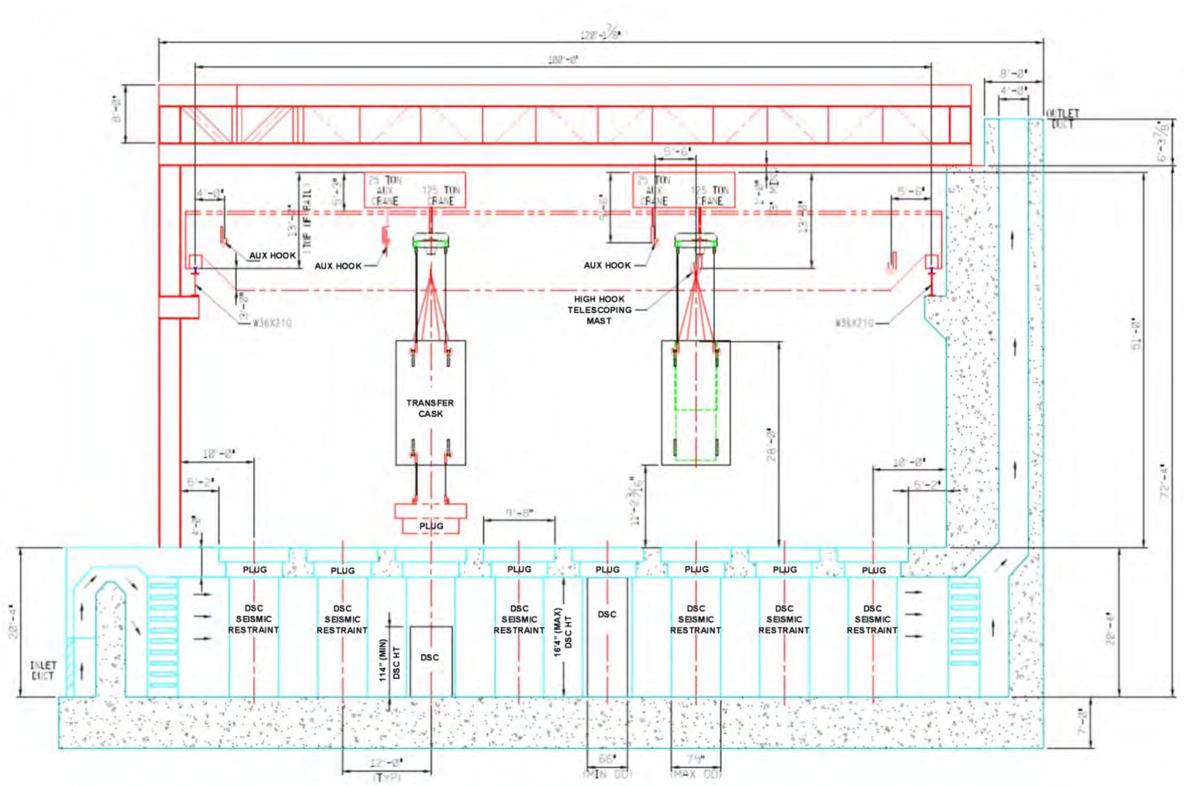
The railcar packaging of the transport cask is removed in the railbay using one of the CHB OTB crane. The transport cask cover, impact limiters, and hold down straps are removed and stored. The transport cask is then upended by the OTB Crane servicing the railbay and placed on a cart in the vertical orientation. The lid is removed and a lifting lug is bolted onto the top of the STAD canister. The cart is then moved into the transfer cell.

If the vault has an integral CHB, the STAD canister is extracted by the shielded transfer sleeve hoist and transferred to the vault storage location. It the vault uses a standalone CHB, the STAD canister is lifted into a shielded transfer cask and lowered into a transfer cask. This cask is very similar in design to a transport cask and is used to move the STAD canister to the vault building by means of a cask transporter.

The crane positions the shielded transfer sleeve over the transfer vault and indexes itself over the port in the roof of the vault. It lowers a hoist that grapples the STAD canister by the lifting lug and lifts it out of the shielded transfer cask and locks it into position in the shielded transfer sleeve. The crane then repositions the shielded transfer sleeve over the selected storage location in the vault. The grapple at the bottom of the shielded transfer sleeve engages the shield plug and the crane lifts the plug out shield floor. The shield plug is placed to one side and the STAD canister is relocated back over the opening. The STAD canister is then lowered into the lower vault and placed on the vault floor.

The STAD canisters are secured laterally in the vault by the STAD canister seismic restraint system that consists of I-Beams embedded in the floor to prevent the STAD canister from sliding sideways during a seismic event. The top restraint consists of a cage attached to the bottom of the shield operating floor extending down into the vault area far enough to capture the top of the shortest STAD canister in the industry. For STAD canisters that are very small in diameter, adaptors are used to minimize the impact against the seismic restraint systems as necessary to avoid damage to the STAD canisters. The shield plug is replaced. **Figure C3-9** shows the relationships of the various components and structures in the air-cooled vault area.

Figure C3-9
Cross-Section of the Storage Vault



It should be noted that after the shielded transfer cask is placed into the transfer vault, workers are not needed to be near the STAD canister during the entire process. Cameras and other remote sensing devices are used to identify and verify the placement of the STAD canister in the vault. Once the shield plug is replaced, the dose rates in the vault building storage hall are quite low and workers can attach the sensors and the tamper-proof seals on the storage location without appreciable exposures.

2.5.2 Limits to Operation

Railbay

Operations in the railbay are arguably the most important of the operations at the ISF to determine the throughput. The storage sequence cannot begin until the first railbay activity is completed, and the cycle cannot be completed until the last activity in the railbay is finished. So, railbay activities limit the maximum throughput of the ISF.

The S-BGV with integral CHB design has only one railbay with two rail lines. This limits the number of railcars that can be unloaded to maintain a constant supply of transport casks to be unloaded. Since there are two rail lines in the railbay, the CHB is able to supply two STAD canisters to be place into overpacks every four days.

Adding another rail line to the railbay could eliminate this problem by enabling the transfer cells to remain in continuously operation throughout the week. However, a second OTB crane would be needed that can act in parallel with the existing crane.

The S-BGV with a standalone CHB design has two railbays and two independent OTB cranes servicing the railbays. Also, the design separates the placement of STAD canister into the vault storage locations from the activities in the railbays which is a significant improvement in operations. So, while the S-BGV with integral CHB places a STAD canister in 2½ shifts compared to 4 shifts for the S-BGV with standalone CHB, the latter can place five STAD canisters into storage per week compared to 2 to 2½ STAD canisters per week.

CHB Overhead Traveling Bridge Crane

The railbay requires a heavy lift crane in order to maneuver the transport cask off of the railcar and onto the transfer cart in the CHB. It also requires a crane to reverse this process and to replace the transport cask onto the railcar. While these activities are underway, they dominate the OTB crane and it is unavailable for any other activity. The CHB has only one OTB crane. This is adequate to support the existing design with only two rail lines in the railbay, but it limits the potential throughput to 2½ STAD canisters per week. As described above, if the railbay is expanded to support three rail lines instead of two, the OTB crane availability would need to be doubled in order to increase throughput.

The OTB cranes would probably need to operate on the same set of rails, so doubling them would not necessarily double the throughput. It would be necessary to ensure that the next crane to transfer a load to or from the railbay would be shuffled to ensure that the cranes would not interfere with each other during operations.

There is only one CHB OTB crane. It is in constant use during the eight hour shifts for the 40 hour week. Maintenance and testing activities can be conducted during the overnight or the weekends. However, there is a major outage of the OTB crane; the throughput of the ISF will be seriously impacted.

Vault Building Overhead Traveling Bridge Cranes

One CHB OTB Crane and the CHB railbay design can send at most one STAD canister to the Vault Building on two consecutive days, and then there is a break where no STAD canisters are sent to the Vault Building for two days. Each crane takes two shifts to handle each STAD canister. So, the Vault Building cranes are therefore continuously used. This leaves the two overnight shifts for maintenance and testing. However, if there is a major problem with the crane it will seriously impact the ISF throughput.

Transfer Cells

The vertical storage system transfers require canister transfer cells to provide shielding and to simplify operations during the transfer of the STAD canisters from the transport cask into the shielded transfer sleeve. Each canister transfer vault consists of a door to allow a transport cask on a transfer cart to enter and exit the cell and a transfer port in the roof of the vault to permit the movement of the STAD canister into the shielded transfer sleeve. It is necessary to have a minimum of two canister transfer cells.

C3-2.6 Time and Motion Analysis

C3-2.6.1 Methodology

No one has operated a national scale ISF for the dry storage of SNF and no one has handled SNF in a STAD canister. For this study, a high-level operational sequence was developed by the concept designers. These high-level activities were then decomposed into their constituent activities. At this level, the activities were generally ones that had been performed by operators at existing nuclear facilities, or that could be estimated by small extrapolations of existing operational experience. Interviews were conducted with several individuals with real, hands-on operational experience with moving SNF to achieve a consensus on the completeness, the durations and the staff size necessary to achieve each of these constituent activities. These were then pieced together to develop a bottom up estimate of durations and crew sizes for each step.

Additional steps were added to recognize the practice of having a “Plan of the Day” meeting and a safety meeting at the start of each shift. Also, steps such as HP surveys of the emptied transport casks, and adding seismic restraints to packages containing SNF at the end of a shift were added to allow time for these necessary steps.

Once the operational sequence was developed, the sequences were considered in parallel to determine how many STAD canisters could be placed per week. Several basic assumptions were made. The first was that a large supply of transport casks on railcars was staged on the site ready for processing. If the ISF rail yard is empty or contains only two railcars during a week, this time and motion study does not apply. The available railcars will simply be processed and the Canister Handling Crews will be given other duties to fill up the week. So, the first inherent assumption is that the logistics supply chain is adequate to fully challenge the capacity of the ISF.

Secondly, this study only considers operations that are already developed and in operation at existing operating nuclear plant experience. No unusual enhancements were considered. The shielded transfer sleeve is a multi-purposed device that is a logical extension of commonly employed devices. If it becomes too complex to design and deploy, a light-duty OTB crane that moves the shield plugs in the storage hall would be a simple expedient to simplify the design challenge. However, this assessment of the Below Grade Vault did not consider automating the transfer or adding a great deal of remote sensors to the area to eliminate personnel exposures.

Finally, a major assumption for the Time and Motion Analysis was that no operation involving the movement of a STAD canister would be started during a shift if it could not be completed by the end of that shift. This is necessary because the CHB does not operate continuously, so no load would be left hanging or in some other unstable condition that would jeopardize the integrity of the SNF or its confining structures in the event of a design basis event. Abandoning the STAD canister in mid-operation would leave the canister in a potentially compromised position without qualified canister handling expertise on hand in case of emergency. Furthermore, the STAD canister was assumed to be secured seismically at the end of each shift.

As stated earlier, this study considers only a single 8-hour shift at 40 hours per week with no overtime. Clearly, the throughput could easily be increased by adding workers and shifts, and indeed that would be a cost effective expedient if additional capacity is desired. However, a working assumption of this study is only a single shift of 40 hours is necessary per week. Based on the certain problems with the logistics of moving SNF to the site, it is considered that this is a reasonable approach.

C3-2.6.2 Conclusion

It was determined that the throughput with all of the assumptions is an average of 2.5 STAD canisters placed into storage each week for vaults with integral CHBs and 5 STAD canisters placed into storage each week for vaults with standalone CHBs. Several observations came out of the Time and Motion Analysis.

First, the benefit of the vault with standalone CHBs comes from the ability to readily support a two railbay CHB. It requires more people to staff the site the site during the cask handling activities and it takes longer for each STAD canister to be placed into storage, but it permits better work force efficiency and doubles the throughput of the integral CHB design. The throughput is independent of what size STAD canister is considered. So, while the movement of STAD canister is the same, the placement of SNF into storage is very different. **Table C3-6** captures the differences among the STAD canister options available.

Table C3-6
ISF Throughput Using STAD canisters

Option	STAD Canister	STAD Canister Capacity		MTHM per Year (260 STADs/yr)	5000 MTHM Time
		PWR	BWR		
S-UGSa	Small	16	36	1898	2.6 years
S-UGSb	Medium	12	32	1404	3.6 years
S-UGSc	Large	21	44	2470	2.0 years

First, with the CHB having two rail lines, it is the OTB cranes that determine the maximum throughput of the CHB. The single OTB crane is the limiting element in the throughput of this alternative. It precludes increasing the throughput of the facility and should it fail or experience an outage, it would effectively prevent the CHB from functioning. Adding another CHB OTB crane would have no impact on ISF throughput without massive redesign of the CHB.

Second, the Vault Building (or vault area) OTB cranes are fully utilized and possibly overextended. Using more cranes with more limited roles might make for a more reliable system, albeit at the price of complexity and the need for more operators. The need to swap out the lifting devices between picking the shielded transfer cask and managing the complex shielded transfer sleeve may be too daunting of a design challenge. However, as currently configured, the Cranes in the Vault Building are at the limits of their capability.

Third, there needs to be two cask transporters on site to develop and maintain full ISF throughput for the standalone CHB design. These are extremely complex machines and could be unreliable if used as much as this concept requires. One cask transporter would possibly be able to maintain the ISF throughput, but having two is seen as a necessary precaution.

Fourth, this concept is easier for the security team to protect because it is concentrated and contained. External threats and internal threats are easier to identify and to defeat than is the case for an external facility.

Finally, this concept is unaffected by weather and other environmental conditions during the loading process. Therefore, STAD canister placement is not impacted by external conditions so the ISF can be sited anywhere without the throughput being impacted. The minimal impact of the movement of the transfer cask containing the STAD canister from the CHB to the vault building was judged to be of negligible importance.

Figures C3-10 and C3-11 show the schedule for the S-BGV alternative. The activities on the Y-axis are the steps necessary to process the STAD canisters from when they enter the CHB until the empty transport cask has been reinstalled on the railcar and removed from the CHB. The time across the top of the schedule is in hours. The red bars are critical path activities; the blue are near critical path activities. It has been assumed that once a STAD canister has been placed in the storage configuration in the vault, a period of 24-hours is necessary to perform the required surveillance and safeguards activities. This is shown as a green dashed line on this chart but is not really part of the Canister Handling Crew's responsibility. These activities are done by ISF Operations. The activities include a series of temperature, air flow and radiation measurements over the initial 24-hour period to validate that the expected performance has been achieved.

The schedules in **Figures C3-10 and C3-11** were then placed in series and in parallel to establish the maximum throughput of the ISF. **Figures C3-12 and C3-13** show the work plan for S-BGV that shows how the workflow would proceed. The Gantt chart bars have been colored to show the equipment used to accomplish the activity. The color coding permits the viewer to easily see when the schedule is causing a conflict in the vault building. The operational cycle repeats every four weeks and during that period, 10 STAD canisters are placed into storage. That is an average of 2.5 STAD canisters per week.

Figure C3-10
Time Motion Schedules for Below Grade Vault using STAD canisters – S-BGVa

STADs Stored Vertical in Vault with Integral CHB	
0)	Plan of the day and safety meeting
1)	Receive transport cask at BGV/AGV
2)	Remove impact limiters and place in temporary storage
3)	Upend and lift transport cask off of railcar and place on transfer cart
4)	Remove transport cask cover using jib crane and set down
4a)	Secure the Transport cask and the transfer cart seismically
4b)	Plan of the day and safety meeting
5)	Hoist lifting lug to top of STAD and bolt in place
6)	Position transfer cart in transfer cell and close shield doors
7)	Position shielded transfer sleeve on bridge crane above transfer cell
8)	Lower hoist, grapple lifting lug, and raise STAD into shield sleeve
9)	Transfer STAD to vault storage location
10)	Remove shield plug above vault storage location
11)	Lower STAD into storage position on vault floor
12)	Replace shield plug above vault storage location
12a)	Turnover to operations
13)	Return crane to operating floor
14)	Remove transport cask from transfer cell
15)	Install transport cask lid
16)	Lift transport cask and transfer to maintenance
16a)	Survey and wipedown transport cask
17)	Lift transport cask, place on railcar, and downend
17a)	Plan of the day and safety meeting
18)	Install impact limiters on transport cask
19)	Release railcar for shipment

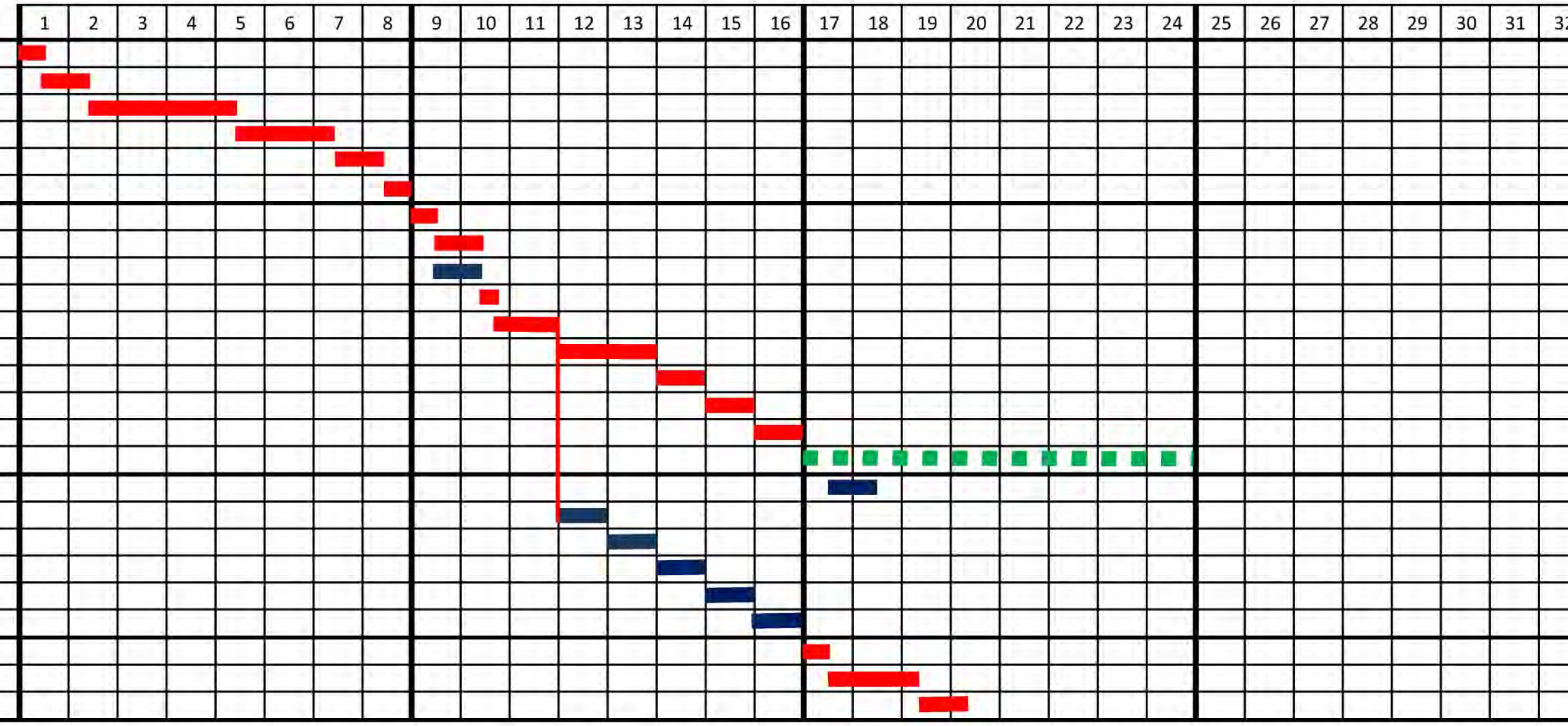


Figure C3-11
Time Motion Schedules for Below Grade Vault using STAD canister (Cont'd)

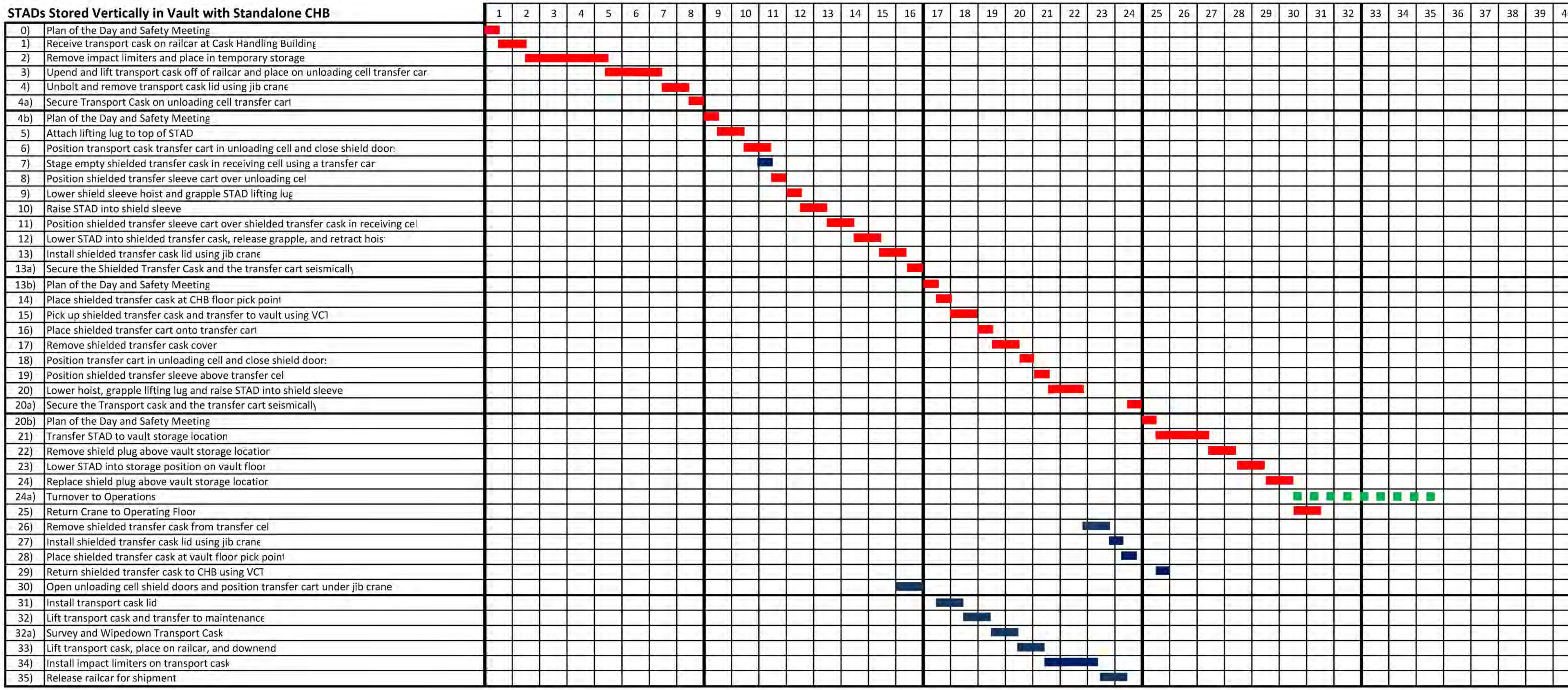


Figure C3-12
Typical Work Plan for Below Grade Vault Using STAD canisters

Integral CHB

	Week 1					Week 2				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Rail #1	Transport Cask #1 Unload	DPC #1 Transfer to Vault	Transport Cask #1 Reload		Transport Cask #3 Unload	DPC #3 Transfer to Vault	Transport Cask #3 Reload		Transport Cask #5 Unload	DPC #5 Transfer to Vault
Rail #2		Transport Cask #2 Unload	DPC #2 Transfer to Vault	Transport Cask #2 Reload		Transport Cask #4 Unload	DPC #4 Transfer to Vault	Transport Cask #4 Reload		Transport Cask #6 Unload

	Week 3					Week 4				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Rail #1	Transport Cask #5 Reload		Transport Cask #7 Unload	DPC #7 Transfer to Vault	Transport Cask #7 Reload		Transport Cask #9 Unload	DPC #9 Transfer to Vault	Transport Cask #9 Reload	
Rail #2	DPC #6 Transfer to Vault	Transport Cask #6 Reload		Transport Cask #8 Unload	DPC #8 Transfer to Vault	Transport Cask #8 Reload		Transport Cask #10 Unload	DPC #10 Transfer to Vault	Transport Cask #10 Reload

NOTES*:*
1. The highlighted boxes show the critical path activity in the Railbays. Note that work is always on going in the railbays.
2. The cycle is 2 ½ shifts long, but delaying the repackaging of the transport cask enables better utilization of the vault systems.
3. This process is the same for STAD canister sizes.
4. The vaults with integral CHB design can process 10 DPCs in four weeks; averaging 2.5 a week.

Figure C3-13
Typical Work Plan for Below Grade Vault Using STAD canister (Cont'd)

Standalone CHB

	Week 1					Week 2				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Railbay #1	Transport Cask #1 Unload	DPC #1 Transfer to VB	Transport Cask #1 Reload	Place STAD #1 in Vault	Transport Cask #5 Unload	DPC #5 Transfer to Vault	Transport Cask #5 Reload	Place STAD #5 in Vault	Transport Cask #9 Unload	DPC #9 Transfer to Vault
Railbay #1	Place STAD #18 in Vault	Transport Cask #2 Unload	DPC #2 Transfer to Vault	Transport Cask #2 Reload	Place STAD #2 in Vault	Transport Cask #6 Unload	DPC #6 Transfer to Vault	Transport Cask #6 Reload	Place STAD #6 in Vault	Transport Cask #10 Unload
Railbay #2	Transport Cask #19 Reload	Place STAD #19 in Vault	Transport Cask #3 Unload	DPC #3 Transfer to Vault	Transport Cask #3 Reload	Place STAD #3 in Vault	Transport Cask #7 Unload	DPC #7 Transfer to Vault	Transport Cask #7 Reload	Place STAD #7 in Vault
Railbay #2	DPC #20 Transfer to VB	Transport Cask #20 Reload	Place STAD #20 in Vault	Transport Cask #4 Unload	DPC #4 Transfer to Vault	Transport Cask #4 Reload	Place STAD #4 in Vault	Transport Cask #8 Unload	DPC #8 Transfer to Vault	Transport Cask #8 Reload

	Week 3					Week 4				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Railbay #1	Transport Cask #9 Reload	Place STAD #9 in Vault	Transport Cask #13 Unload	DPC #13 Transfer to Vault	Transport Cask #13 Reload	Place STAD #13 in Vault	Transport Cask #17 Unload	DPC #17 Transfer to Vault	Transport Cask #17 Reload	Place STAD #17 in Vault
Railbay #1	DPC #10 Transfer to Vault	Transport Cask #10 Reload	Place STAD #10 in Vault	Transport Cask #14 Unload	DPC #14 Transfer to Vault	Transport Cask #14 Reload	Place STAD #14 in Vault	Transport Cask #18 Unload	DPC #18 Transfer to Vault	Transport Cask #18 Reload
Railbay #2	Transport Cask #11 Unload	DPC #11 Transfer to VB	Transport Cask #11 Reload	Place STAD #11 in Vault	Transport Cask #15 Unload	DPC #15 Transfer to Vault	Transport Cask #15 Reload	Place STAD #15 in Vault	Transport Cask #19 Unload	DPC #19 Transfer to Vault
Railbay #2	Place STAD #8 in Vault	Transport Cask #12 Unload	DPC #12 Transfer to Vault	Transport Cask #12 Reload	Place STAD #12 in Vault	Transport Cask #16 Unload	DPC #16 Transfer to Vault	Transport Cask #16 Reload	Place STAD #16 in Vault	Transport Cask #20 Unload

NOTES:

1. The highlighted boxes show the critical path activity in the Railbays. Note that work is always on going in the railbays.
2. The railcars are removed after the work crews are done with them and replaced by the next railcar to be processed.
3. The cycle is four shifts long.
4. This process is the same for all STAD canister sizes.
5. The standalone CHB design can process 20 STAD canisters in four weeks; averaging 5 a week

C3-3.0 ISF Construction

The ISF will consist of a number of features and structures that will need to be constructed for the facility to operate. They include:

1. ISF Site (with access road and utilities)
2. Railroad spur and yard
3. Vault with integral or standalone Cask Handling Building
4. Protected Area (security boundary, cameras, intrusion detection and lighting)
5. Administration building
6. Security/access control building
7. Warehouse/maintenance facilities

C3-3.1 ISF Site

The ISF site is assumed to be placed on approximately one square mile of property. Not all of the land will require construction, only the area for the ISF. An access road and electrical utilities will need to be constructed into the property. The site access road will consist of an asphalt paved 2 lane road from the nearest highway into the ISF. The location of the site will determine if mechanical utilities (domestic water, wastewater, natural gas) can be supplied from local means or if these will need to be self-contained. A remote site requiring self-contained utilities can use water wells or trucked-in tanks of water depending on the underground water capability. Wastewater can be discharged through drain fields. Propane gas can be supplied if no natural gas lines are near the site.

The site will require an Owner Controlled Area (OCA) fence which will likely consist of a chain link fence to discourage trespassers from entering the site and keep animals out. The fence requires minimal construction and establishes a good facility boundary. Just inside the fence a gravel security road can be constructed to enable guard patrols around the site.

The purpose of the OCA is to establish the portion of the property that maintains a level of secured control. Within this boundary, security maintains control and patrols for unauthorized individuals. In addition, 10 CFR 72.106 requires that all SNF storage and handling operations be maintained at least 100 meters from the OCA boundary. All CSF functions are contained within this boundary.

C3-3.2 Railroad Spur and Yard

The ISF will need railroad tracks from the mainline to receive incoming train consists and prepare for outgoing train consists. A rail portal at the Protected Area boundary and a rail yard near the storage area will also be required.

The purpose for the rail yard is to provide adequate railcar storage for incoming and outgoing SNF train consists, and access to the CHB. The rail yard must be designed to allow flexibility for maneuvering yard switchers, railcars, buffer cars, and escort cars.

It is assumed that the rail yard will consist of at least 4 tracks – 2 tracks to receive inbound trains and 2 tracks for staging outbound trains. The yard includes a runaround track to permit the yard switchers access around the tracks. The yard also includes a lead line and a spur off the lead line accessing the CHB.

Construction of the rail yards will involve excavation, structural fill, potential geotextile materials to maintain soil stability, gradation to establish various elevations to ease railcar movements, heavy steel rail, ties, several rail turnouts, ballast placement, lighting, and other minor railroad related features.

C3-3.3 Storage Area

The storage area resides within the reinforced concrete storage vault. The storage hall above the shielded storage and steel framed structure whose operating floor is at grade elevation. The vault will be a long, open bay approximately 100 ft. wide by 800 ft. long.

The base of the vault and the operating floor will house a thick reinforced concrete slab approximately 60 inches thick, which will house the STAD canisters. The S-BGV will utilize a natural cooling method of passing outside air directly across the canisters within the vault and up through the vault's chimney, creating a natural air flow based on the heat generated by the STAD canisters and the height of the chimney. The vault will be designed to ensure adequate safety and to mitigate the effects of site environmental conditions, natural phenomena, security events, and accidents including stability and liquefaction caused by earthquake conditions over the life of the facility.

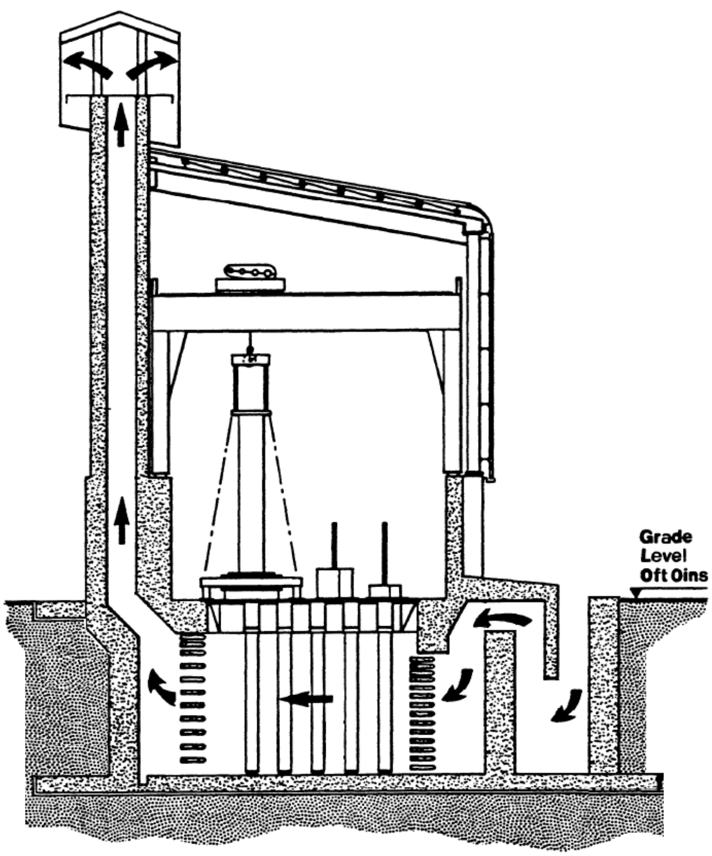
A vault design holds spent fuel in individual STAD canisters vertically within a concrete structure forming the vault. The STAD canisters would be transferred from the transportation cask and placed within a cell of the vault with a shield plug placed on top. The tops of the shield plugs would be level and integrated within the operating floor. The vault itself is located below the operating floor and has a concrete floor that the STAD canisters rest on and inlet and outlet air cooling ducts. The ceiling of the vault (also the operating floor) would be a composite steel and concrete structure. This ceiling and the floor of the vault would maintain the array of STAD canisters since the canisters would be sitting within a receiver on the vault floor and within one on the vault ceiling to ensure complete capture of the DPC and ensure no movement during a seismic event, sub-criticality, and efficient cooling.

Cooling air will enter through an inlet vent at grade elevation, pass around a labyrinth to prevent radiation streaming, enter the vault, and exit through the chimney. The passive cooling system is self-regulating, driven by natural buoyancy of warm air, and is naturally immune to partial blockage of the inlet or outlet vents as the air velocity will increase to account for the blockage. This affords the ISF several days to clear the vent in the unlikely event of a blockage.

Since the vault is a massive concrete structure and the STAD canisters are stored below grade, there will be little to no radiation dose outside of the vault structure. Even on the operating floor, as long as the shield plugs are in place, there will be less than a 1mrem/hr dose rate.

A typical below grade vault configuration storing up to 5,000 MTHM of SNF for the ISF will need to store up to 450 STAD canisters as shown on **Figure C3-14**.

Figure C3-14
Typical Below Grade Vault Storage System – Elevation View



C3-3.4 Cask Handling Building

The purpose of the CHB is threefold; 1) receive SNF shipments; 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 building cell and transfer canisters from the transport casks to storage overpacks for vertical systems. The building is designed to provide physical protection for the canisters and radiation shielding to the workers.

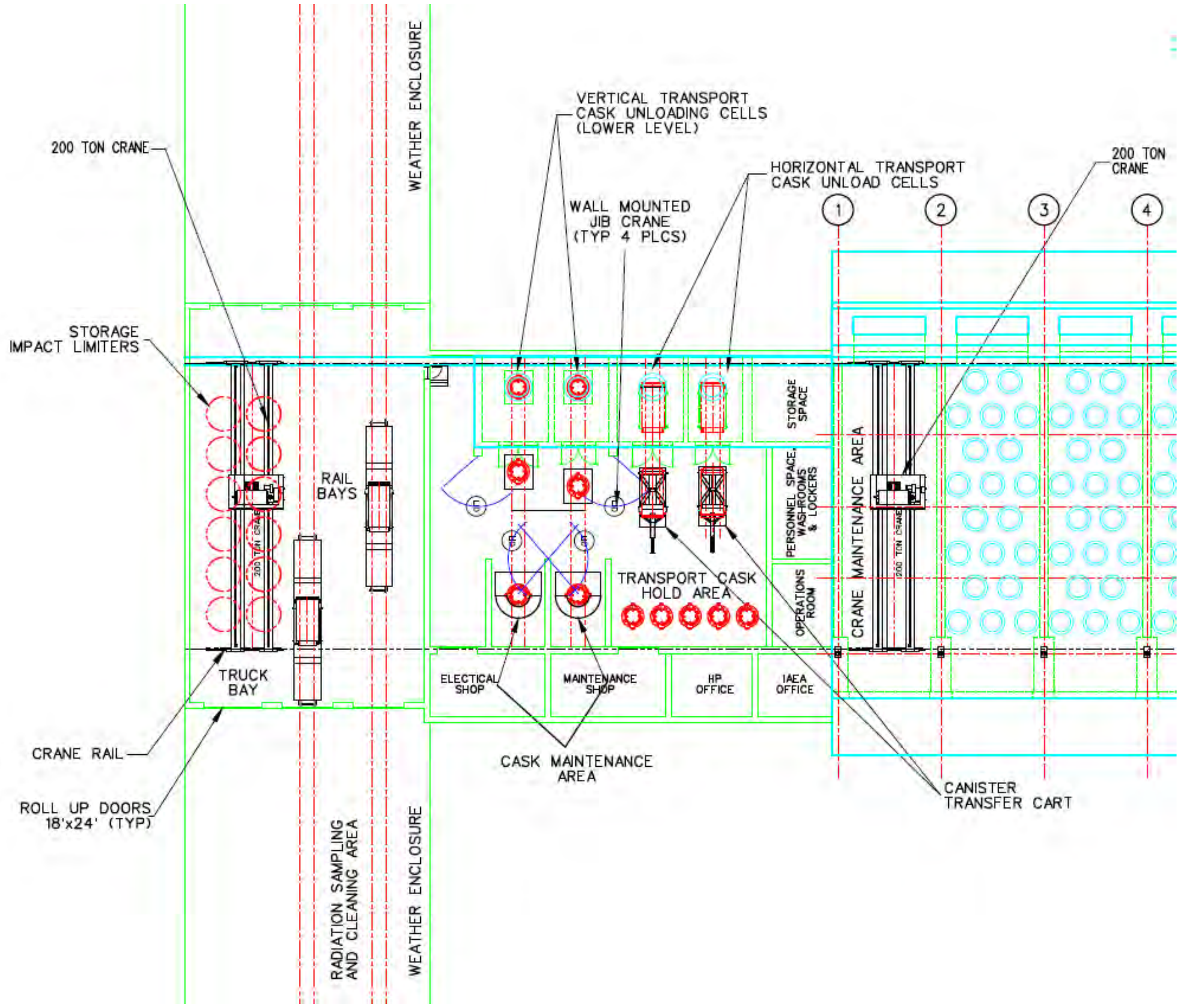
The CHB for this report has been designed with 2 rail bays, 2 truck bays, 4 vertical canister transfer cells, 2 - 200 ton single-failure-proof overhead bridge cranes, laydown area for impact limiters and other Transport Cask equipment, staging area for transport casks and office area. The CHB would be a reinforced concrete structure with thick walls to protect all Transport Casks, STAD canister, overpacks, and cask-handling equipment from the effects of earthquakes, tornado winds, tornado-generated missiles, fire, and explosions. The throughput would be 3,000 MTHM/yr with one shift per day, 5 days per week.

The CHB would be a reinforced concrete structure with thick walls to protect all SNF casks, canisters, overpacks, and cask-handling equipment from the effects of earthquakes, tornado winds, tornado-generated missiles, fire, and explosions.

The CHB is designed to provide radiological shielding during canister transfer operations. Four vertical type canister transfer cells with reinforced concrete walls shield workers from dose intensive operations.

Figure C3-15 shows a plan view of the CHB for the a vault using an integral CHB.

Figure C3-15
Cask Handling Building for an Integral CHB



C3-3.5 Protected Area

The PA is an area within the OCA large enough to encompass the ISF rail yards, CHB, and S-BGV. The PA consists of two physical barriers: (1) a security fence and (2) a nuisance fence separated by a 20-foot wide isolation zone. Within the isolation zone is an intrusion detection system that provides ground surveillance to detect any unauthorized entry into the PA. Assessment of unauthorized intruders is provided by illumination along the PA perimeter and throughout the storage area and a CCTV system, consisting of both fixed and pan-tilt-zoom cameras to monitor activities around the PA boundary from the security building.

The PA is surrounded by a passive vehicle barrier system (VBS) that is constructed of large concrete blocks to prevent any vehicles from getting near the PA boundary. The VBS is physically placed at a distance so that a pressure wave from a vehicle-born improvised explosive device cannot affect the storage containers or cask handling activities. Active VBSs are placed at large gates that accommodate railcars loaded with SNF transport casks or vehicles to prevent any unauthorized entry. These VBSs can be lowered once the railcar or vehicles are inspected and cleared for entry.

Security equipment is typically powered from normal off-site power supplies. However, in the event of a loss of off-site power, an Uninterruptable Power System (UPS) consisting of batteries would be used to provide seamless power to all electronic security equipment. The UPS and site lighting would be backed up by an emergency diesel-powered generator located within the PA.

Bullet resistant enclosures would be situated at strategic locations within the PA to provide protected locations for security force personnel during a security event.

C3-3.6 Site Support Buildings

The ISF will need to include a number of support buildings. An administration building will need to be constructed to house managers, admin staff, engineers, document storage, licensing records, health physics personnel, radiological records, training rooms, etc.

A security/access control building will need to be constructed to house security personnel, security managers, the Central Alarm Station, safeguards information, etc. The building can be sited at the PA boundary to provide access control for personnel entering the storage area. This most likely would include a badging station, explosion detectors, metal detector to monitor persons entering the secured area, x-ray machines to monitor materials brought onsite, and turnstiles delineating the PA boundary.

A warehouse/maintenance building will need to be constructed to stockpile materials shipped to the ISF for overpack fabrication, pad construction, inspection equipment, general supplies, etc. This structure could also double as a maintenance building for general maintenance activities as well as transporter and canister handling equipment maintenance.

The ISF would also include a number of other features such as fire protection, potable water, sanitary drains, electrical power and distribution, and communications.

C3-4.0 ISF Expansion

C3-4.1 Storage Area Impact

ISF expansion of another 5,000 MTHM would require constructing another vault building. Construction of the second 5,000 MTHM storage area should be performed outside of the ISF PA to facilitate construction activities without stressing security. Once the new vault is constructed, the PA would be expanded to encompass it. Of course, this type of construction would mean that a significant corridor would need to be placed between vaults to ensure that construction workers receive as low as reasonably achievable (ALARA) radiation dose from the existing loaded storage units.

The PA would be expanded in size as required to accommodate the new vault including fencing, intrusion detection system equipment, number of CCTV cameras and yard illumination.

Electrical power would need to increase to accommodate a larger ISF to account for the additional security, lighting and temperature monitoring equipment. The Uninterruptable Power System (UPS) and security backup emergency diesel-powered generator would need to be able to accommodate the new loads of the larger site.

C3-4.2 Increased Throughput Impact

The CHB constructed for the ISF has a throughput capacity of 3,000 MTHM/yr which may be adequate for an expanded ISF. Even if the throughput requirements are increased to 4,500 MTHM/yr, the CHB would not need to be enlarged. Rather, adding a second shift would effectively double the throughput of the building to 6,000 MTHM.

To expand the ISF, the rail yards, Administration Building Warehouse/Maintenance Building, Security/Access Control Building and other site infrastructure utilities may not require many modifications. Backup electrical power service for illumination and security of the larger storage area, additional security guards, increased CCTV and intrusion detection equipment are a few modifications that may be required to accommodate the expanded ISF. For example, these additions may require a larger Security/Access Control Building for the additional security personnel as well as a larger CAS for the increased CCTV coverage. However, if the ISF is designed with the understanding of the expanded ISF that doubles the vault storage area, then these items could easily be included in the initial design.

C3-4.3 Modular Expansion Impact

For vault storage, the only modular construction would be the construction of an additional vault. No other changes in the ISF would be modular type design.

C3-5.0 Performance of Structures, Systems and Components

C3-5.1 Structural and Seismic Evaluation

Structural evaluations of storage alternatives must be performed to demonstrate compliance with the applicable requirements given in 10CFR72, sections 72.122 and 72.236. These sections specify structural performance requirements for facilities and storage systems to maintain the confinement, subcriticality, radiation shielding, and retrievability of the SNF under normal operations, off-normal conditions, accident scenarios, and design basis natural phenomena conditions. For all dual purpose canister storage systems associated with the NPP's, the STAD canister is designated as the confinement boundary. The types of structural loading that the STAD canister must be qualified to withstand at the ISF include deadweight, internal pressure, and thermal expansion under normal and off-normal environmental conditions, handling loads, drops and tip-over events, explosive overpressure events, and design basis natural phenomena events including fires, floods, tornado winds, and earthquakes. NUREG-1536 (Reference C3-5) provides guidance for the types of structural modeling, structural analysis methods, NRC-approved design codes and standards for different storage system components, loading conditions and combinations, and acceptance criteria for performing the structural analyses required to meet the functional requirements described above.

Structural evaluations of the below grade meet the requirements described above will be performed and documented in safety analysis reports accepted by the NRC during licensing. The environmental, accident and natural phenomena loading conditions, structural models, material properties, and displacement, force, and stress-strain results documented in these evaluations are used as a basis of comparison, to make judgments regarding the seismic performance of storage and transportation systems under the general loading conditions defined for the and Expanded ISFs.

The below and above grade vaults are long, narrow concrete structures, which house bare STAD canisters inside ventilated, shielded concrete storage bays. The design of the two vaults are identical, except the above grade vault has the top of its base slab located at grade, and the below grade vault has the top of the operating floor located at grade. The seismic response of the below grade vault will be less than that of the above ground vault, due to the building embedment. Parametric studies of similar structures indicate that partial embedment on the order of 0.2 times the building width reduces the peak seismic demands by as much as 67%. Therefore, the results from the seismic analysis of the above ground vault envelops the loads the below grade case and will be used as representative of the seismic performance of the below grade vault, accounting for the reduced demand by decreasing the reinforcing bar by 10%. Also, there are five optional floor plans for each vault, which are differentiated based on storage orientation (all vertical, all horizontal, and both vertical and horizontal) and transport cask unloading location (integral to vault, and in a separate CHB). In order to limit the number of evaluations to something manageable, the vault with the highest projected cost - the above ground vault with all vertical storage and a separate CHB for cask unloading – will be seismically evaluated, and the results will be used to develop the base cost estimate. Approximate costs for other options will be determined by accounting for the design differences between options, where significant.

C3-5.2 Thermal Evaluation

Thermal evaluations of storage alternatives must be performed to demonstrate compliance with the applicable requirements given in 10CFR72, sections 72.122 and 72.236. The basic thermal performance requirement is for the storage system to provide adequate passive cooling capacity to maintain the temperatures of storage system materials below their allowable limits. NUREG-1536 provides guidance for the types of thermal modeling, the basic heat transfer considerations, the environmental conditions and accident scenarios, and temperature acceptance criteria for the fuel cladding that the thermal evaluations must address.

Thermal evaluations of the vault storage meet the requirements described above and will have been performed in Safety Analysis Reports accepted by the NRC during the licensing process. The environmental conditions, thermal models, and temperature results documented in these evaluations are used in this report as a basis of comparison, to make judgments regarding the thermal performance of storage and transportation systems under the conditions defined for the ISFs.

In the below grade vault, vertical STAD canister and horizontal STAD canister in lift frames are stored standing up on the base slab which forms the floor of the vault. The vault storage area is isolated from the occupied portions of the building one floor above by the five foot thick operating floor. Shield plugs in the operating floor can be removed to provide access for placement and retrieval of STAD canisters using an overhead crane, but when installed, isolate the atmosphere in the vault storage area from the area above the operating floor. The vault storage area is separated into individual bays which span the width of the building by concrete walls which isolate one bay from the next. A concrete stack runs the length of the storage area along one side of the building. Each bay has an air intake on one side of the building and is open to the stack on the other side. When STAD canisters are placed in a bay and the shield plugs are re-installed, the decay heat from the STAD canisters warms the air in the bay which exhausts upward through the stack. The air exiting the stack is replaced by air flowing into the bay through the air intake on the opposite side of the bay. Thus, a self-sustaining cross flow develops which passively removes the decay heat from the bay. The amount of airflow through the bay is a function of the heat generated in the bay, the stack height and flow area, and the frictional losses along the flow path. Since the stack height and flow area are fixed parameters, the airflow reaches an equilibrium state where the differential pressure due to the stack effect is balanced by the frictional losses along the flow path. After equilibrium is reached, the flow is self-regulating, in that any decrease in the decay heat generated will reduce the driving pressure due to the stack effect, which reduces the flow and associated frictional losses until the system reaches a new equilibrium state at a lower value of flow. Therefore, the thermal performance of a vault is evaluated by determining if the decay heat generated induces sufficient airflow to maintain STAD canister temperature limits within their allowable values.

A computational fluid dynamics (CFD) analysis of the proposed design for the vault has been performed to verify whether or not the vault design meets required thermal performance criteria. In the analysis, a thermal model of a representative section through a vault bay was developed, including the air intake, the vault storage area with the base slab below and operating floor above, a row of (8) STAD canisters, and the exhaust stack. Appropriate (symmetric) boundary conditions were coded along the cut faces of the model. Adiabatic boundary conditions were coded on concrete surfaces, which is a good first approximation since concrete is a rather poor conductor of heat. Each STAD canister was assigned a decay heat generation rate of 25kW, which is conservative with respect to the maximum heat load for SNF from any plant. The heat from each STAD canister was distributed to the model as a uniform heat flux over the canister sides and top. This uniform distribution is conservative compared to the actual STAD canister heat flux distribution, where a shield plug at the top of the STAD canister blocks almost all heat transfer through the top, directing it preferentially out the sides. The environmental temperature considered in the analysis was the extreme accident temperature of 120°F, given in section.

The CFD solver calculated the steady-state temperature distribution, the airflow rates, and the heat fluxes throughout the model, based on the input geometry, the constitutive properties of air, and the applied heat loading described above. Both convection and radiation heat transfer mechanisms were considered in solving the model. Temperature contour plots of the model were generated, as well as tabular results, including the projected maximum centerline cladding temperature, maximum stainless steel temperatures, and maximum concrete temperatures. These results are discussed in the following sections.

C3-5.3 Radiological Evaluation

The exposures to radiation for the workers in this study are based on historical radiological source terms from dry storage systems at commercial nuclear plants. They demonstrate differences among the various options rather predict actual doses. STAD canisters would be licensed for newer spent fuel with different source terms that are yet to be determined. Therefore, doses from STAD canisters were not calculated for this study. However, some factors are noteworthy:

1. Due to self-shielding within the STAD canister, the contact dose rate for any size STAD should be within a few percent of the contact dose rate for other size STAD canister

containing the same SNF. Since worker dose rates are determined by a few activities that involve close contact with the canister, the worker exposures for the different STAD canisters are based primarily on the handling activities required not the STAD type.

2. The activities necessary to transfer a STAD canister from a rail car to the storage location are assumed in this report to be similar to the commercial DPC processes in order to provide a comparison of the different storage alternatives. STAD canisters and their associated transport, transfer casks or storage units can be designed to remove or reduce dose intensive activities. For example, attaching and removing lifting lugs to DPCs is major contributor to dose rates. An integral lifting means on the STAD will remove considerable worker dose.
3. STAD transport casks, transfer casks and storage units can be designed with improved shielding. STAD canisters are smaller and lighter than commercial DPCs, so the various shielding casks can be heavier without impact shipping or lifting infrastructure. This can reduce worker dose without changes to rolling stock or cask handling equipment.
4. STAD handling systems can be designed with more automated features reducing manual activities next to the canister. Commercial systems were developed as temporary expedients to address fuel pool capacity and life extension issues. STAD canisters can be designed to improve performance based on industry experience.
5. Study #1 determined that worker doses are fairly consistent for all alternative storage methods. Study #2 determined that the method used to process incoming SNF shipments has a greater effect on worker dose than the storage method – more automation can substantially reduce worker doses versus manual handling. Similar results are likely to be the same with STAD canisters.
6. Offsite doses to the public are expected to be very similar to commercial systems. Offsite dose is a function of shielding and distance. Doses to the public can be reduced with additional system or building shielding and/or by increasing the distance from the storage area to the Owner Controlled Area boundary. The exposures to radiation for the workers due to STAD canister processing at the ISF cannot be assessed at this time since they are still conceptual. It is very difficult to predict what overall dose would be received for each canister transfer let alone the dose each worker receives.

C3-5.4 Design Life, Aging and Maintenance Evaluation

Currently, storage systems may be designed for 40 to 100 years but are only permitted to be licensed for a period of up to 40 years. Prior to February 16, 2011, when 10 CFR 72.42, Duration of License; Renewal (for specific licenses) and 10 CFR 72.240, Conditions for Spent Fuel Storage Cask Renewal (for CoCs for general licenses) were revised to permit 40 year license durations, licenses and CoCs for storage systems had a duration of 20 years.

Therefore, most of the storage systems currently in place at ISFSIs are only licensed for 20 years. In order to renew the license and extend the storage license, NUREG-1927, Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance (Reference C3-6) requires that an applicant demonstrate that the effects of aging will be adequately managed so that the intended safety function(s) of SSCs identified in the scope of license renewal will be maintained consistent with the current licensing basis for the period of extended operation. The NRC requires that an Aging Management Review (AMR) be performed that consists of identifying ISFSI components relied on for safety, susceptible materials in those components, environments to which susceptible materials are exposed, aging effects, and development of an aging management program to manage aging effects and protect against degradation of age-sensitive components (such as by performing inspections of age-sensitive components and replacing components that have a life expectancy of less than the license renewal period being requested in the anticipated environment). For purposes of this section, it is assumed that the original license has a duration of 20 years and a 40 year license extension is requested, so the licensee will need to demonstrate the in-scope component materials will withstand the anticipated environment for a total of 60 years, or provide a plan for replacing age-sensitive components at acceptable analyzed intervals. If the initial license was for a 40 year duration, and a 40 year license extension is requested, then the licensee would need to demonstrate the in-scope components are acceptable for 80 years in the storage environment.

The AMR identifies susceptible materials of subcomponents in the in-scope SSCs that are exposed to environments that could cause age-related degradation. The functions required to be performed by the individual subcomponents of these in-scope SCCs (determined in previous section) are identified in applicable tables in this AMR section of the application for ISFSI license renewal.

The NRC's Draft Revision 1 of NUREG-1927, Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel (Reference C3-7 explains the purpose of the AMR as follows:

> "The purpose of the aging management review (AMR) is to assess the proposed aging management activities (AMAs) for structures, systems, and components (SSCs) determined to be within the scope of renewal. The AMR addresses aging mechanisms and effects[1] that could adversely affect the ability of the SSCs (and associated subcomponents) from performing their intended functions during the period of extended operation. The reviewer should verify that the renewal application includes specific information that clearly describes the AMR performed on SSCs within the scope of renewal."

> Footnote 1 in this quotation states: "In order to effectively manage an aging effect, it is necessary to determine the aging mechanisms that are potentially at work for a given material and environment application. Therefore, the aging management review process identifies both the aging effects and the associated aging mechanisms that cause them."

The license application needs to include an Aging Management Review (AMR) that is comprised of four major steps that are summarized as follows:

1) <u>Identification of In-Scope Subcomponents Requiring AMR</u>

Structures, Systems and Components (SSCs) within scope of the aging evaluation are identified as those that are 1) classified as important to safety (ITS), and 2) classified as not important to safety but whose failure could prevent an ITS function from being fulfilled. SSCs within scope are determined based on review of the ISFSI Materials License, ISFSI SAR, ISFSI Tech Specs, NRC's SER for the ISFSI and docketed licensing correspondence related to the ISFSI.

2) <u>Identification of Susceptible Materials and Applicable Environmental Conditions</u>

For the subcomponents of in-scope SSCs that require AMR, the next step is identification of materials of construction susceptible to aging and the environments (e.g., temperature, pressure, radiation, wet vs. dry, etc.) that these materials normally experience.

3) <u>Identification of Aging Mechanisms and Effects Requiring Management</u>

Aging mechanisms potentially at work on susceptible materials in given environments (corrosion, cyclic stress fatigue, radiation embrittlement, etc.) are determined. Aging effects (manifestation of aging mechanisms) of material / environment combinations are compiled from industry and plant operating experience through use of industry standards and reference materials, including metallurgical literary references. During this process, the question is asked, are the potential aging effects credible given the identified materials and environmental conditions of storage?

4) <u>Determination of Activities Required to Manage Aging Effects (Aging Management Program)</u>

The final step in the AMR process involves the determination of activities necessary to manage the effects of aging. If the aging review determines that certain materials may not be able to support a 60 year life in the environment that they are normally exposed to, then an Aging Management Program needs to be established for those subcomponents to extend the life of the storage system to 60 years (such as by performing inspections of vulnerable subcomponents to determine their continued adequacy, or replacing the associated subcomponent at specified intervals).

Each of the four above steps of the AMR process are discussed in more detail in the following paragraphs.

C3-5.4.1 Aging Management Review (AMR)

Identification of In-Scope Components Requiring AMR

During this first step in the AMR process, the in-scope SSCs are further reviewed to identify and describe the subcomponents that support the SSC intended function. Intended functions of interest in the AMR are sub-criticality control, pressure boundary integrity (confinement of fission products), heat transfer, structural support (protection against environmental phenomena) and shielding. The subcomponents and associated intended functions are identified by reviewing the applicable current licensing basis (CLB) documentation sources.

SSCs and associated subcomponents within the scope of renewal fall into the following scoping categories:

(1) They are classified as important to safety (ITS), as they are relied on to do one of the following functions:

i. Maintain the conditions required by the regulations, specific license, or CoC to store spent fuel safely;

ii. Prevent damage to the spent fuel during handling and storage; or

iii. Provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

These SSCs ensure that important safety functions are met for (1) confinement, (2) radiation shielding, (3) sub-criticality control, (4) heat-removal capability, (5) structural integrity, and (6) retrievability of the spent fuel.

(2) They are classified as not important to safety but, according to the design bases, their failure could prevent fulfillment of a function that is important to safety.

Subcomponents that perform or support any one of the identified intended functions will require an AMR. Those components that do not support an intended function can be excluded from further evaluation in the AMR with supporting justification. The SSCs within the scope of renewal are screened to identify and describe the subcomponents with intended functions. It should be recognized that SSC subcomponents may degrade by different modes, or have different criteria for evaluation from the overall component (i.e., different materials or environments). SSC subcomponents may also have different performance requirements for support of safety functions.

Typically, the application for ISFSI license renewal tabulates the results of the AMR, including a listing of subcomponents and the intended function provided by each subcomponent, material group, environment, aging effects requiring management and aging management activity required. The AMR results tables also identify subcomponents that did not support the SSC intended function and are not subject to AMR, with justification for their exclusion.

Identification of Materials and Environments

The second step of the AMR process requires the identification of materials of construction and the environments to which these materials are exposed, for the in-scope ISFSI subcomponents that require an AMR. Environmental data may include: temperature, wind, relative humidity, relevant atmospheric pollutants and deposits, exposure to precipitation, marine fog, salt, or water exposure, radiation field (gamma and neutron), the service environment (e.g., embedded, sheltered, or outdoor), and gas compositions (e.g., external: air; internal: inert gas such as helium).

The environments to which components are exposed play a critical role in the determination of potential aging mechanisms and effects. A documentation review is required to quantify the environmental conditions to which the in-scope ISFSI SSCs are continuously or frequently exposed (conditions known to exist on a recurring basis). As noted in the next section, normal operating conditions are evaluated and not accident conditions.

The storage system FSAR is typically used to determine the intended functions and materials of construction for cask subcomponents that are in-scope of ISFSI license renewal. Additional documentation, drawings and technical reports should also be reviewed during the AMR process as required to obtain clarifications of the intended materials of construction and functions performed by in-scope ISFSI subcomponents.

The specific materials of construction for the cask and fuel assembly subcomponents requiring aging management review are identified and evaluated for the renewal period.

Identification of Aging Mechanisms and Effects Requiring Management

The third step in the AMR process is to identify the aging mechanisms and effects requiring management. A Material Aging Effects Report (MAER) is typically prepared for the storage system in question. This report needs to include aging mechanisms and effects that theoretically occur as well those that have actually occurred based on industry operating experience and the ISF operating experience for the appropriate material and environmental conditions. Aging effects are presented in this report in terms of material / environment combinations.

The environments considered in the evaluation are the environments that the subcomponents normally experience. Environmental stressors that are conditions not normally experienced, such as accident conditions, or that may be caused by a design problem, are considered event-driven situations and are not characterized as sources of aging. Such event-driven situations would be evaluated at the time of event, with corrective actions taken as necessary.

To effectively manage an aging effect, it is necessary to determine the aging mechanisms that are potentially at work for a given material and environment application. Therefore, the AMR process needs to address both the aging mechanisms as well as the aging effects. Selective mechanisms are only applicable under certain environmental conditions, such as high temperature or moisture. The identified aging mechanisms need to be characterized by a set of applicable conditions that must be met for the mechanism to occur and/or propagate. The application for ISFSI license renewal should identify aging effects based on the aging mechanisms potentially at work in given environments on susceptible subcomponent materials (e.g., general corrosion of carbon steel, stress corrosion cracking and crevice and pitting corrosion of stainless steel, cyclic stress fatigue, radiation embrittlement, boron depletion of neutron absorber due to neutron flux, etc.). Aging effects (manifestation of aging mechanisms) of material / environment combinations are compiled from industry and plant operating experience through use of industry standards and reference materials, including metallurgical literary references. The majority of aging mechanisms will be extracted from industry documents (including NRC and EPRI) for the applicable material/environmental combinations. For instance, the EPRI Dry Cask Characterization Project final report (Reference C3-8) is a primary source for fuel assembly and dual purpose canister internals aging mechanism evaluations. During the process of identifying aging effects the question is asked, are the potential aging effects credible given the identified materials and environmental conditions of storage?

Appendix D, Table D-1, of NUREG-1927 lists potential aging effects and possible aging mechanisms that should be considered. This information is also available from a table in Appendix C to NUREG-1557 (Reference C3-9). Section 3.4 of the NRC's Draft Revision 1 of NUREG-1927 lists the following sources of information that should be used to identify applicable aging mechanisms and effects:

- site maintenance, repair, and modification records;

- corrective action reports, including root cause evaluations;
- lead system inspection results ;
- maintenance and inspection records from ISFSI sites with similar SSC materials and operating environments;
- industry records;
- applicable operating experience outside the nuclear industry;
- applicable consensus codes and standards;
- NRC reports;
- other applicable guidance for determining if an aging mechanism or effect should be managed for the period of extended operation.

Section 3.4 of the NRC's Draft Revision 1 of NUREG-1927 gives the following examples of potential aging mechanisms and effects that may be identified by reviewing the above sources of information:

> "(1) cracking or loss of strength as a result of cement aggregate reactions in the concrete, (2) cracking or loss of material as a result of freeze-thaw degradation of the concrete (requires the presence of moisture combined with temperatures below freezing), (3) reinforcement corrosion and concrete cracking as a result of chloride ingress, (4) accelerated corrosion of steel structures and components and stress corrosion cracking of austenitic stainless steels as a result of atmospheric deposition of chloride salts."

Other possible aging effects are settlement, change in dimension and change in material properties. The applicant for renewal of an ISFSI specific license is not required to take further action if an SSC is determined to be within the scope of renewal but is found to have no potential aging effects for the period of extended operation.

The AMR defines two methods for addressing potential aging mechanisms and effects: TLAA and AMP, both of which are discussed below.

Time-Limited Aging Analyses to Identify Aging Effects

Time-Limited Aging Analyses (TLAAs) are calculations performed to evaluate the life of subcomponents of interest. TLAAs are defined in Section 3.5 of the NRC's Draft Revision 1 of NUREG 1927, as those licensee calculations and analyses that meet all of the following criteria:

1. Involve SSCs important to safety within the scope of the specific-license renewal, as delineated in Subpart F of 10 CFR Part 72;

2. Consider the effects of aging;

3. Involve time-limited assumptions defined by the current operating term;

4. Were determined to be relevant by the specific licensee or certificate holder in making a safety determination;

5. Involve conclusions or provide the basis of conclusions related to the capability of SSCs to perform their intended safety functions (analyses that do not affect the intended functions of the SSCs are not considered TLAAs); and

6. Are contained or incorporated by reference in the design bases.

The defined operating term should be explicit in the analyses. Simply asserting that the SSC is designed for a service life or ISFSI life is not sufficient. The assertions must be supported by a calculation, analyses, or testing that explicitly include a time limit.

Examples of TLAAs described in the past applications for license renewal are: 1) cracking of the dual purpose canister (DPC) shell due to fatigue from thermal cycling; 2) change in material properties of epoxy seal in DPC penetration (for temperature monitoring) due to exposure to ionizing radiation; and 3) canister basket poison plate depletion of boron due to increase in neutron exposure for 60 year life of ISFSI; change in properties of boron-polyethylene front access cover plate due to increased radiation exposure over 60 year life of ISFSI.

Operating Experience Review for Process Confirmation

Typically, the potential aging effects for the ISFSI material and environment combinations are compiled from common industry and plant operating experience through the use of accepted industry standards and reference materials, including various metallurgical literary references relating specific materials and environments to aging effects and mechanisms.

A further review of industry and plant specific operating experience for the ISFSI should also be performed in order to confirm the applicability of previously identified potential aging mechanisms/effects and to identify any aging effects not previously addressed.

The application for ISFSI license renewal will need to address the various observations resulting from ISFSI operating experience with the storage systems. This information should address items specific to the subcomponents. As an example; Dominion identified corrosion of lid bolts and outer metallic lid seals on some of the TN-32 casks stored at the Surrey ISFSI. The corrosion was most prevalent on the down-slope side of the cask lid. As part of the investigation, the bolt torque was checked and it was determined that there had been no torque relaxation. The corrosion of the lid bolts and outer metallic seal was the result of external water intrusion in the vicinity of the lid bolts and outer metallic seal. It was determined that the connector seal for the electrical connector in the cask protective cover was leaking due to improper installation of the connectors. Therefore, this degradation was not related to aging.

Activities Required to Manage Aging Effects (Aging Management Program)

The fourth and final step in the AMR process involves the determination of the aging management activities or Aging Management Programs (AMPs) to be credited or developed for managing the effects of aging. Section 3.6 of Draft Revision 1 of NUREG-1927 states the following regarding AMPs:

> "Aging management programs (AMPs) monitor and control the degradation of SSCs within the scope of renewal so that aging effects will not result in a loss of intended functions during the period of extended operation. An AMP includes all activities that are credited for managing aging mechanisms or effects for specific SSCs. An effective AMP prevents, mitigates, or detects the aging effects and provides for the prediction of the extent of the effects of aging and timely corrective actions before there is a loss of intended function."

> "Aging management programs should be informed, and enhanced when necessary, based on the ongoing review of both site-specific and industry-wide operating experience. Operating experience provides direct confirmation of the effectiveness of an AMP and critical feedback for the need for improvement. As new knowledge and data become available from new analyses, experiments, and operating experience, licensees and CoC holders should revise existing AMPs (or pertinent procedures for AMP implementation) to address program improvements or aging issues."

Section 3.6.1 of the NRC's Draft Revision 1 of NUREG-1927 indicates that an AMP should contain the following elements:

1. Scope of Program,
2. Preventive actions,
3. Parameters monitored or inspected,
4. Detection of aging effects,
5. Monitoring and trending,
6. Acceptance criteria,
7. Corrective actions,
8. Confirmation process,

9. Administrative controls, and
10. Operating experience.

To the extent practical, existing ISFSI programs and/or activities are credited for the management of aging effects that could cause a loss of component intended function during the license renewal period. If the aging review determines that certain materials cannot support the required life in the environment that they are normally exposed to, then an AMP needs to be established for those subcomponents to extend the life of the storage system for the duration of the license renewal period (such as by performing inspections of vulnerable subcomponents to determine their continued adequacy, or replacing the associated subcomponent at specified intervals). The application for ISFSI license renewal will need to discuss development of AMPs to address subcomponents whose materials are susceptible to age-related degradation. AMPs for ISFSIs typically include visual inspections of cask external surfaces to look for signs of deterioration due to corrosion (general corrosion for carbon steel subcomponents due to moist atmospheric environments, and crevice and/or pitting corrosion for stainless steel surfaces that are subject to wetting), and monitoring area radiation levels, airborne and smearable contamination levels at selected areas of the ISFSI. Increased radiation / radioactivity levels could indicate reduction in shielding, breach of the SFA cladding or loss of cask confinement. Inspection intervals are established at frequencies that provide confidence the subcomponents of interest will not experience age-related adverse effects that could prevent them from performing their intended functions.

C3-5.5 Postulated Accident Evaluation

The accident descriptions to follow refer to "Design Event" levels given in ANSI/ANS 57.9, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)" (Reference C3-10). As explained in NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" (Reference C3-11): "Off-normal events are those expected to occur with moderate frequency or once per calendar year. ANSI/ANS 57.9 refers to these events as Design Event II. Accident events are considered to occur infrequently, if ever, during the lifetime of the facility. ANSI/ANS 57.9 subdivides this class of accidents into Design Event III, a set of infrequent events that could be expected to occur during the lifetime of the ISFSI, and Design Event IV, events that are postulated because they establish a conservative design basis for SSCs important to safety. The effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches, are considered to be accident events."

Section 15.4 of NUREG-1567 identifies acceptance criteria for accidents, including the following:

> Criticality: 10 CFR 72.124(a) requires that the spent fuel must be maintained in a subcritical condition (i.e., keff $\leq$ 0.95), and at least two unlikely, independent and

concurrent or sequential changes must be postulated to occur in the conditions essential to nuclear criticality safety before a nuclear criticality accident is possible (double contingency).

Confinement: 10 CFR 72.128(a)(3) requires that the systems important to safety must be evaluated, using appropriate tests or by other means acceptable to the Commission, to demonstrate that they will reasonably keep radioactive material confined under credible accident conditions. NUREG-1567 states that “A breach of a confinement barrier is not acceptable for any accident event.”

Retrievability: 10 CFR 72.122(l) requires that “Storage systems must be designed to allow ready retrieval of spent fuel, high-level radioactive waste, and reactor-related GTCC waste for further processing or disposal.” The definition for Important to Safety SSCs in 10 CFR 72.3 includes those features whose function is to “provide reasonable assurance that spent fuel, high-level radioactive waste, or reactor-related GTCC waste can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.”

Instrumentation: 10 CFR 72.122(i) states in part: “Instrumentation systems for dry storage casks must be provided in accordance with cask design requirements to monitor conditions that are important to safety over anticipated ranges for normal conditions and off-normal conditions. Systems that are required under accident conditions must be identified in the Safety Analysis Report.”

Radiological Dose: 10 CFR 72.104 requires that for off-normal events, annual dose equivalent to any individual located beyond the controlled area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as a result of exposure to planned discharges to the general environment, direct radiation from operations of the ISFSI, and cumulative radiation from uranium fuel cycle operations in the area. 10 CFR 72.106(b) requires that any individual located at or beyond the nearest controlled area boundary must not receive a dose greater than 5 rem to the whole body or any organ from any design basis accident.

C3-5.5.1 Earthquake

An earthquake is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. Earthquakes are associated with faults in the upper crust of the earth’s surface. SSCs classified as Important to Safety are required to be designed to resist the effects of the design basis ground motion in accordance with the requirements of 10 CFR 72.122(b).

10 CFR Part 72.103, "Geological and Seismological Characteristics for Applications for Dry Cask Modes of Storage on or after October 16, 2003," gives requirements for determining Design Earthquake Ground Motion (DE) at sites for spent fuel storage, and NRC Regulatory Guide 3.73 "Site Evaluations and Design Earthquake Ground Motion for Dry Cask Independent Spent Fuel Storage and Monitored Retrievable Storage Installations" (Reference C3-12) provides guidance on applying the rules in Part 72.103 to arrive at an acceptable DE that satisfies the requirements of Part 72. In general, Part 72.103 allows use of a standardized DE described by an appropriate response spectrum anchored at 0.25 g for sites in non-seismically-active areas east of the Rocky Mountain Front and requires a seismic evaluation elsewhere. For the ISF, a probabilistically-derived horizontal ground acceleration design value of 0.75 g is used to provide a bounding value for all potential ISF sites.

Depending on the specific storage system, the acceptance criteria for seismic design may include some or all of the following:

i. The loaded overpacks will not impact each other during the DE event.

ii. The loaded overpack will not slide excessively.

iii. The loaded overpack will not tip over.

iv. The confinement boundary will not be breached.

C3-5.5.2 Tornado Winds and Missiles

The storage system is designed to withstand loads associated with the most severe meteorological conditions, including extreme winds, pressure differentials, and missiles generated by a tornado. The extreme design basis wind is derived from the design basis tornado. Extreme wind is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. The design basis tornado loading is defined for a given region (identified in NRC Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants" (Reference C3-13). It is conservatively assumed that Region I design basis tornado loading applies to the ISF. The design basis tornado wind loading for this region is defined as a tornado with a maximum wind speed of 230 mph and a 1.2 psi pressure drop occurring at a rate of 0.5 psi/sec.

In addition, the ISF is designed to withstand the effects of tornado-generated missiles that could be created by the passage of the tornado as identified in Regulatory Guide 1.76, Rev. 1, and discussed in Sections 3.3.2 (Tornado Loadings) and 3.5.1.4 (Missiles Generated by Extreme Winds) of NUREG 0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, (Reference C3-14). Tornado-driven missiles, identified in the following table, are assumed to impact a storage system in a manner that produces maximum damage. Regulatory Guide 1.76, Rev. 1, identifies the following design basis missiles for Region I:

Missile Description	Total Mass (lbs)	Velocity (mph)
Automobile	4000	92
Schedule 40 Pipe (6. 625 inch-diameter), 15 ft long	287	92
Solid Sphere (1-inch-diameter)	0.147	17.7

Alternatively, there are other spectrums of tornado missiles that have been accepted by the NRC (for which spent fuel storage systems have been qualified) that could be reviewed for potential use at the ISF.

The combination of tornado winds with the most massive missile, a 4,000 lb automobile traveling at 92 mph, needs to be evaluated in accordance with Section 3 of NUREG-0800, since it tests storage system stability. The wind tip-over moment is applied to the cask at its maximum rotation position following the worst-case missile strike. The schedule 40 pipe missile tests the capacity of the storage system to resist penetration, and the small solid steel sphere missile tests barrier openings. Canister tip-over potential and reduction in shielding from tornado-borne projectile strikes are evaluated.

C3-5.5.3 Flood

Flooding is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. 10 CFR 72.122(b)(2) requires that SSCs Important to Safety must be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lighting, hurricanes, floods, tsunami, and seiches, without impairing their capability to perform safety functions.

The probable maximum flood (PMF) is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions.

Other potential sources of flooding considered include effects from an upstream dam breach, seismically induced flooding due to landslides in the site area, occurrence of the PMF with superposition of wind-wave activity on nearby water bodies, flooding due to tsunamis and ice conditions, and flooding from local intense precipitation.

The storage system is designed to withstand severe flooding, including pressure and water forces associated with deep and moving flood waters. Resultant loads on the storage system consist of buoyancy effects, static pressure loads, and velocity pressure due to water velocity. The flood is assumed to deeply submerge the storage system without the canisters collapsing, buckling, or allowing water in-leakage under the hydrostatic pressure from the flood; and, where applicable, without sliding and cask tip-over occurring. Full blockage of the air inlets by submergence in water is addressed by emergency action planning based on the individual storage device's capabilities. For more information on blockage of air inlets, refer to "Loss of Cooling Accident."

C3-5.5.4 Fire

Fire is classified as a human-induced Design Event IV as defined in ANSI/ANS-57.9. The storage system must withstand elevated temperatures due to a fire event. Credible fires from various sources such as buildings, fuel spills, and other combustible materials are analyzed for heat flux using standard analysis techniques from NFPA and compared with acceptance criteria for the storage system. Possible effects from wildfires are also evaluated, addressing fire magnitude, duration, propagation, and heat generation.

Fires analyzed include those that could occur during transfer operations and those affecting stored fuel. Canister integrity during smaller fire events is qualified by heat flux comparison with a bounding fire for which an approved canister analysis has been performed. Fires affecting structures in which transfer operations and storage of fuel occur have been analyzed to ensure continued reliability.

Based on the analyses, the canister storage and transfer systems meet the general design criteria of 10 CFR 72.122(c), which states that SSCs Important to Safety must be designed and located so that they can continue to perform their safety functions effectively under credible fire exposure conditions. A fire at the ISF (or a wildfire adjacent to the ISF Protected Area) would not cause a radioactive release, even if no credit were taken for firefighting by personnel or for automatic fire detection/suppression systems.

C3-5.5.5 Explosion

Explosion is classified as a human-induced Design Event IV as defined in ANSI/ANS-57.9. The ISF storage system must withstand loads due to an explosion. Potential onsite (internal and external) and offsite explosions are investigated.

NRC Regulatory Guide 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plants" (Reference C3-15) provides guidance for calculating safe distances from transportation routes, based on calculated overpressures at various distances created by postulated explosions from accidents. The Regulatory Guide indicates that overpressures which do not exceed 1 psi at the storage site would not cause significant damage and states:

> under these conditions, a detailed review of the transport of explosives on these transportation routes would not be required.

In lieu of the 1 psi overpressure selected in the Regulatory Guide, the overpressure for which the storage system is qualified (e.g., 3 psi, 5 psi, 10 psi) is used to determine the safe standoff distance from the source of the potential explosion.

There are no credible internal explosive events since the canister is comprised of non-explosive materials, it is filled with an inert gas, and materials are compatible with the operating environment. Likewise, the mandatory use of the protective measures at the ISF site to prevent fires and explosions and the absence of any need for an explosive material during canister loading, transfer, and unloading operations eliminates the scenario of an onsite explosion as a credible event, except during canister movement, which requires investigation of any nearby onsite-specific potential explosive sources.

Any design basis overpressure from an offsite explosion (e.g., from a truck, rail car, barge, fuel storage tank, munition depot, chemical processing plant, petroleum refinery, natural gas facility, etc.) must be investigated and, if credible, analyzed.

Based on the analyses, the canister storage and transfer systems meet the general design criteria of 10 CFR 72.122(c), which states that SSCs Important to Safety must be designed and located so that they can continue to perform their safety functions effectively under credible explosion exposure conditions.

C3-5.5.6 Canister Drop Accident

NUREG-1567 considers both off-normal cask drops and more severe cask drop accidents. With regards to an off-normal event involving a cask drop that is less than the design allowable lift height, Section 15.5.1.1 of NUREG-1567 states:

> The drop of the confinement cask at less than design allowable height is one of the hypothetical off-normal scenarios that the applicant must evaluate. The evaluation must show that the cask integrity and fuel spacing geometry are not compromised if the cask is dropped from a relatively low height. It must also show that the cask will continue to store fuel safely after such a drop.

For accident conditions, the hypothetical drop of a storage canister is classified as Design Event IV as defined by ANSI/ANS-57.9.

With regards to a cask drop accident, Section 15.5.2.2 of NUREG-1567 identifies the key items to be evaluated assuming a cask drop, including decelerations, evaluation of calculated stress intensities against the allowable stresses identified in the applicable code, evaluation of buckling stability for each component of the cask confinement subjected to compressive loading, and evaluation of deformation of cask internal members that could contribute to fuel assembly spacing geometry (for criticality concerns). While this guidance may apply to transport casks that do provide a confinement boundary, it may not be directly applicable to the transfer casks that are used to transfer canisters from transport casks to storage overpacks. In addition, in the event the spent fuel cask handling systems meet the NRC criteria for “single-failure-proof” (discussed in Section 9.1.5 of NUREG-0800, "Overhead Heavy Load Handling Systems”), the NRC does not require a cask drop accident to be postulated nor its consequences to be analyzed.

Within the alternative storage systems, there are two basic drop situations, with certain potential drop accidents that necessitate analysis and/or operational restrictions, as identified below:

(1) Handling inside the transport cask receiving structure and canister transfer facility:

- A drop of the transport cask with its impact limiters removed prior to being handled by the single-failure-proof crane requires analysis and operational restrictions.
- Transport cask drop accidents (other than above) and transfer cask drop accidents are precluded by the use of a single-failure-proof handling system, consisting of an overhead crane whose main hoist meets the NRC criteria for a single-failure-proof crane (i.e., NUREG-0554, "Single-Failure-Proof Cranes for Nuclear Power Plants," (Reference C3-16) or ASME NOG-1, "Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)" (Reference C3-17)).

(2) Handling outside the transport cask receiving structure and canister transfer facility (i.e., during cask transfer to the storage area):

- For some transport systems, it is required to assume a cask drop and, therefore, the lift height is limited to a height that has been fully analyzed for the assumed cask drop accident (e.g., TransNuclear transfer casks and NAC storage casks).
- For other systems (e.g., Holtec Vertical Cask Transporter), the lifting apparatus is required to meet ANSI N14.6 "American National Standard for Radioactive Materials

- Special Lifting Devices for Shipping Containers Weighing 10 000 Pounds (4500 kg) or More" (Reference C3-18) criteria for allowable stresses and to have redundant drop protection features. For these systems, no height restriction is required for cask transfer.

- For potential drops when a canister is being handled, lifts of canisters loaded with spent nuclear fuel are performed using single-failure-proof equipment and lifting devices that comply with the stress limits of ANSI N14.6 and have redundant drop protection to render an uncontrolled lowering of the payload non-credible, so a canister drop accident need not be postulated.

C3-5.5.7 Loss of Cooling Accident (LOCA)

The various spent fuel storage system alternatives all use passive air cooling of the dry storage canisters. The cooling air flow is driven by natural convection with cool air at ambient temperature entering the canister storage area near the bottom of the canister(s), rising as it is heated by the relatively hot outer surface of the canister(s), and exiting the canister storage area by outlet vents above the canisters.

It is credible that various types of debris or materials such as plastic sheets could blow into the canister storage area and block some of the air vents, thus reducing air flow and causing canister temperatures and spent fuel cladding temperatures to increase. Complete blockage of the air inlet ducts is classified as a Design Event IV accident condition as defined by ANSI/ANS-57.9. In addition, partial blockage of the cooling air vents is also analyzed as an off-normal condition, such as by assuming that one-half of the area of the air inlet vents is blocked. Thermal analyses are required to be performed to determine storage system temperatures, including canister and spent fuel cladding temperatures. The resulting temperatures are compared with the applicable temperature limits for off-normal (partial vent blockage) and accident or faulted conditions (complete blockage of air inlets).

Typically, the thermal analysis of partial blockage determines final steady-state temperatures of the storage system that result from the reduced air flow rates and these are compared to the maximum allowable temperatures of the various components to demonstrate the storage system can acceptably withstand this partial blockage with no operator actions.

For the accident condition involving postulated complete blockage of the air inlet vents, a transient thermal analysis is performed that determines the time at which temperatures of storage system components that are classified as Important to Safety exceed their maximum allowable temperatures for accident conditions, such as spent fuel cladding, canister confinement or canister basket material temperatures. This time is then used to establish a conservative required frequency of inspection or temperature monitoring of the storage system that ensures temperature limits will not be exceeded. This inspection frequency is then incorporated into the Technical Specifications that govern operations of the spent fuel storage facility. With regard to this inspection frequency requirement, Section 6.5.1.1 of NUREG-1567 recommends the following paragraph be incorporated into the Technical Specifications, based on results of the accident analysis that assumes complete blockage of air inlet vents:

> Surveillance requirement: Periodic surveillance will be performed to ensure that there is no blockage of cooling air flow in the heat removal system. This surveillance [typically based on the minimum time for stored material cladding or other material Important to Safety (e.g., shielding) to reach a threshold temperature in the event of a complete blockage occurring immediately following the prior surveillance.

Surveillance of cooling air vents for blockage can either be performed by visual inspection of the air inlet and outlet vents or by checking temperature readings of the temperature monitoring system to verify temperatures for each storage system are within allowable limits. ISFSIs frequently use temperature detectors mounted in the outlet vents to assess the performance of the natural convection air cooling system, since blockage of cooling air vents will result in reduced airflow with consequent increased air outlet temperatures. For ISFSIs with a relatively large number of storage systems, temperature monitoring is used to ensure worker doses are ALARA, since significant dose can be accrued by workers performing routine inspections of storage system air vents (typically, daily inspections are required), which requires the inspector to be in the near vicinity of the spent fuel storage systems.

C3-5.5.8 Off-Normal and Extreme Environmental Temperature

Ambient environmental temperatures must be evaluated for periods during which handling operations take place and also for the long time period over which spent fuel storage will occur. The various cask vendors have analyzed their products for intended use typically to cover all ISFSI sites in the continental U.S.

Minimum short-term temperature limitations are specified to ensure a sufficient safety margin against brittle fracture during handling. A typical operational limitation would be around 0°F, so it is likely that operational temperature restrictions imposed for other reasons may be more stringent (e.g., the minimum allowable temperature for crane operation). The lower bound off-normal temperature limit, applicable to long-term storage, is typically about -40°F.

Storage systems are designed for upper bound off-normal temperatures in the range of about 100°F, which is assumed to persist for a sufficient duration to allow the system to reach thermal equilibrium. The accident condition extreme ambient environmental temperature is typically around 125°F. Upper bound limitations are based on analyses that determine the storage system's ability to properly convey heat away from the spent fuel. Extreme environmental temperature is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9.

C3-5.5.9 Lightning

Lightning is classified as a natural phenomenon Design Event III as defined in ANSI/ANS-57.9. Because a direct lightning strike of a storage SSC is a credible occurrence, the ISF storage system must withstand loads due to lightning, with the canister retaining its confinement integrity, and thereby preventing release of radioactivity. The lightning path to ground will vary, depending on the storage system alternative; but for each alternative, the canister will be protected from the effects of a lightning strike. (For example, for above-ground vertical cask storage, the steel shell of the overpack will convey the lightning to ground and the lightning will not pass through the canister, which is surrounded by the cask steel, so the strike will not affect the canister integrity.) Therefore, no offsite doses would result from this accident.

C3-5.5.10 C3 Alternative Applicability

Each of the previously discussed design basis accidents for each alternative will be slightly different since each of the alternatives' design handles each of the accidents differently. The below list summarizes the applicability of the accidents with regard to Alternative C3 (S-BGV):

1. Seismic (C3-5.5.1)

   The S-BGV will be designed to adhere fully to the requirements discussed in C3-5.5.1. A site-specific seismic analysis will be performed to ensure all components of the S-BGV are qualified for the chosen ISF site's seismic input. Since the vault is underground, the seismic input will be reduced.

2. Tornado Winds / Missiles (C3-5.5.2)

   The S-BGV will be qualified to the NRC's tornado winds and missile criteria as discussed in C3-5.5.2. While the vault itself and the exhaust stack will be required to withstand the tornado wind forces, the building around the vault will employ blow-off panels to reduce the wind forces on the superstructure. The vault structure and exhaust chimney will be analyzed to withstand the design basis tornado missiles as discussed in C3-5.5.2

3. Flooding (C3-5.5.3)

   The S-BGV will comply with all flooding requirements discussed in C3-5.5.3. Flooding is of particular concern with an underground vault system as the air inlet vent is below grade and will thus be required to have a drain system in order to preclude the vent from being completely blocked by water.

4. Fire (C3-5.5.4)

   The S-BGV will comply with all fire protection requirements discussed in C3-5.5.4, including fire sources from nearby buildings, fuel spills, combustibles, and wildfires. This will also include internal fuel spills as the cask handling building will be integral with the vault and will required to be analyzed to ensure the STAD canisters' shell temperature is not exceeded during a design basis fire.

5. Explosion (C3-5.5.5)

   The S-BGV will comply with all explosion requirements from NRC Reg Guide 1.91 as discussed in C3-5.5.5. Since the vault would be underground, the exposure of the STAD canisters to an explosion risk is minimal.

6. Canister Drop Accident (C3-5.5.6)

   The S-BGV system will comply with all canister drop requirements from NUREG-1567 as discussed in C3-5.5.6. All material handling systems will be classified as Single-Failure-Proof as and thus not require postulation of a dropped STAD canister.

7. Loss of Cooling Accident (LOCA) (C3-5.5.7)

   The S-BGV will comply with all LOCA requirements discussed in C3-5.5.7. The S-BGV alternative will use passive air cooling of the STAD canisters through an underground vault. The cooling air flow is driven by natural convection with cool air at ambient temperature entering the vault near grade level, passing through the vault, and rising as it is heated by the relatively hot outer surface of the canisters, and exiting the vault by outlet vents through a building chimney.

8. Off-Normal and Extreme Environmental Temperature (C3-5.5.8)

   The S-BGV will comply with all off-normal and extreme environment temperature requirements discussed in C3-5.5.8 based on the environmental maximum temperatures at the ISF site.

9. Lightning (C3-5.5.9)

   The S-BGV will comply with all lightning requirements discussed in C3-5.5.9.

C3-5.6 Licensing Evaluation

C3-5.6.1 Overview

10 CFR Part 72 governs ISFSI licensing. There are two options for licensing an ISFSI: (1) a specific license and (2) a general license. However, 10 CFR 72.210 only authorizes the use of a general license at a power reactor site with a 10 CFR Part 50 or 10 CFR Part 52 license. Since it is not anticipated that the ISF would be located at the site of a nuclear power plant, the ISF would be governed by a 10 CFR Part 72 specific license.

The process for obtaining a specific ISFSI license is similar to that for obtaining a license for a fuel cycle facility under 10 CFR Part 70 (Reference C3-19). The applicant submits a License Application (LA) in accordance with 10 CFR 72.16 that includes the information required by 10 CFR 72.22 through 10 CFR 72.28. The primary documents comprising the LA are as follows:

- Safety Analysis Report (SAR) that assesses safety of the storage system and the ISFSI facility (used as basis for NRC preparation of the Safety Evaluation Report)
- Environmental Report (used as basis for NRC preparation of the Environment Impact Statement)
- Proposed Technical Specifications
- Quality Assurance (QA) program
- Decommissioning Plan
- Emergency Plan
- Security Plan

C3-5.6.2 Licensing Process

Upon receipt of the application, the NRC establishes a docket number and reviews the application for completeness. If the application is deemed complete, the NRC prepares and publishes a notice of docketing in the Federal Register (FR). The notice of docketing identifies the site of the ISF and includes either a notice of hearing or a notice of proposed action and opportunity for hearing pursuant to 10 CFR 72.46. 10 CFR 72.46 provides the regulations governing the hearing process with references to 10 CFR Part 2 (Reference C3-20), as appropriate.

The NRC will request a hearing upon the notice of docketing if a statute specifically requires it, or if they believe it to be in the public interest, notwithstanding any requests for hearing submitted by parties who believe they having standing in the licensing action. 10 CFR 2.105(a)(7) specifies that if the NRC is not required by statute to conduct a hearing and does not find that a hearing is in the public interest, a notice of proposed action is instead published in the FR.

The notice of proposed action includes the time frame for any person whose interest may be affected by the proceeding to file a request for a hearing or a petition for leave to intervene if a hearing has already been requested. A request for hearing on a 10 CFR Part 72 License Application must be submitted, with the contentions upon which the hearing would be litigated, within 60 days of the notice of docketing. It is worth noting that if the 10 CFR Part 72 specific license applicant is incorporating design information pertaining to a previously NRC-certified spent fuel storage cask design by reference into the application, any hearing held to consider the application will not include any cask design issues pursuant to 10 CFR 72.46(e).

If any requests for hearing are received on the notice or proposed action, the NRC will establish an Atomic Safety Licensing Board (ASLB) to review the hearing requests and contentions for admittance. For the ASLB to admit a contention and grant a hearing, the requestor needs to have standing in the proceeding per 10 CFR 2.309(d), and at least one contention must meet the criteria in 10 CFR 2.309(f). The NRC may also permit discretionary intervention of someone not having standing under the strict requirements of 10 CFR 2.309(e).

Admitted contentions are litigated through a review of documents submitted by the petitioner and may require court testimony and/or documents to be submitted by the applicant, at the discretion of the ASLB. Hearings would take place after issuance of the Final Environmental Impact Statement (EIS). The ASLB may decide to start the hearings prior to completion of the NRC staff Safety Evaluation Report (SER). A license would not be granted until all hearings are completed and the contentions resolved in favor of the applicant. At that point, the Director of the Office of Nuclear Material Safety and Safeguards would request Commission authorization to issue the license pursuant to 10 CFR 72.46(d). While petitioners may appeal the resolution of contentions in the courts, the license would likely be issued without awaiting resolution of those court appeals.

The NRC reviews the application for a specific license, and generally there are several rounds of requests for additional information.

10 CFR 72.42, Duration of License; Renewal, paragraph (a) states the following:

> Each license issued under this part must be for a fixed period of time to be specified in the license. The license term for an ISFSI must not exceed 40 years from the date of issuance. The license term for an MRS must not exceed 40 years from the date of issuance. Licenses for either type of installation may be renewed by the Commission at the expiration of the license term upon application by the licensee for a period not to exceed 40 years and under the requirements of this rule.

C3-5.6.3 License Application

NUREG-1571, "NRC Information Handbook on Independent Spent Fuel Storage Installations," (Reference C3-21) summarizes key requirements for a specific license application, as follows:

- Siting Evaluation Factors (10 CFR 72 Subpart E)—The site characteristics, including external, natural, and manmade events, that may directly affect the safety or the environmental impact of the ISFSI.
- General Design Criteria (10 CFR 72 Subpart F)—Applies to the design, fabrication, construction, testing, maintenance, and performance requirements for structures, systems, and components important to safety.
- Quality Assurance (10 CFR 72 Subpart G)—The planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service as applied to design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, modification, and decommissioning.
- Physical Protection (10 CFR 72 Subpart H)—The detailed plans for ISFSI security.
- Personnel Training (10 CFR 72 Subpart I)—The program for training, proficiency testing, and certification of ISFSI personnel who operate equipment or controls important to safety.

The NRC will review the specific license application and complete an evaluation of potential environmental impacts of the ISFSI in accordance with the National Environmental Policy Act of 1969 (NEPA), as amended (Reference C3-22). The NRC will prepare an EIS in accordance with 10 CFR Part 51 (Reference C3-23). Following its safety review and resolution of comments, the NRC issues a Materials License along with its SER and final EIS. The SER describes the conclusions of the staff's safety review based on the applicant's SAR and assesses the technical adequacy of the ISFSI and the spent fuel storage system(s).

Safety Analysis Report

The level of effort associated with preparation of the ISFSI SAR for a specific license can be reduced considerably by taking advantage of the permission granted in 10 CFR 72.46(e) to select storage systems with SARs that have been reviewed and approved by the NRC (with Certificate of Compliances [CoC] having been issued for the storage systems), or storage systems that are currently undergoing NRC review per 10 CFR 72, Subpart L. 10 CFR 72.46(e) states: "If an application for (or an amendment to) a specific license issued under this part incorporates by reference information on the design of a spent fuel storage cask for which NRC approval pursuant to subpart L of this part has been issued or is being sought, the scope of any public hearing held to consider the application will not include any cask design issues." With this approach, the NRC will focus its review on site-specific issues and storage system/site interface issues. This helps streamline the specific licensing process. Should the applicant select a storage system that has neither been reviewed and approved by the NRC nor is currently undergoing NRC review, the NRC must review information associated with the proposed spent fuel storage system as part of the specific license application, which would extend the review time.

Detailed guidance as to information that needs to be included in the ISFSI SAR that is submitted with the license application is provided by Regulatory Guide 3.48, "Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage)" (Reference C3-24). Additional information to enable the NRC staff review in accordance with NUREG-1567 should also be included in the SAR, along with information from any applicable NRC Interim Staff Guidance (ISG). The SAR for the ISF will need to identify and evaluate each of the storage systems that will be used at the ISF to store SNF. For each individual system, the ISF SAR will need to address the following key topics specified in the NUREG-1567 Standard Review Plan:

- General description of the storage system
- Design criteria
- Structural evaluation
- Thermal evaluation
- Shielding evaluation
- Criticality evaluation
- Confinement evaluation

- Material evaluation
- Operating procedures
- Acceptance tests and maintenance program
- Radiation protection (occupational exposures, public exposures, ALARA measures)
- Accident analyses
- Operating controls (technical specifications)
- Quality assurance
- Decommissioning

The previous topics are addressed in the storage system vendors' SARs that have been approved by the NRC for general and specific ISFSI licenses; these documents can be incorporated by reference into the ISF SAR. It is envisioned that the ISF SAR will have a main body that describes and analyzes the ISF design and generic operations, with a separate appendix that serves as the SAR for each individual storage system. The ISF SAR will benefit in that it will primarily use SNF storage systems that have already been licensed under the provisions of 10 CFR Part 72, Subpart K, and have existing Final Safety Analysis Reports (FSARs) that have been approved by the NRC and can be referenced. A specific revision of the vendors' FSARs would need to be chosen for incorporation into the ISF ISFSI SAR. Changes to the vendors' FSARs thereafter would not automatically be incorporated by reference into the ISF SAR, but would require evaluation by the ISF license applicant for incorporation.

The SAR would include descriptions of the safety analyses and other technical evaluations for the ISFSI in each SAR chapter, incorporating by reference any required information for the storage system designs. The format and content would coincide with the chapters of the SRP in NUREG-1567 and any applicable Interim Staff Guidance documents amending that guidance. Formatting the ISFSI SAR in this manner sets the stage for a more efficient NRC technical review because the SRP establishes the format and content template for the NRC's SER.

Environmental Report

The Environmental Report (ER) that is submitted with the License Application is prepared to address the requirements of Subpart E of 10 CFR Part 72, Siting Evaluation Factors, and Subpart A of 10 CFR Part 51, National Environmental Policy Act - Regulations Implementing Section 102(2), using the guidance provided in NRC NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs," (Reference C3-25). The ER contains the following key topics:

- General description of the proposed activities and discussion of need for the facility

- Site interfaces with the environment, including geography, demography, land use, ecology, climatology, hydrology, geology and seismology, historical and cultural features, and background radiation levels.
- Description of the facility, including appearance, construction, operations and effluent control
- Environmental effects of facility construction and operation, including transportation of radioactive material, and effects of decontamination and decommissioning
- Environmental effects of accidents involving radioactive materials, including transportation accidents
- Proposed environmental monitoring programs
- Economic and social effects of facility construction and operation, including cost benefit analysis
- Facility siting (site selection process) and design alternatives
- Environmental approvals including federal, state, and local regulations and permits

As noted above, the NRC will need to prepare a complete EIS for the ISF based on the ER submitted by the licensee, in accordance with 10 CFR Part 51 requirements.

C3-5.6.4 Licensing of Alternative Systems

The approach to licensing of the different alternative systems would be the same as that described above. Key differences involve the information that would be required in the License Application are discussed in the following paragraphs.

Alternative 3, Below Grade Vault Storage

Like Alternative A4, the use of a vault does away with pad storage and places each STAD canister into a large self-contained vault module structure. The ISFSI at the former Fort St. Vrain (FSV) reactor site in Colorado uses the Modular Vault Dry Store (MVDS) system in an above grade vault. The FSV MVDS has a specific license (Materials License No. SNM-2504), so has its own SAR and Technical Specification, with analyses specific to the FSV site. Vaults are designed as robust, hardened reinforced concrete structures. The vaults are typically laid out so that the STAD canisters can be hung from a concrete floor much like a test tube rack, with a support stool at the bottom of each canister that the canister bottom rests upon. An overhead bridge crane can access the entire vault storage area and provides the means to move STAD canisters from the unloading point where STAD canisters are removed from transport casks to the STAD canister's designated storage position. At the FSV MVDS, a canister handling machine is used for movement of a STAD canister between the transport cask unload port and the port on the operating floor through which the canister is lowered into its storage vault. Following loading of a STAD canister into its storage vault, a large shield plug is placed in the port in the operating floor to provide radiation shielding above the top of the canister, to attenuate dose rates so workers can walk across the operating floor and not receive significant doses. Cooling of the STAD canisters is accomplished by means of passive chimney stack effect from an inlet vent in the front of the vault through the STAD canister storage area to a chimney where air exits from the back of a vault, with chimney height designed to draw the desired air flow. The entire facility is enclosed with walls and a roof. The vault width is typically limited to the span of the bridge crane and can be of various lengths to accommodate the desired storage capacity.

The below grade vault would be designed so that the operating floor would be at ground level and the STAD canister storage area would be below grade. The below grade vault positions the STAD canisters so that direct radiation from the sides of STAD canisters is shielded by the ground.

All operations such as STAD canister offload from a transport cask, STAD canister transfer from the transport cask to the canister handling machine and from the canister handling machine into the STAD canister storage vault, are performed within the MVDS structure if the CHB is integral to the vault or performed in the CHB if it is a standalone structure.

There are significant licensing challenges with Alternative 4 since vault storage for large commercial STAD canisters is still conceptual, unlike other storage methods. In order to store 450 STAD canisters, a vault 100 ft. in width would need to be about 800 ft. long increasing the complexity of the structure. The canisters (fuel storage containers) at FSV are carbon steel cylinders one-half inch thick, 16 ft. long but only 18 inches diameter, so designed for a single column of fuel (which at FSV consists of 6 graphite blocks stacked end-to-end). The FSV canister lid is 1.5 inches thick bolted to the body of the canister by means of 24 one-half inch diameter steel bolts, sealed with double metal O-rings. For this type of canister closure, leakage of the gas inside the canister to atmosphere is a credible event, so the FSV SAR assumes leakage of fission products past the O-ring seals in what is termed the "Maximum Credible Accident in the FSV SAR." For storage of commercial STAD canisters with their redundant seal welded closure lids, accidents involving leakage of STAD canisters are not credible and not required to be postulated or analyzed in the ISF SAR.

Canisters stored in the existing FSV vaults do not have the increased performance issues such as weight and thermal loading characteristic of commercial STAD canisters. Since the performance capability of a vault is unknown, rigorous analyses will need to be performed to show that the STAD canisters could be safely stored in a vault, the vault could perform as desired, and the results of these analyses described in the ISF SAR. These analyses would include structural, thermal and radiation shielding analyses of the STAD canisters in vault storage. In addition, it is considered that criticality analyses will be necessary since there is potential for neutrons from one STAD canister reaching adjacent STAD canisters due to the relatively close packing of canisters stored in vaults with no intervening materials that would shield and attenuate the neutron flux.

Most STAD canister in existing dry fuel storage systems will have a much higher decay heat rate than the FSV canisters. When canisters were initially loaded into the FSV MVDS, a canister containing average decay heat fuel elements would have 330 watts total decay heat. In contrast, a single commercial STAD canister could have up to 100 times this heat release rate, or on the order of 33 kW. The thermal study performed by CB&I for this report determined that heat removal using the chimney stack effect for natural convection cooling in a vault is limited to thermal outputs much less than the licensed limits in existing commercial STAD canister storage methods. STAD canisters with hotter SNF may not be able to be adequately cooled in a vault which would require longer pool cooling prior to storage. This would need to be addressed in the ISF SAR and the ISF licensing process.

Design and licensing tasks would be extensive and involve significantly more time than the other storage methods. As noted above, the FSV MVDS is operated under a specific ISFSI license and the FSV SAR cannot be referenced under as is the case for FSARs associated with an ISFSI general license. In addition, the NRC has never licensed a vault system for storing large commercial STAD canisters. The performance characteristics of a vault would need to be licensed as part of the ISF Specific License which would require considerable development in the ISF SAR costing more NRC review time.

Like Alternatives 2 and 3, this vault storage method would involve obtaining a single license for systems owned by four different spent fuel storage system vendors. Therefore, the use of this method could incur proprietary conflicts that could be difficult to resolve, possibly involving legal issues.

Similar to the standardized overpacks in Alternative 2 and the UMAX VVMs in Alternative 3, the vault is a one-size-fits-all system that would have to accommodate all the different STAD canister sizes. Each floor opening would likely be the same diameter which would require some means to keep smaller STAD canisters secure. This would necessitate design and fabrication provisions for the smaller STAD canisters such as shims or spacers to ensure they would not rattle around during an earthquake. These features would need to be evaluated in the ISF SAR, reviewed by the NRC and certified in the licensing proceedings.

C3-5.7 Security Evaluation

The purpose of security at an interim storage facility is to protect the SNF against acts of radiological sabotage and theft or diversion that could lead to an unreasonable risk to the health and safety of the public. The ISF must meet the requirements of 10 CFR 73 (Reference C3-26). In order to accomplish this task the ISF will need to establish and maintain a physical protection system which consists of the following:

- Controlled access
- Visual surveillance
- Detection and assessment of unauthorized individuals
- Adversary response
- Measures to resistance to explosive devices

The physical security systems must be designed to protect against loss of control of the ISF.

Controlled Access

Controlled access is maintaining control of a clearly demarcated area and isolation of the material or persons within it. The features at the ISF that afford controlled access include a fenced Owner Controlled Area (OCA) typically established at the property boundaries, vehicular access gates into the property where security personnel can verify the identification and authorization of all persons and vehicles entering the site, a Protected Area (PA) with two physical barriers (fences or structures) designed to thwart physical intrusion, and personnel and vehicle access barriers into the PA. All of these features are required of the ISF regardless of the storage system utilized. However, the area required may vary depending on the storage alternative used thus affecting the OCA and PA boundary distances.

For S-BGV storage, the PA will need to be approximately 250 acres in size which would require a perimeter fence roughly 2- 3 miles in length.

Visual Surveillance

Visual surveillance is establishing security guards around the PA who maintain an unobstructed view of the PA at all times. This may be performed from bullet resistant enclosures (BREs) placed around the PA which are occupied by security guards, closed circuit TV (CCTV) cameras that are viewed by security guards at the Central Alarm Station (CAS) or secondary Alarm Station (SAS) or security guards patrolling the site. BREs are situated at strategic locations within the PA to provide protected locations for security force personnel during a security event.

Vault storage has a major advantage in that few exterior and interior BREs or cameras are required to maintain line of sight around and within the vault storage area. Since all storage is within a secured building, there are very few security risks to the canisters.

Detection and assessment of unauthorized individuals

Detection of unauthorized individuals is maintained by establishing an intrusion detection system that can detect unauthorized penetration through the isolation zone located between the PA boundary fences and tamper devices on doors and equipment that send an alarm to alert security staff when the PA or security equipment is breached. Assessment of unauthorized individual is established by illuminating the PA with sufficient lighting that security guards can adequately determine the nature of the intrusion either visually or by the CCTV system. The intrusion and CCTV systems are monitored continually by security staff at the CAS and SAS.

S-BGV storage will not affect the detection and assessment capabilities as the initial PA will encompass the size of the expanded S-BGV.

Adversary Response

Adversary response is the ability to prevent or delay the attempted theft of SNF or radiological sabotage by armed response personnel. Adversary response also includes the ability to provide timely communication to a designated response force such as the local law enforcement agency whenever necessary.

S-BGV storage will not affect adversary response since this is primarily a function of the vault building, security staff and communication equipment.

Measures to resistance to explosive devices

Resistance to explosive devices intended to disable security personnel or radiological sabotage is maintained by establishing engineered barriers that prevent such explosions from damaging SNF storage containers or disabling security personnel. Engineered barriers consist of access points designed to slow the speed of approaching vehicles by turns, speed humps, or a serpentine design and a vehicle barrier system (VBS) made of thick reinforced concrete walls or heavy steel portal gates that are installed at a prescribed distance from the SNF or cask handling activities. The VBS prevents entry of vehicle-borne explosive devices. Its distance from the storage area minimizes the impact of an explosion if one were to occur.

Resistance to explosive devices is also maintained by passing persons through explosive and metal detectors, checking all hand-carried items by X-ray machines and inspecting all vehicles and deliveries by security personnel.

Since the entire system is within a below-grade vault within a secured building, the S-BGV storage system has excellent resistance to high explosion pressure waves. This ability enables the VBS to be placed much closer to the PA which effectively reduces the overall footprint of the PA.

C3-6.0 Summary

In general, the use of STAD canisters offers a standardized method of SNF storage. Use of a single storage system simplifies handling equipment and operations. Only one storage overpack and concrete storage pad design is required which reduces analyses, design and licensing time.

There are also dry cask storage industry issues that can be resolved with STAD canisters. Elimination of the need to affix a temporary lifting lug to the top of the STAD canister would significantly reduce dose rates. Also the transport cask could be designed with lids on either end so that traditional canister transfer is eliminated and the canister could be directly transferred into a storage unit from the transport cask.

STAD canisters represent a marked increase in the number of units required due to the reduced capacity from current commercial storage systems. This increase will affect the cost as a whole. The size of the STAD canister also factors into the cost – the more canisters required, the higher the costs. The use of a 4-pack container for the small STAD canisters helps defray some of the storage issues as well as cost. STAD canisters contain fewer assemblies than a current DPCs being used in the industry. This means that for a given amount of effort less MTHM will be placed into storage. Instead of 450 overpacks as in other commercial alternatives, the STAD canister forces the use of between 500 and 1000 overpacks, depending on the size STAD canister ultimately selected. The storage pad would need to be substantially larger for STAD canister alternatives and the cost could be a significant penalty.

STAD canisters do not currently exist and no design standard has been accepted. Moreover, the NRC has not reviewed STAD canisters yet in any licensing application, so it is not clear what the final configuration of STAD canisters will be. Likewise, there eventually will need to be a transfer system developed that takes SNF assemblies out of their NRC-licensed canisters and to repackage them in STAD canisters. The process for doing this is undefined, it is not licensed, and there are no facilities available to make this exchange.

In summary, the pros and cons of this alternative in comparison with the other alternative using STAD canisters is listed from the highest most significant impact to the lowest least significant impact are as follows:

<u>Pros</u>

- Since the STAD canister storage is effectively indoors, the vault alternative may provide a more controlled environment than other Alternatives. The STAD canisters are stored within the building largely away from the effects of weather (although there is some effect since the cooling air is drawn into the building past the STAD canisters. The STAD canisters would likely feel humidity changes during wetter weather and temperature changes between summer and winter).

- The ground provides radiation shielding and protection from design basis explosions.
- The below grade vault is lower than an above grade vault which improves its resistance to earthquakes. The overhead crane is lower so it won't exert the loads on the structure during an earthquake.
- A vault shields STAD canisters from view, easing security concerns.
- A vault removes the possibility of STAD canister tipover caused by an earthquake or other postulated accidence since the STAD canisters are locked into position within the vault.

Cons

- A vault is a large nuclear structure impacted by potential seismic, construction, cost issues typically associated with large nuclear projects. In order to store 500 to 1,000 STAD canisters, a vault 100 feet in width would need to be between 1,000 and 2,000 feet long increasing the complexity of the structure.
- The thermal characteristics of STAD canisters are unknown. FSV canisters have relatively low energy densities compared to STAD canisters containing much hotter newer SNF. The study performed by CB&I determined that heat removal using stack effect in a vault is limited. Newer STAD canisters with hotter SNF may not be able to be adequately cooled in a vault which would require longer pool cooling prior to storage.
- Vault throughput is limited due to cask handling congestion in the storage hall.

C3-7.0 References

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APPENDIX C4

STUDY 3 – ALTERNATIVE DRY STORAGE METHODS FOR STANDARD SNF CANISTERS

Alternative 4 – Above Grade Vault Using STAD Canisters (S-AGV)

Alternative 4 – Above Grade Vault Using STAD Canisters (S-AGV)

C4-1.0 Description of Storage Alternative

Alternative 4 evaluates the use of above grade, air-cooled vaults to store Standardized Transportation, Aging and Disposal (STAD) canisters. Internationally, air-cooled vaults have been used to store spent nuclear fuel (SNF) and high level wastes from reprocessing plants. In the USA, air-cooled vaults have been used or proposed to store non-LWR SNF. An air-cooled vault design was chosen to house the SNF from the decommissioned Fort St. Vrain (FSV) High Temperature Gas Cooled Reactor.

The concept of STAD canisters were developed by the U.S. Department of Energy (DOE) as a means of addressing the variability of the spent nuclear fuel (SNF) storage issues that confronted the Department when faced with consolidating the SNF at a single location. In addition to the multitude of dual-purpose canister dry storage designs that have been deployed at reactor sites, several dry canister-based dry storage systems were not designed for transportation and may not be able to be certified for transport, even if packaged in a transport cask.

The DOE has decided to consider three STAD canister designs which are shown in **Figure C4-1**. Small STAD canisters (4 PWR/9 BWR) and medium STAD canisters (12 PWR/32 BWR) are specified by the DOE "Performance Specification for Small and Medium Standardized Transportation, Aging and Disposal Canister Systems," (Reference C3-1). Large STAD canisters (21 PWR/44 BWR) are specified by DOE "Transportation, Aging, and Disposal Canister System Performance Specification," (Reference C3-2).

All three of these STAD canister sizes are considered together in this alternative at the Interim Storage Facility (ISF). The variations in size will be called S-BGVa for the small STAD canister, S-BGVb for the medium STAD canister, and S-BGVc for the large STAD canister.

The small STAD canisters can be handled individually but that would greatly increase the amount of canister transfers required at the ISF. The small STAD canisters can also be packed in a 4-pack STAD multi-can storage container so that they can be handled as a single package, resulting in 16 PWR assemblies or 36 BWR assemblies being shipped in the multi-can storage container.

Figure C4-1
Proposed STAD Canister Sizes

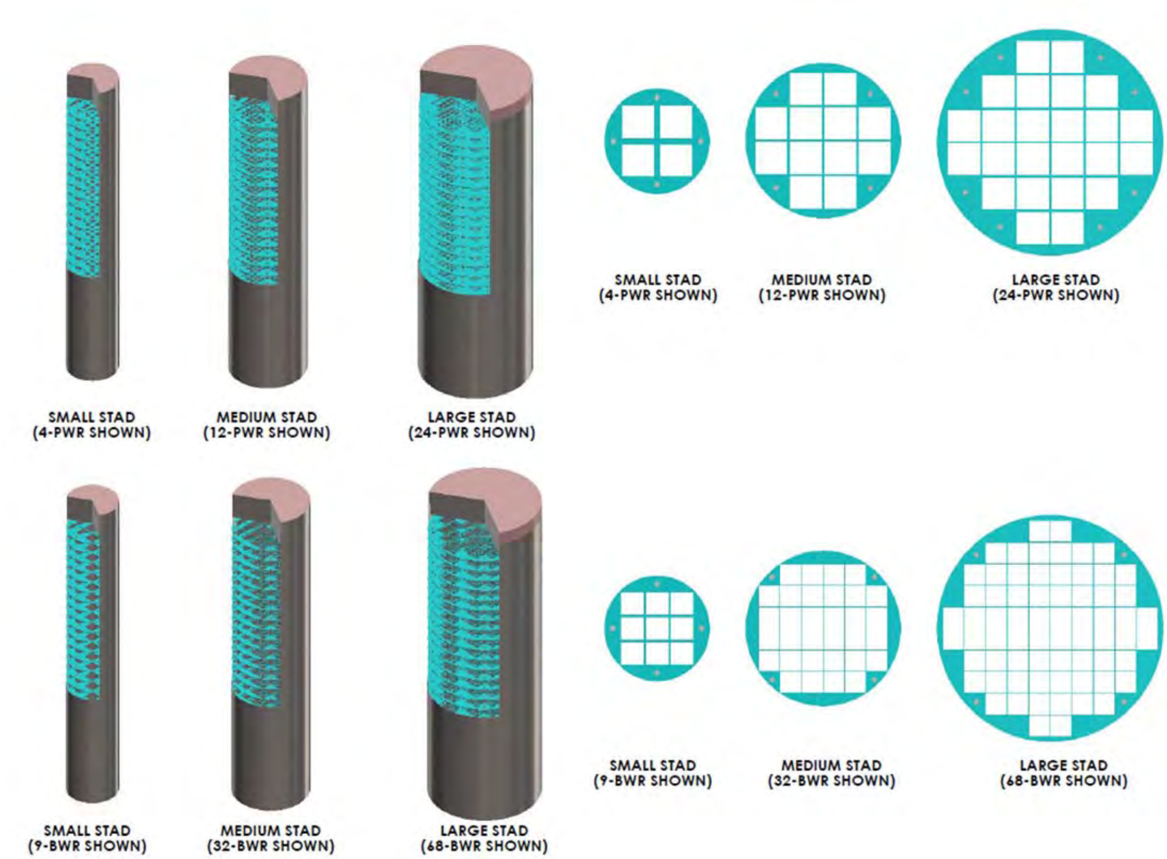


Table C4-1 summarizes the three STAD canister capacities.

Table C4-1
STAD Canister Capacities

Option	STAD	Shipment	PWR	BWR	MTHM per Overpack
S-BGVa	Small	4 each	16	36	7.3
S-BGVb	Medium	1 each	12	32	5.4
S-BGVc	Large	1 each	21	44	9.5

This study has assumed that a 32 PWR assembly commercial DPC received at the ISF contains approximately 14.5 MTHM.[1] The large STAD canister contains only 66% of the number of PWR assemblies as the 32-assembly PWR DPC in current use. Part of the

[1] Some of the legacy DPCs contain fewer fuel assemblies so that the average mass per DPC is actually 11.1 MTHM for the ISF.

reasoning for this is that the lower-capacity STAD canister may be used to transport SNF with higher decay heat than could occur using a 32-assembly DPC. Smaller capacity packages generally can transport SNF with higher decay heat due to more efficient heat transfer in the smaller packages.

During transportation, the STAD canisters are loaded into a transport cask that provides shielding and structural protection to the STAD canister. Impact limiting devices are attached to the ends of the transport cask for additional protection during transit. The shipping package must comply with the requirements of 10CFR71 (Reference C4-3). Four small STAD canisters will be shipped in a Multi-can storage container that uses a common handling mechanism to enable handling all of four small STAD canister as a single entity. For storage, the STAD canisters must comply with the requirements of 10CFR72 (Reference C4-4).

In this concept, a large shielded structure is constructed that houses an array of storage locations into which STAD canisters can be placed. It has a large service hall covered by an overhead traveling bridge crane. The floor of this hall is the shield structure covering the air-cooled vault. A shield plug is fitted into the floor over each storage location. Below this shield plug is a seismic restraint system that secures the STAD canister in a way that prevents movement in the event of a seismic event. The vault area beneath this shield floor is designed to encourage passive air flow around the STAD canisters. Exhaust stacks on one side of the vault allow the air warmed by the STAD canisters to escape while air inlets on the other side of the vault draw cool outside air into the building. This natural draft system provides bulk cooling to remove the decay heat from the SNF. **Figure C4-2** shows a 3D rendering of a conceptual vault design that could store commercial SNF.

The Modular Vault Dry Storage (MVDS) technology was developed in the early 1980s to store SNF and is currently in use at Fort St. Vrain in the United States and Paks in Hungary. **Figure C4-3** shows the Fort St. Vrain ISFSI which is the only MVDS above grade vault type ISFSI in the United States storing commercial SNF. **Figure C4-4** shows the above grade vault at Paks Hungary.

Typically, air-cooled vaults used for the storage of nuclear wastes have stored individual fuel assemblies in vertical storage locations. The ISF air-cooled vaults will need to accommodate STAD canisters that house many fuel assemblies and it will need to accommodate STAD canisters designed to be stored vertically.

The STAD canisters will be loaded with SNF and transported to the ISF site by rail. The STAD canisters will be fitted with the necessary adaptor frames to compensate for any size variations relative to the standard used to size the vault storage seismic restraint system.

Figure C4-2
3D Rendering of a Conceptual Vault

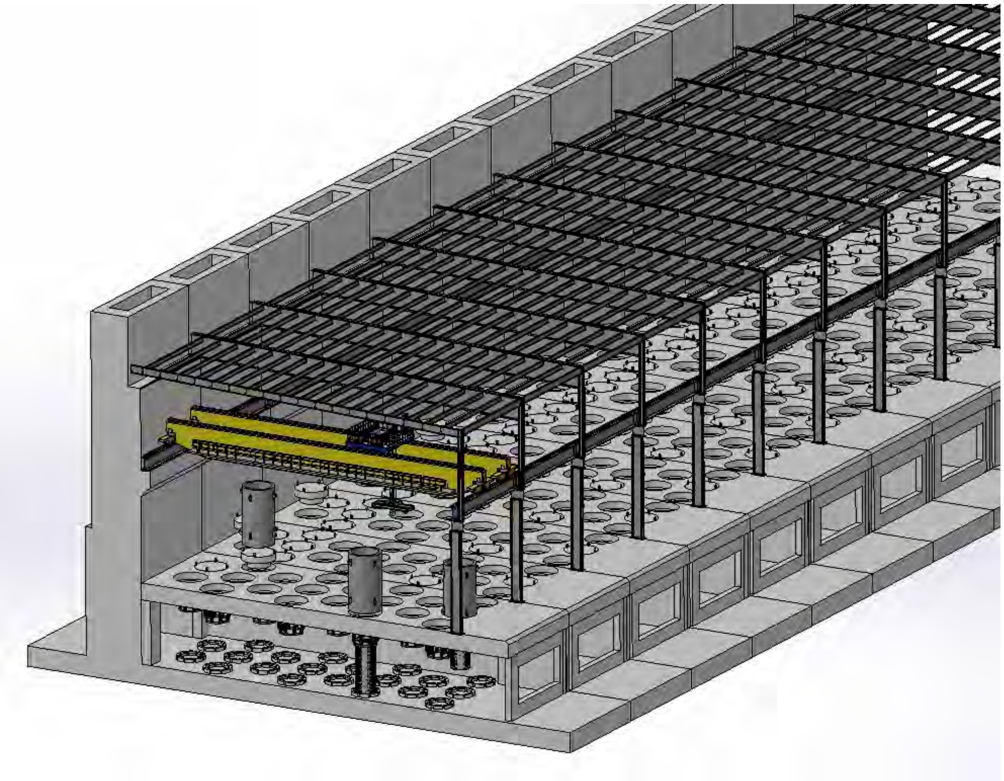


Figure C4-3
Fort St. Vrain Above Grade Vault

Source: Idaho National Laboratory

Figure C4-4
Paks Hungary Above Grade Vault

Source: Hungarian Atomic Energy Authority

C4-2.0 Concept of Operations

C4-2.1 Facility Layout

Figure C4-5 through **Figure C4-6** show the Above Grade Vault overall site layout for all three sized STAD canisters. The transport casks are delivered to the site by rail. Most likely, the railroad carrier will park the unit train at a siding off site and the ISF dedicated tug will be dispatched to retrieve the unit train. This small locomotive brings the railcars from the mainline siding to the Rail Interchange Siding Yard at the northwest corner of the ISF site.[2] At this point, the unit cars are disconnected and the security detachment who accompanied the shipment is relieved. There is a powered derailer preventing unauthorized rolling stock onto the siding yard without clearance.

The individual transport railcars are moved to the Railcar Security Inspection Area located at the entrance of the ISF protected area. There, site security officers complete the review of the shipping paperwork and perform a thorough check of the rolling stock and the packaging to ensure that there is no contraband on the shipment. The railroad tracks have a powered derailer that is positioned at the gate to the protected area to prevent unauthorized access into

[2] For this study, North is at the top of the figure. The ISF can in fact be situated in any orientation, but for clarity of this description, North is up; East is right; etc.

the protected area via rail. After the security inspection, the transport cask railcars are moved into the SNF Delivery Rail Yard / Staging Area until being moved into the CHB.

The CHB is where the transition from the rolling stock to the storage vault begins. As a result, it is located near the Rail Yard / Staging Area. It is accessible by two sets of rails, into a single railbay. The CHB is centrally located to access different vaults.

Transport casks are brought into the CHB from the staging area via the rollup doors on either the west or the east end of the railbay. Materials and supplies are brought in via the loading dock/truckbay on the east side of the CHB.

Personnel entrances and support facilities are located at the southeast corner of the ISF site. These facilities include the ISF Office Building, Warehouse, Security Entrance, parking lots, electrical substation, fire water tanks and pump house, emergency diesel generators and fuel storage tanks, and the ISF Visitor’s Center.

The designs of the S-AGV variants are impacted by the size of the STAD canister. Small STAD canisters require more storage space to store the same amount of SNF. **Figure C4-5** shows S-AGVc, **Figure C4-6** shows S-AGVb and **Figure C4-7** shows S-AGVc.

Figure C4-5
Conceptual Site Plan of the S-AGV Using Small STAD Canisters

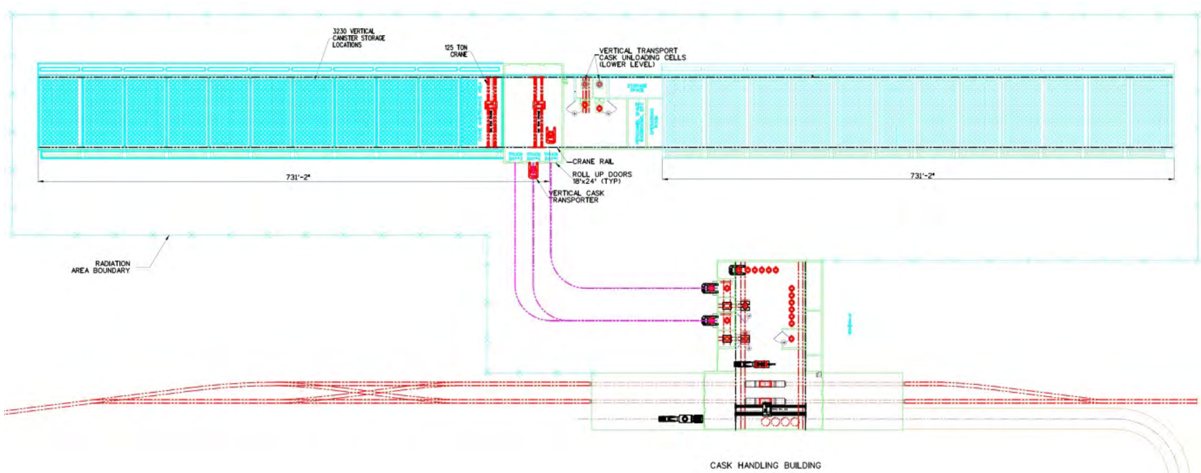
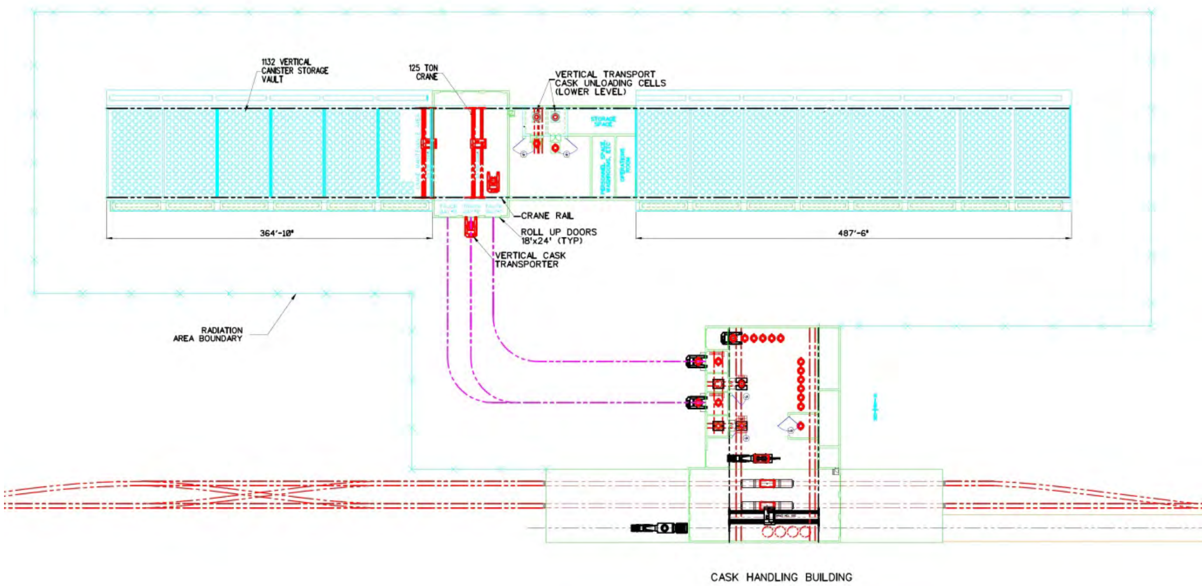
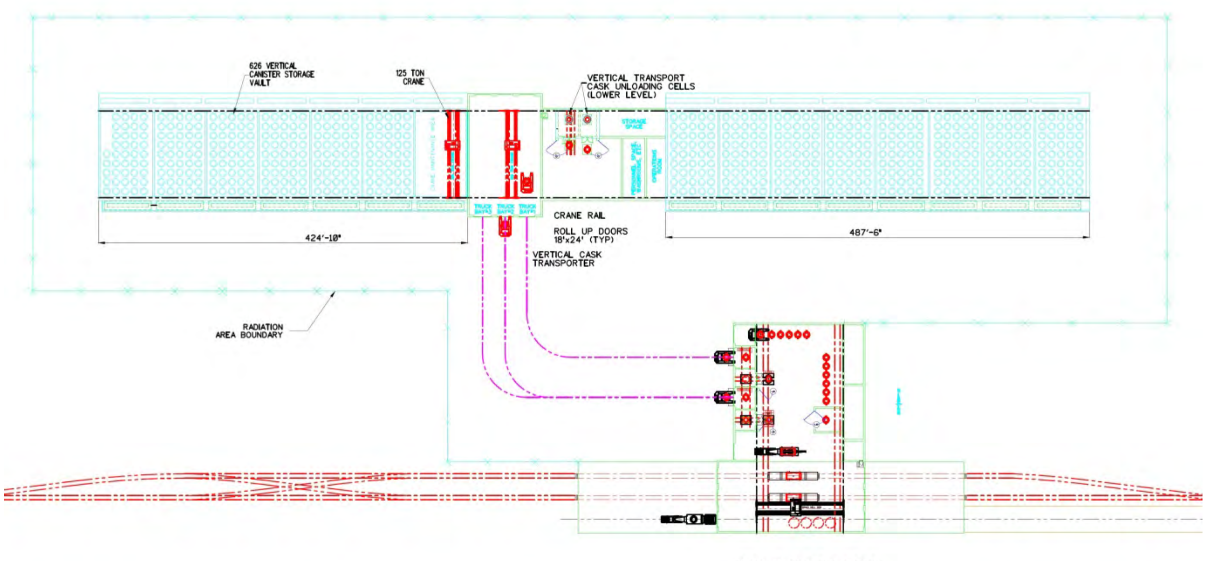


Figure C4-6
Conceptual Site Plan of the S-AGV Using Medium STAD Canisters



The STAD canister is transferred from the transport cask into a shielded transfer cask in the CHB. The shielded transfer cask is picked up by a Vertical Cask Transporter (VCT) and transported to the vault building operating floor. This is done to separate the placement of the STAD canister in the vault from the recycling of the transport cask.

Figure C4-7
Conceptual Site Plan of the S-AGV Using Large STAD Canisters



The total cycle time for a cask handling evolution is determined by how rapidly the crew can turn around the transport cask. Using the shielded transfer cask enables the crew to begin recycling the transport cask in parallel with the placement of the STAD canister. This adds several complex and heavy components to the ISF inventory but it significantly increases the throughput. It also concentrates most of the STAD preparation activities in the CHB. This allows for better utilization of the work crews by segregating the types of work into the appropriate buildings.

Once inside the vault building, the STAD canister is removed from the shielded transfer cask into a shielded transfer sleeve in a dedicated vertical transfer vault. The shielded transfer sleeve is attached to the overhead traveling bridge crane that moves the STAD canister to the storage location in the vault.

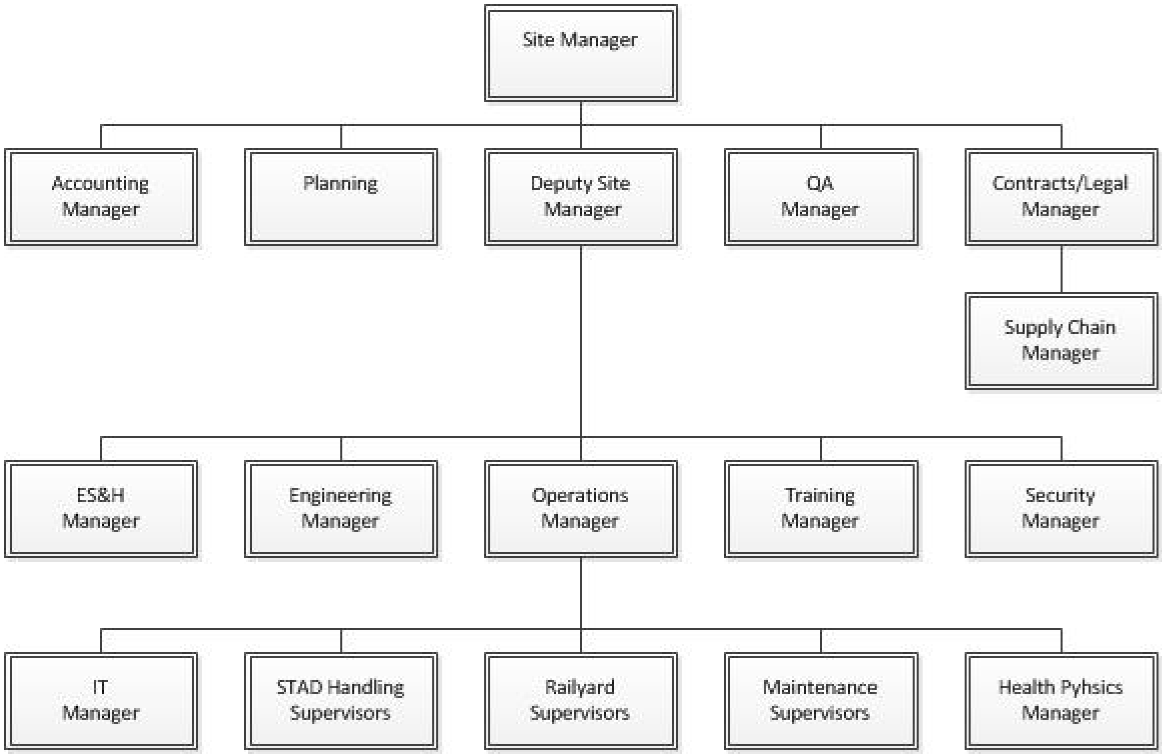
C4-2.2 ISF Operations

The ISF operates on a 24-hour, 7-days a week basis, but Canister Handling operations are limited to a single 8-hour shift, 40-hour work week. This has been done because the logistics issues associated with delivering a large number of transport casks to the site do not warrant around-the-clock Canister Handling operations. It also provides the ability to accommodate surges of work that might be necessary by the simple expedient of adding additional Canister Handling crew shifts. It is assumed that the ISF is operated by an independent contractor so that many of the administrative and Human Resource functions of an organization are not required within the site organization. The costs for these off-site services are covered in the overhead calculation for labor. **Figure C4-8** is the chart of the site organization.

There are two phases to ISF operations: Canister Handling Operations and Storage Facility Surveillance and Maintenance Operations. The Canister Handling Operations are the activities necessary to accept SNF packaged in STAD canisters from nuclear generators and to place the SNF into interim storage on site. This activity lasts only a few years and involves the most labor intensive activities experienced at the ISF. Additional Canister Handling Operations will be necessary at the end of ISF life when the stored SNF is repackaged and shipped to its final destination, whether that is a repository or a recycling facility. However, that effort is not within the scope of this study.

Storage Facility Surveillance and Maintenance Operations are the ongoing activity that spans the entire operational lifetime of the ISF. This consists of all the activities necessary to plan, to monitor the performance and aging of the storage systems used to house and cool the SNF, and to provide for the safeguards and security necessary to protect the facility from unwanted intrusions and/or damage. The Surveillance and Maintenance Operations begin immediately upon the commissioning of the ISF and continue until the last STAD canister has been removed.

Figure C4-8
Typical ISF Organization Chart



The ISF has a fairly active rail yard system with a dedicated crew of train experts managing the rolling stock and ensuring that the unit trains are rapidly brought onto site after being put on a nearby siding by the railroad company. This is a full-time support activity that includes two tugs and a maintenance facility for servicing them as well as the railcars associated with the delivery of the SNF to the ISF.

Regular plant maintenance required for the equipment necessary to perform the heavy lifts and heavy load movements necessary to fulfill the SNF handling function. This includes the overhead traveling bridge (OTB) crane servicing the railbay, the Vault Building cranes, the transfer carts in the CHB and the Vault Building, and the shield sleeve. Cranes, carts and specialty components that handle SNF packages need to have single-failure-proof designs and be inspected and maintained rigorously to ensure operability and safety.

In addition to physical labor, the ISF requires planning and engineering to support operations. The planning function needs to encompass not only the activities on the ISF site proper, but must be well informed about the SNF transportation system and recovery and repackaging of SNF from the nuclear generators. Engineering activities are required for safety analyses and modifications to processes and materials to support SNF storage. Also, record keeping is required to identify the origin of each STAD canister in storage at the ISF, its contents, the SNF characteristics and its storage location at the ISF. In addition, all material certifications for each STAD canister and other materials used for cask and STAD canister handling need to be meticulously maintained for easy retrieval in the future.

The lifting lug assemblies that are bolted to the top of the STAD canisters to enable them to be lifted by cranes and hoists are un-retrievable in the vaults. There is not shielding in the air-cooled vault between STAD canisters. Work crews cannot go into the vault to retrieve the lifting lug assemblies due to the high dose rates. Therefore, the lifting lug assemblies are considered consumables. They are fabricated off-site by contract shops. The procurement group is responsible for assuring that enough lifting lug assemblies are available in the warehouse to support ISF activities.

Finally, the largest functional activity at the ISF is physical security. The security group's functions will include daily, routine site security activities as well as inspection of all materials coming onto the site. This security function is the largest single group of the organization and is a 24-7 operation. The vault concepts have a significant advantage over other pad-based storage alternatives in this area. Since the STAD canisters are stored within a reinforced concrete vault that requires special equipment to access, the rest of the site can easily afford two lines of sight over the ISF site in order to locate and to identify intruders. So, while a traditional overpack system might require as many as four security locations to establish the necessary security coverage, the vault concepts can achieve this same requirement with only two. This results in a smaller security force than is needed for other pad-based storage systems. In addition, the IAEA oversight systems would be simplified since a couple of dedicated cameras would be able to survey the entire storage area to assure inspectors that no diversion of potentially strategic materials occurs.

Table C4-2 is a listing of the site organization staff. The organizational staff would be adequate to support the activities at the ISF necessary to support the Canister Handling activities. This staff totals 128 but does not include the Canister Handling crew. Many of the staff personnel are cross trained to enable them to support cask handling activities if necessary. If the alternate for the AGV includes a standalone CHB, then the number of Security personnel would increase by 10 (two per shift) and the number of Facility Operators would increase by 5 (one per shift). So, the total for an AGV with Standalone CHB would be 143.

Table C4-2
Site Organization

Position	Staff	Position	Staff
Site Manager	1	Mechanical Engineers	4
Deputy Site Manager	1	I&C Engineers	1
Security Manager	1	Quality Engineers	2
Operations Manager	1	Buyers	2
ES&H Manager	1	Planners	4
QA – Manager	1	Security	45
Accounting Manager	1	Trainers	4
Purchasing Manager	1	Rail yard Operators	2
Contracts/Legal Manager	1	Facility Operators	16
Manager of Engineering	1	Supervisors	4
Training Manager	1	Mechanics	4
Health Physics Manager	1	Electricians	4
HR Manager	1	IT Technicians	3
HR Specialists	2	IT Manager	1
Health Physicists	2	Administration Assistants	4
Nuclear Safety Engineers	2	EMT	1
Electrical Engineers	2	RR Tug Engineers/Brakemen	4
Civil/Structural Engineers	2		
		Total	128

C4-2.3 Canister Handling Crew Size

The Canister Handling Operations staff is dedicated to the movement of SNF packages around the site. These operations are carried out by dedicated crews who focus on certain areas of the operation. This way, when multiple STAD canisters are processed each week, a crew learns specialized skills that will improve efficiency. The crews are: 1. the Railbay Crew, 2. the Cask Transfer Crew, and 3. the Vault Building Crew.

The Railbay Crew consists of the skilled crafts necessary to prepare the transport cask to be unloaded and later to be reassembled to be shipped back to the generator. These activities include receipt inspection of the as-received package, removal and storage of the impact limiters, removal and storage of the transport cask cover, and removal and storage of the tie-down straps. Then, the Railbay Crew rigs the transport cask to be lifted by the OTB crane and places it on the transfer cart in the CHB.

The Cask Transfer Crew then positions the transport cask in the transfer cell and transfers the STAD canister into the shielded transfer cask. The crew then repositions the shielded transfer cask so that it can be picked by the vertical cask transporter. The Cask Transfer Crew also removes the transport cask from the shielded transfer cell and prepares it for the lift that will return it to the railway.

The Vault Building Crew is responsible for the placement of the STAD canister into the vault. If the design employs an integral CHB, these workers operate the vault crane and the shielded transfer sleeve to place the STAD canister into the vault. If the design employs a standalone CHB, these workers have the additional responsibility of using the cask transporter to pick the shielded transfer cask and transport the STAD canister to the Vault Building via the heavy haul road.

The Vault Building Crew positions the shielded transfer cask on a powered transfer cart. The cart is then positioned in a vertical transfer vault and the STAD canister is extracted into the shielded transfer sleeve attached to the overhead traveling bridge crane. The shielded transfer sleeve is then positioned in the vault area to affect the placement of the STAD canister.

Table C4-3 shows the staffing for each major activity necessary to move a STAD canister from the transport cask to the storage vault for an integral CHB and a standalone CHB. It can be seen in **Table C4-3** that the vaults with standalone CHBs require a significantly larger staff.

The Heavy Equipment operators are the operators of the cask transporters that transport the STAD canisters in their shielded transfer casks from the CHB to the Vault Building(s). Because the distance between the CHB and the Vault Buildings is short, and because the cask transporters are only used to deliver the shielded transfer casks between buildings, the ISF only needs two VCTs for operations. Due to the complexity of these machines, one spare cask transporters is required.

In order to establish the size of the crews, **Table C4-3** below needs to be used in conjunction with the time motion studies presented in **Section C4-2.6**. Depending on the location of the the CHB, several shifts a week do not require a full complement of workers for the entire shift. The idled workers will be rotated back to the matrixed workforce for other assignments as necessary. Certain workers such as the crane operator, the Health Physics techs and the QA/QC inspectors are area workers in that they are assigned an area and service the SNF canister only when it is that area. The crane operators use radio remote controllers for the OTB cranes, the shielded transfer sleeve hoists and for jib cranes so that one person could, in fact, operate all of the cranes in a certain area. The mechanics and riggers are task focused and only work on the STAD canister to accomplish certain activities

Table C4-3, Basis of Staffing

	STADs Stored Vertically in Vault with Integral CHB	Supervisor	Mechanics	Electricians	Riggers	Operations*	HP	QA/QC	Crane	RR Ops*	Heavy Eq. Operator	Security*	Total Staff	Duration (hrs)
0)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	0	0	11	0.5
1)	Receive transport cask at BGV/AGV	1	2	2	0	1	2	1	0	2	0	2	13	1
2)	Remove impact limiters and place in temporary storage	1	2	0	2	0	2	0	1	0	0	0	8	3
3)	Upend and lift transport cask off of railcar and place on transfer cart	1	0	0	2	0	0	0	1	0	0	0	4	2
4)	Remove transport cask cover using jib crane and set down	1	2	0	2	0	2	0	1	0	0	1	9	1
4a)	Secure the transport cask and the transfer cart seismically	1	2	0	2	0	0	1	1	0	0	0	7	0.5
4b)	Plan of the day and safety meeting	1	2	2	2	0	2	1	1	0	0	0	11	0.5
5)	Hoist lifting lug to top of STAD and bolt in place	1	2	0	1	0	0	0	0	0	0	0	4	1
6)	Position transfer cart in transfer cell and close shield doors	1	0	0	2	0	0	0	0	0	0	0	3	1
7)	Position shielded transfer sleeve on bridge crane above transfer cell	1	0	0	2	0	0	0	1	0	0	0	4	0.5
8)	Lower hoist, grapple lifting lug, and raise STAD into shield sleeve	1	0	0	2	0	0	1	1	0	0	0	5	1.25
9)	Transfer STAD to vault storage location	1	0	0	2	0	0	0	1	0	0	0	4	2
10)	Remove shield plug above vault storage location	1	0	0	2	0	0	0	1	0	0	0	4	1
11)	Lower STAD into storage position on vault floor	1	0	0	2	0	0	1	1	0	0	0	5	1
12)	Replace shield plug above vault storage location	1	0	0	2	0	2	1	1	0	0	0	7	1
12a)	Turnover to operations	1	0	2	0	2	2	1	0	0	0	0	8	24
13)	Return crane to operating floor	1	0	0	0	0	0	0	1	0	0	0	2	1
14)	Remove transport cask from transfer cell	1	0	0	2	0	0	0	1	0	0	0	4	1
15)	Install transport cask lid	1	2	0	2	0	2	1	1	0	0	1	10	1
16)	Lift transport cask and transfer to maintenance	1	0	0	2	0	0	0	1	0	0	0	4	1
16a)	Survey and wipedown transport cask	1	0	0	0	0	2	0	0	0	0	0	3	1
17)	Lift transport cask, place on railcar, and downend	1	2	2	2	0	0	0	1	0	0	2	10	1
17b)	Plan of the day and safety meeting	1	2	0	2	0	2	1	1	0	0	0	9	0.5
18)	Install impact limiters on transport cask	1	2	0	2	0	0	1	1	0	0	0	7	2
18a)	Plan of the day and safety meeting	1	0	0	0	0	2	1	0	0	0	0	4	0.5
19)	Release railcar for shipment	1	0	0	0	1	2	1	0	2	0	2	9	1

* These categories are loaned to the Cask Handling Crew

Table C4-3, Basis of Staffing (Cont'd)

	STADs Stored Vertically in Vault with Standalone CHB	Supervisor	Mechanics	Electricians	Riggers	Operations*	HP	QA/QC	Crane	RR Ops*	Heavy Eq. Operator	Security*	Total Staff	Duration (hrs)
0)	Plan of the Day and Safety Meeting	1	2	2	2	0	2	1	1	0	0	0	11	0.5
1)	Receive transport cask on railcar at Cask Handling Building	1	0	2	0	1	2	1	0	2	0	2	11	1
2)	Remove impact limiters and place in temporary storage	1	2	0	2	0	0	1	1	0	0	0	7	3
3)	Upend and lift transport cask off of railcar and place on unloading cell transfer cart	1	0	0	2	0	0	0	1	0	0	0	4	2
3a)	Remove railcar from Railbay	0	0	0	0	1	0	0	0	2	0	2	5	1
4)	Unbolt and remove transport cask lid using jib crane	1	2	0	2	0	0	0	1	0	0	0	6	1.3
4a)	Secure Transport Cask on unloading cell transfer cart	1	2	0	2	0	0	1	1	0	0	0	7	0.5
4b)	Plan of the Day and Safety Meeting	1	2	2	2	0	2	1	1	0	1	0	12	0.5
5)	Attach lifting lug to top of STAD	1	2	0	2	0	0	0	1	0	0	0	6	1
6)	Position transport cask transfer cart in unloading cell and close shield doors	1	0	0	2	0	0	1	1	0	0	1	6	1
7)	Stage empty shielded transfer cask in receiving cell using a transfer cart	1	0	0	2	0	0	0	1	0	0	0	4	0.5
8)	Position shielded transfer sleeve cart over unloading cell	1	0	0	2	0	0	0	1	0	0	0	4	0.5
9)	Lower shield sleeve hoist and grapple STAD lifting lug	1	0	0	2	0	2	0	1	0	0	0	6	0.5
10)	Raise STAD into shield sleeve	1	0	0	2	0	2	1	1	0	0	0	7	1
11)	Position shielded transfer sleeve cart over shielded transfer cask in receiving cell	1	0	2	2	0	2	1	1	0	1	0	10	1
12)	Lower STAD into shielded transfer cask, release grapple, and retract hoist	1	0	0	2	0	0	1	1	0	0	0	5	1
13)	Install shielded transfer cask lid using jib crane	1	2	0	2	0	0	0	1	0	0	0	6	1
13a)	Secure the Shielded Transfer Cask and the transfer cart seismically	1	2	0	2	0	2	1	1	0	0	0	9	1
13b)	Plan of the Day and Safety Meeting	1	0	0	2	0	2	1	1	0	0	0	7	1
14)	Place shielded Transfer Cask on CHB floor pick point	1	0	0	2	0	0	0	1	0	0	0	4	1
15)	Pick up shielded transfer cask and transfer to BGV using omni-loader	1	0	0	2	1	2	1	0	0	1	2	10	1
16)	Place shielded transfer cart onto transfer cart	1	0	0	2	0	0	0	1	0	0	0	4	0.5
17)	Remove shielded transfer cask Lid	1	2	0	2	0	2	0	1	0	0	0	8	1
18)	Position transfer cart in unloading cell and close shield doors	1	0	0	2	0	0	0	1	0	0	0	4	0.5
19)	Position shielded transfer sleeve above transfer cell	1	0	0	2	0	0	0	1	0	0	0	4	0.5
20)	Lower hoist, grapple lifting lug and raise STAD into shield sleeve	1	0	0	2	0	0	1	1	0	0	1	6	1
20a)	Secure the Transport cask and the transfer cart seismically	1	0	0	2	0	0	0	1	0	0	0	4	1
20b)	Plan of the Day and Safety Meeting	1	2	2	2	0	2	1	1	0	1	0	12	0.5
21)	Transfer STAD to vault storage location	1	0	0	0	1	0	0	0	2	0	2	6	2
22)	Remove shield plug above vault storage location	1	2	0	2	0	0	0	1	0	0	0	6	1
23)	Lower STAD into storage position on vault floor	1	2	0	2	0	0	1	1	0	0	0	7	1
24)	Replace shield plug above vault storage location	1	0	0	0	1	1	1	0	2	0	2	8	1
24a)	Turnover to Operations	0	0	2	0	2	2	1	0	0	0	0	7	24
25)	Return Crane to Operating Floor	1	0	0	2	0	0	0	1	0	0	0	4	1
26)	Remove shielded transfer cask from transfer cell	1	0	0	2	0	0	0	0	0	0	0	3	1
27)	Install shielded transfer cask lid using jib crane	1	2	0	2	0	0	0	1	0	0	0	6	1
28)	Place shielded transfer cask at vault floor pick point	1	0	0	2	0	0	0	1	0	0	0	4	1
29)	Return shielded transfer cask to CHB using omni-loader	1	0	0	2	0	0	0	0	0	1	0	4	1
30)	Open unloading cell shield doors and position transfer cart under jib crane	1	0	0	2	0	0	0	1	0	0	0	4	1
31)	Install transport cask lid	1	2	0	2	0	0	1	1	0	0	0	7	1
32)	Lift transport cask and transfer to maintenance	1	0	0	2	0	0	0	1	0	0	0	4	1
32a)	Survey and Wipedown Transport Cask	1	0	0	0	0	2	0	0	0	0	0	3	1
33)	Lift transport cask, place on railcar, and downend	1	2	2	2	0	0	0	1	0	0	0	8	1
34)	Install impact limiters on transport cask	1	2	0	2	0	0	1	1	0	0	0	7	2
35)	Release railcar for shipment	1	0	0	0	1	2	1	0	2	0	2	9	1

* These categories are loaned to the Cask Handling Crew

The results of this effort are summarized in **Table C4-4** below. This staffing estimate is approximate since not all crafts are required for an entire shift. Also, some intermediate steps do not require a certain craft, but in reality, they do not disappear. These interruptions do not materially impact the assessment. The ISF labor pool will be a matrix structure where necessary craft and managers will be drawn from the site organization staff as necessary to achieve the desired operations. This is an obvious requirement because of the variability in the Canister Handling Crew size by shift in **Table C4-4**. Based on this study, the site organization staff will need to be increased by 23 workers to achieve the desired ISF throughput during the Canister Handling phase of the facility's life cycle for the S-BGV design. This results in a total ISF staff of 151 for the BGV with Integral CHB. The Cask Handling crew size for the S-BGV with standalone CHB is more than double at 50, but the benefit of the dual railbay can be seen quite clearly as the crew for the S-BGV with standalone CHB is uniform. This is why the throughput of this design is double the throughput of the S-BGV with Integral CHB. This efficiency of labor utilization is significant benefit of the standalone CHB concept.

Table C4-4
Canister Handling Crew Makeup (Integral CHB) [3]

	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Maximum*
Supervisor	1	2	2	1	1	2
Mechanics	2	4	4	2	2	3
Electricians	2	2	2	2	2	2
Riggers	2	6	6	2	2	4
HP	2	4	4	2	2	3
QA/QC	1	2	2	1	1	2
Crane Operator	1	3	3	1	1	2
Heavy Eq. Operator	0	0	0	0	0	0
Total	11	23	23	11	11	18

* To the nearest whole person

Canister Handling Crew Makeup (Standalone CHB) [3]

	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Maximum*
Supervisor	4	4	4	4	4	4
Mechanics	8	8	8	8	8	8
Electricians	6	6	6	6	6	6
Riggers	10	10	10	10	10	10
HP	10	10	10	10	10	10
QA/QC	5	5	5	5	5	5

[3] Remediation is not part of this study's work scope and is not addressed other than to note that the packages are not accepted on site regardless of their condition.

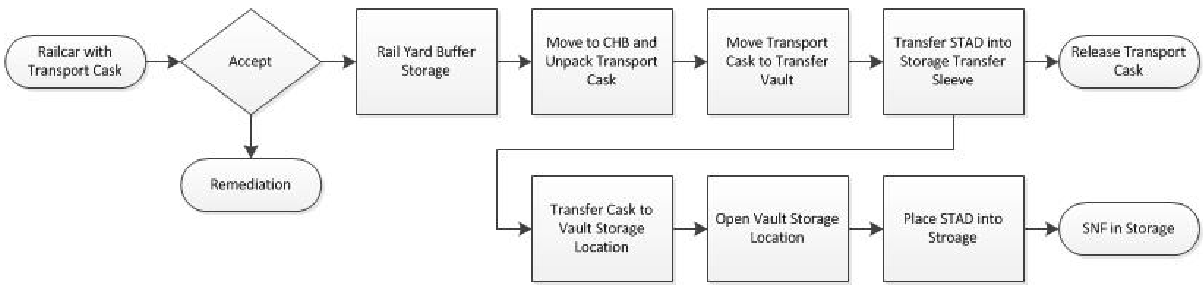
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Maximum*
Crane Operator	5	5	5	5	5	5
Heavy Eq. Operator	2	2	2	2	2	2
Total	50	50	50	50	50	48

* To the nearest whole person

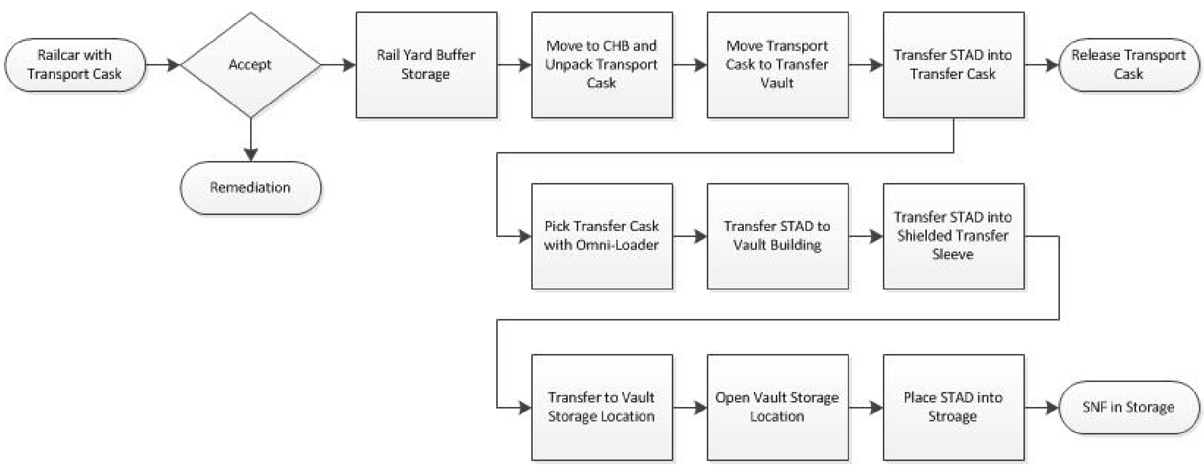
C4-2.4 Material Handling Flow Diagram

Figure C4-9 is a representation of the material handling flow for the Above Grade Vault alternative for the ISF with integral CHB. It describes the material flows of the operation.

Figure C4-9
Canister Handling Material Handling Flow Diagram S-AGV (Integral CHB) [4]



Canister Handling Material Handling Flow Diagram S-AGV (Standalone CHB) [4]



[4] Remediation is not part of this study's work scope and is not addressed other than to note that the packages are not accepted on site regardless of their condition.

It should be noted that there are no significant differences in the processing times necessary for STAD canisters regardless of their size. Since they all contain SNF that is just as susceptible to damage regardless of how many assemblies are in each container and since the dose rates and weights are all substantial, all lifts and other movements must be carefully planned and executed to avoid damage to the fuel or injury to the workers. The difference is that the number of STAD canisters necessary to achieve the ISF quantity of 5000 MTU is larger for STAD canisters.

C4-2.5 Operations

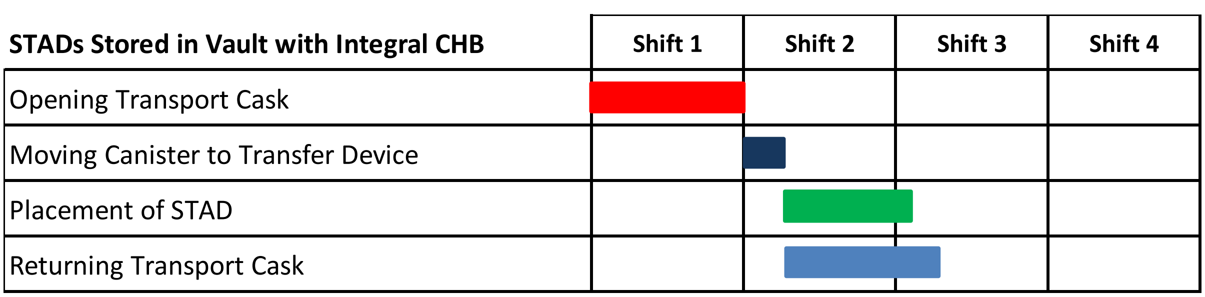
C4-2.5.1 Operational Sequence

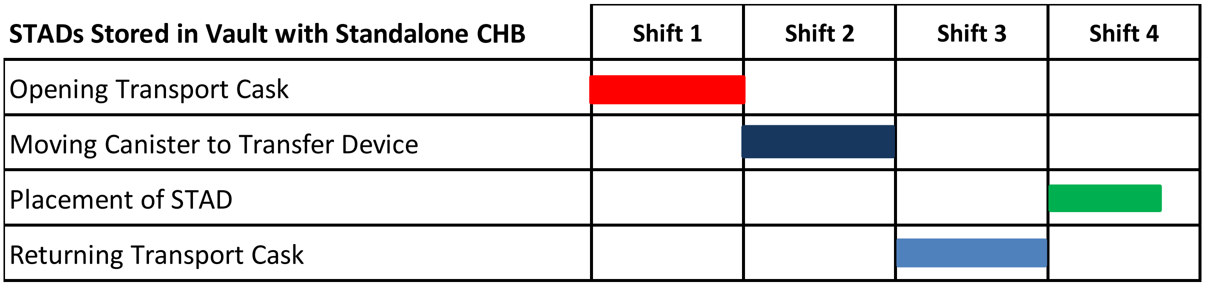
Canister Handling operations are a series of heavy lifts and crane movements that move the SNF in sealed STAD canisters from the rail head to the storage vault. The operational sequence was benchmarked against ISFSI operations at operating nuclear plants. Although no one has actually performed all of the operations at an ISF, each operation has a precedent established in the nuclear industry. The crew sizes and the durations necessary to perform each activity therefore has basis. This benchmarking provides the underpinning supporting this operational sequence and the Time and Motion analysis the follows in **Section C4-2.6**.

Figure C4-10 shows the high-level schedule for the two storage concepts in Above Grade Vault assuming 8-hour shifts. The operational sequence once the transport cask is accepted into the CHB can be divided into four large blocks:

1. Opening the transport cask
2. Moving the STAD canister into the transfer device or system
3. Transfer of the STAD canister to the storage location and
4. Preparing for the turnaround of the transport cask.

Figure C4-10
High-Level Operational Sequence A-AGV





The key to cycling STAD canisters through this sequence is the time it takes to recycle the transport cask. Is can be seen that the time it takes to move the STAD canister from the transport cask into the shielded transfer cask and then into the shielded transfer sleeve in the Vault Building is essentially a two shift exercise. However, the transport cask is released from its duty half way through that process, enabling it to be recycled in three shifts. The actual placement of the STAD canister into storage takes place on the fourth shift but it takes place in a separate building from the transport cask activities so it has no impact on the cycle time. So, the use of the shielded transfer cask enables a three-shift process rather than a four shift process.

Ironically, when one integrates the operational sequence for the S-AGV with Integral CHB, it becomes necessary to delay the repackaging the transport cask until the third shift to enable the maximum throughput. If one relies on the 2½ shifts shown above, the throughput is two STAD canisters per week. If the repackaging is delayed to enable the unpacking of a second Transport Cask, the throughput can be improved to 2½ STAD canisters per week.

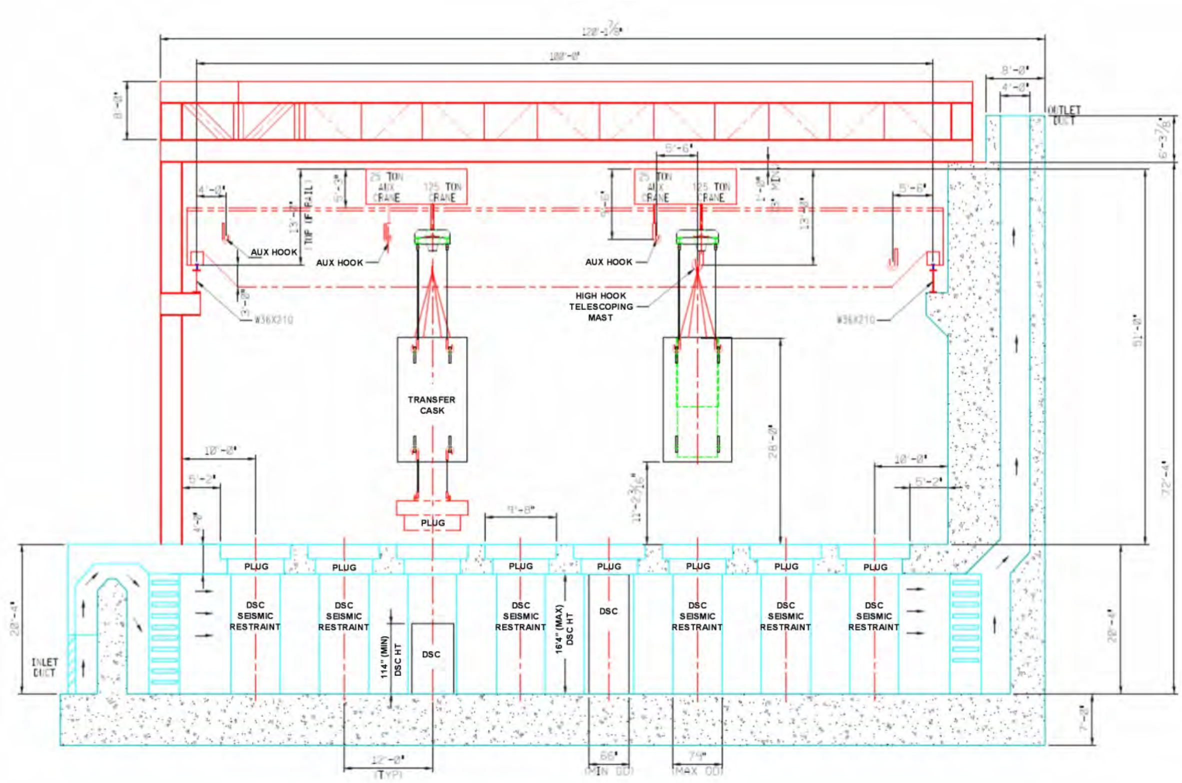
The railcar packaging of the transport cask is removed in the railbay using one of the CHB OTB crane. The transport cask cover, impact limiters, and hold down straps are removed and stored. The Transport cask is then upended by the OTB Crane servicing the railbay and placed on a cart in the vertical orientation. The lid is removed and a lifting lug is bolted onto the top of the STAD canister. The cart is then moved into the transfer cell.

If the vault has an integral CHB, the STAD canister is extracted by the shielded transfer sleeve hoist and transferred to the vault storage location. It the vault uses a standalone CHB, the STAD canister is lifted into a shielded transfer cask and lowered into a transfer cask. This cask is very similar in design to a transport cask and is used to move the STAD canister to the vault building by means of a cask transporter.

The crane positions the shielded transfer sleeve over the transfer vault and indexes itself over the port in the roof of the vault. It lowers a hoist that grapples the STAD canister by the lifting lug and lifts it out of the shielded transfer cask and locks it into position in the shielded transfer sleeve. The crane then repositions the shielded transfer sleeve over the selected storage location in the vault. The grapple at the bottom of the shielded transfer sleeve engages the shield plug and the crane lifts the plug out shield floor. The shield plug is placed to one side and the STAD canister is relocated back over the opening. The STAD canister is then lowered into the lower vault and placed on the vault floor.

The STAD canisters are secured laterally in the vault by the STAD canister seismic restraint system that consists of I-Beams embedded in the floor to prevent the STAD canister from sliding sideways during a seismic event. The top restraint consists of a cage attached to the bottom of the shield operating floor extending down into the vault area far enough to capture the top of the shortest STAD canister in the industry. For STAD canisters that are very small in diameter, adaptors are used to minimize the impact against the seismic restraint systems as necessary to avoid damage to the STAD canisters. The shield plug is replaced. **Figure C4-11** shows the relationships of the various components and structures in the air-cooled vault area.

Figure C4-11
Cross-Section of the Storage Vault



It should be noted that after the shielded transfer cask is placed into the transfer vault, workers are not needed to be near the STAD canister during the entire process. Cameras and other remote sensing devices are used to identify and verify the placement of the STAD canister in the vault. Once the shield plug is replaced, the dose rates in the vault building storage hall are quite low and workers can attach the sensors and the tamper-proof seals on the storage location without appreciable exposures.

C4-2.5.2 Limits to Operation

Railbay

Operations in the railbay are arguably the most important of the operations at the ISF to determine the throughput. The storage sequence cannot begin until the first railbay activity is completed, and the cycle cannot be completed until the last activity in the railbay is finished. So, railbay activities limit the maximum throughput of the ISF.

The S-AGV with integral CHB design has only one railbay with two rail lines. This limits the number of railcars that can be unloaded to maintain a constant supply of transport casks to be unloaded. Since there are two rail lines in the railbay, the CHB is able to supply two STAD canisters to be place into overpacks every four days.

Adding another rail line to the railbay could eliminate this problem by enabling the transfer cells to remain in continuously operation throughout the week. However, a second OTB crane would be needed that can act in parallel with the existing crane.

The S-AGV with a standalone CHB design has two railbays and two independent OTB cranes servicing the railbays. Also, the design separates the placement of STAD canister into the vault storage locations from the activities in the railbays which is a significant improvement in operations. So, while the S-AGV with integral CHB places a STAD canister in 2½ shifts compared to 4 shifts for the S-AGV with standalone CHB, the latter can place five STAD canisters into storage per week compared to 2 to 2½ STAD canisters per week.

CHB Overhead Traveling Bridge Crane

The railbay requires a heavy lift crane in order to maneuver the transport cask off of the railcar and onto the transfer cart in the CHB. It also requires a crane to reverse this process and to replace the transport cask onto the railcar. While these activities are underway, they dominate the OTB crane and it is unavailable for any other activity. The CHB has only one OTB crane. This is adequate to support the existing design with only two rail lines in the railbay, but it limits the potential throughput to 2½ STAD canisters per week. As described above, if the railbay is expanded to support three rail lines instead of two, the OTB crane availability would need to be doubled in order to increase throughput.

The OTB cranes would probably need to operate on the same set of rails, so doubling them would not necessarily double the throughput. It would be necessary to ensure that the next crane to transfer a load to or from the railbay would be shuffled to ensure that the cranes would not interfere with each other during operations.

There is only one CHB OTB crane. It is in constant use during the eight hour shifts for the 40 hour week. Maintenance and testing activities can be conducted during the overnight or the weekends. However, there is a major outage of the OTB crane; the throughput of the ISF will be seriously impacted.

Vault Building Overhead Traveling Bridge Cranes

One CHB OTB Crane and the CHB railbay design can send at most one STAD canister to the Vault Building on two consecutive days, and then there is a break where no STAD canisters are sent to the Vault Building for two days. Each crane takes two shifts to handle each STAD canister. So, the Vault Building cranes are therefore continuously used. This leaves the two overnight shifts for maintenance and testing. However, if there is a major problem with the crane it will seriously impact the ISF throughput.

Transfer Cells

The vertical storage system transfers require canister transfer cells to provide shielding and to simplify operations during the transfer of the STAD canisters from the transport cask into the shielded transfer sleeve. Each canister transfer vault consists of a door to allow a transport cask on a transfer cart to enter and exit the cell and a transfer port in the roof of the vault to permit the movement of the STAD canister into the shielded transfer sleeve. It is necessary to have a minimum of two canister transfer cells.

C4-2.6 Time and Motion Analysis

C4-2.6.1 Methodology

No one has operated a national scale ISF for the dry storage of SNF and no one has handled SNF in a STAD canister. For this study, a high-level operational sequence was developed by the concept designers. These high-level activities were then decomposed into their constituent activities. At this level, the activities were generally ones that had been performed by operators at existing nuclear facilities, or that could be estimated by small extrapolations of existing operational experience. Interviews were conducted with several individuals with real, hands-on operational experience with moving SNF to achieve a consensus on the completeness, the durations and the staff size necessary to achieve each of these constituent activities. These were then pieced together to develop a bottom up estimate of durations and crew sizes for each step.

Additional steps were added to recognize the practice of having a "Plan of the Day" meeting and a safety meeting at the start of each shift. Also, steps such as HP surveys of the emptied transport casks, and adding seismic restraints to packages containing SNF at the end of a shift were added to allow time for these necessary steps.

Once the operational sequence was developed, the sequences were considered in parallel to determine how many STAD canisters could be placed per week. Several basic assumptions were made. The first was that a large supply of transport casks on railcars was staged on the site ready for processing. If the ISF rail yard is empty or contains only two railcars during a week, this time and motion study does not apply. The available railcars will simply be processed and the Canister Handling Crews will be given other duties to fill up the week. So, the first inherent assumption is that the logistics supply chain is adequate to fully challenge the capacity of the ISF.

Secondly, this study only considers operations that are already developed and in operation at existing operating nuclear plant experience. No unusual enhancements were considered. The shielded transfer sleeve is a multi-purposed device that is a logical extension of commonly employed devices. If it becomes too complex to design and deploy, a light-duty OTB crane that moves the shield plugs in the storage hall would be a simple expedient to simplify the design challenge. However, this assessment of the Below Grade Vault did not consider automating the transfer or adding a great deal of remote sensors to the area to eliminate personnel exposures.

Finally, a major assumption for the Time and Motion Analysis was that no operation involving the movement of a STAD canister would be started during a shift if it could not be completed by the end of that shift. This is necessary because the CHB does not operate continuously, so no load would be left hanging or in some other unstable condition that would jeopardize the integrity of the SNF or its confining structures in the event of a design basis event. Abandoning the STAD canister in mid-operation would leave the canister in a potentially compromised position without qualified canister handling expertise on hand in case of emergency. Furthermore, the STAD canister was assumed to be secured seismically at the end of each shift.

As stated earlier, this study considers only a single 8-hour shift at 40 hours per week with no overtime. Clearly, the throughput could easily be increased by adding workers and shifts, and indeed that would be a cost effective expedient if additional capacity is desired.

However, a working assumption of this study is only a single shift of 40 hours is necessary per week. Based on the certain problems with the logistics of moving SNF to the site, it is considered that this is a reasonable approach.

C4-2.6.2 Conclusion

It was determined that the throughput with all of the assumptions is an average of 2.5 STAD canisters placed into storage each week for vaults with integral CHBs and 5 STAD canisters placed into storage each week for vaults with standalone CHBs. Several observations came out of the Time and Motion Analysis.

First, the benefit of the vault with standalone CHBs comes from the ability to readily support a two railbay CHB. It requires more people to staff the site the site during the cask handling activities and it takes longer for each STAD canister to be placed into storage, but it permits better work force efficiency and doubles the throughput of the integral CHB design. The throughput is independent of what size STAD canister is considered. So, while the movement of STAD canister is the same, the placement of SNF into storage is very different. **Table C4-5** captures the differences among the STAD canister options available.

Table C4-5
ISF Throughput Using STAD canisters

Option	STAD Canister	STAD Canister Capacity		MTHM per Year (260 STADs/yr)	5000 MTHM Time
		PWR	BWR		
S-UGSa	Small	16	36	1898	2.6 years
S-UGSb	Medium	12	32	1404	3.6 years
S-UGSc	Large	21	44	2470	2.0 years

First, with the CHB having two rail lines, it is the OTB cranes that determine the maximum throughput of the CHB. The single OTB crane is the limiting element in the throughput of this alternative. It precludes increasing the throughput of the facility and should it fail or experience an outage, it would effectively prevent the CHB from functioning. Adding another CHB OTB crane would have no impact on ISF throughput without massive redesign of the CHB.

Second, the Vault Building (or vault area) OTB cranes are fully utilized and possibly overextended. Using more cranes with more limited roles might make for a more reliable system, albeit at the price of complexity and the need for more operators. The need to swap out the lifting devices between picking the shielded transfer cask and managing the complex shielded transfer sleeve may be too daunting of a design challenge. However, as currently configured, the Cranes in the Vault Building are at the limits of their capability.

Third, there needs to be two cask transporters on site to develop and maintain full ISF throughput for the standalone CHB design. These are extremely complex machines and could be unreliable if used as much as this concept requires. One cask transporter would possibly be able to maintain the ISF throughput, but having two is seen as a necessary precaution.

Fourth, this concept is easier for the security team to protect because it is concentrated and contained. External threats and internal threats are easier to identify and to defeat than is the case for an external facility.

Finally, this concept is unaffected by weather and other environmental conditions during the loading process. Therefore, STAD canister placement is not impacted by external conditions so the ISF can be sited anywhere without the throughput being impacted. The minimal impact of the movement of the transfer cask containing the STAD canister from the CHB to the vault building was judged to be of negligible importance.

Figure C4-12 shows the schedule for the S-AGV alternative. The activities on the Y-axis are the steps necessary to process the STAD canisters from when they enter the Canister Handling Building until the empty transport cask has been reinstalled on the railcar and removed from the CHB. The time across the top of the schedule is in hours. The red bars are critical path activities; the blue are near critical path activities. It has been assumed that once a STAD canister has been placed in the storage configuration in the vault, a period of 24-hours is necessary to perform the required surveillance and safeguards activities. This is shown as a green dashed line on this chart but is not really part of the Canister Handling Crew's responsibility. These activities are done by ISF Operations. The activities include a series of temperature, air flow and radiation measurements over the initial 24-hour period to validate that the expected performance has been achieved.

The schedules in **Figure C4-12** were then placed in series and in parallel to establish the maximum throughput of the ISF. **Figure C4-13** shows the work plan for S-AGV that shows how the workflow would proceed. The Gantt chart bars have been colored to show the equipment used to accomplish the activity. The color coding permits the viewer to easily see when the schedule is causing a conflict in the vault building. The operational cycle repeats every four weeks and during that period, 10 STAD canisters are placed into storage. That is an average of 2.5 STAD canisters per week.

Figure C4-12
Time Motion Schedules for Above Grade Vault using STAD canisters

STADs Stored Vertical in Vault with Integral CHB		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	37	39	40
0)	Plan of the Day and Safety Meeting																																								
1)	Receive transport cask at BGV/AGV																																								
2)	Remove impact limiters and place in temporary storage																																								
3)	Upend and lift transport cask off of railcar and place on transfer cart																																								
4)	Remove transport cask cover using jib crane and set down																																								
4a)	Secure the Transport cask and the transfer cart seismically																																								
4b)	Plan of the Day and Safety Meeting																																								
5)	Hoist lifting lug to top of STAD and bolt in place																																								
6)	Position transfer cart in transfer cell and close shield doors																																								
7)	Position shielded transfer sleeve on bridge crane above transfer cell																																								
8)	Lower hoist, grapple lifting lug, and raise STAD into shield sleeve																																								
9)	Transfer STAD to vault storage location																																								
10)	Remove shield plug above vault storage location																																								
11)	Lower STAD into storage position on vault floor																																								
12)	Replace shield plug above vault storage location																																								
12a)	Turnover to Operations																																								
13)	Return Crane to Operating Floor																																								
14)	Remove transport cask from transfer cell																																								
15)	Install transport cask lid																																								
16)	Lift transport cask and transfer to maintenance																																								
16a)	Survey and wipedown Transport Cask																																								
17)	Lift transport cask, place on railcar, and downend																																								
17a)	Plan of the Day and Safety Meeting																																								
18)	Install impact limiters on transport cask																																								
19)	Release railcar for shipment																																								

Figure C4-12
Time Motion Schedules for Above Grade Vault using STAD canisters (Cont'd)

STADs Stored Vertically in Vault with Standalone CHB

0)	Plan of the Day and Safety Meeting
1)	Receive transport cask on railcar at Cask Handling Building
2)	Remove impact limiters and place in temporary storage
3)	Upend and lift transport cask off of railcar and place on unloading cell transfer cart
4)	Unbolt and remove transport cask lid using jib crane
4a)	Secure Transport Cask on unloading cell transfer cart
4b)	Plan of the Day and Safety Meeting
5)	Attach lifting lug to top of STAD
6)	Position transport cask transfer cart in unloading cell and close shield doors
7)	Stage empty shielded transfer cask in receiving cell using a transfer cart
8)	Position shielded transfer sleeve cart over unloading cell
9)	Lower shield sleeve hoist and grapple STAD lifting lug
10)	Raise STAD into shield sleeve
11)	Position shielded transfer sleeve cart over shielded transfer cask in receiving cell
12)	Lower STAD into shielded transfer cask, release grapple, and retract hoist
13)	Install shielded transfer cask lid using jib crane
13a)	Secure the Shielded Transfer Cask and the transfer cart seismically
13b)	Plan of the Day and Safety Meeting
14)	Place shielded transfer cask at CHB floor pick point
15)	Pick up shielded transfer cask and transfer to vault using VCT
16)	Place shielded transfer cart onto transfer cart
17)	Remove shielded transfer cask cover
18)	Position transfer cart in unloading cell and close shield doors
19)	Position shielded transfer sleeve above transfer cell
20)	Lower hoist, grapple lifting lug and raise STAD into shield sleeve
20a)	Secure the Transport cask and the transfer cart seismically
20b)	Plan of the Day and Safety Meeting
21)	Transfer STAD to vault storage location
22)	Remove shield plug above vault storage location
23)	Lower STAD into storage position on vault floor
24)	Replace shield plug above vault storage location
24a)	Turnover to Operations
25)	Return Crane to Operating Floor
26)	Remove shielded transfer cask from transfer cell
27)	Install shielded transfer cask lid using jib crane
28)	Place shielded transfer cask at vault floor pick point
29)	Return shielded transfer cask to CHB using VCT
30)	Open unloading cell shield doors and position transfer cart under jib crane
31)	Install transport cask lid
32)	Lift transport cask and transfer to maintenance
32a)	Survey and Wipedown Transport Cask
33)	Lift transport cask, place on railcar, and downend
34)	Install impact limiters on transport cask
35)	Release railcar for shipment

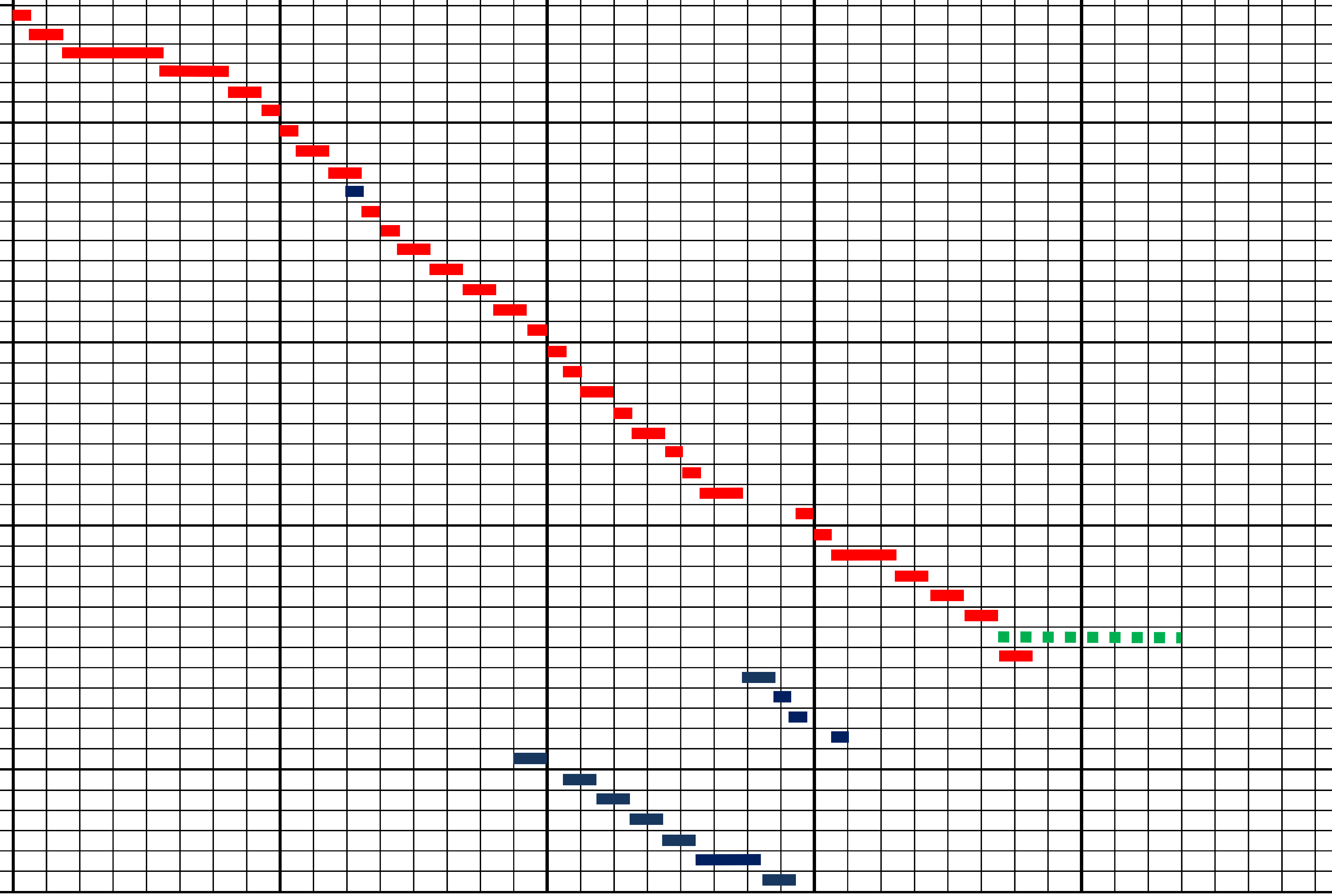


Figure C4-13
Typical Work Plan for Above Grade Vault Using STAD canisters

Integral CHB

	Week 1					Week 2				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Rail #1	Transport Cask #1 Unload	STAD #1 Transfer to Vault	Transport Cask #1 Reload		Transport Cask #3 Unload	STAD #3 Transfer to Vault	Transport Cask #3 Reload		Transport Cask #5 Unload	STAD #5 Transfer to Vault
Rail #2		Transport Cask #2 Unload	STAD #2 Transfer to Vault	Transport Cask #2 Reload		Transport Cask #4 Unload	STAD #4 Transfer to Vault	Transport Cask #4 Reload		Transport Cask #6 Unload

	Week 3					Week 4				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Rail #1	Transport Cask #5 Reload		Transport Cask #7 Unload	STAD #7 Transfer to Vault	Transport Cask #7 Reload		Transport Cask #9 Unload	STAD #9 Transfer to Vault	Transport Cask #9 Reload	
Rail #2	STAD #6 Transfer to Vault	Transport Cask #6 Reload		Transport Cask #8 Unload	STAD #8 Transfer to Vault	Transport Cask #8 Reload		Transport Cask #10 Unload	STAD #10 Transfer to Vault	Transport Cask #10 Reload

NOTES:

1. The highlighted boxes show the critical path activity in the Railbays. Note that work is always on going in the railbays.
2. The cycle is 2 ½ shifts long, but delaying the repackaging of the transport cask enables better utilization of the vault systems.
3. This process is the same for STAD canister sizes.
4. The vaults with integral CHB design can process 10 DPCs in four weeks; averaging 2.5 a week.

Figure C4-13
Typical Work Plan for Above Grade Vault Using STAD canisters (cont)

Standalone CHB

	Week 1					Week 2				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Railbay #1	Transport Cask #1 Unload	STAD #1 Transfer to VB	Transport Cask #1 Reload	Place STAD #1 in Vault	Transport Cask #5 Unload	STAD #5 Transfer to VB	Transport Cask #5 Reload	Place STAD #5 in Vault	Transport Cask #9 Unload	STAD #9 Transfer to VB
Railbay #1	Place STAD #18 in Vault	Transport Cask #2 Unload	STAD #2 Transfer to VB	Transport Cask #2 Reload	Place STAD #2 in Vault	Transport Cask #6 Unload	STAD #6 Transfer to VB	Transport Cask #6 Reload	Place STAD #6 in Vault	Transport Cask #10 Unload
Railbay #2	Transport Cask #19 Reload	Place STAD #19 in VB	Transport Cask #3 Unload	STAD #3 Transfer to Vault	Transport Cask #3 Reload	Place STAD #3 in VB	Transport Cask #7 Unload	STAD #7 Transfer to VB	Transport Cask #7 Reload	Place STAD #7 in Vault
Railbay #2	STAD #20 Transfer to VB	Transport Cask #20 Reload	Place STAD #20 in Vault	Transport Cask #4 Unload	STAD #4 Transfer to VB	Transport Cask #4 Reload	Place STAD #4 in Vault	Transport Cask #8 Unload	STAD #8 Transfer to VB	Transport Cask #8 Reload

	Week 3					Week 4				
	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
Railbay #1	Transport Cask #9 Reload	Place STAD #9 in Vault	Transport Cask #13 Unload	STAD #13 Transfer to VB	Transport Cask #13 Reload	Place STAD #13 in Vault	Transport Cask #17 Unload	STAD #17 Transfer to VB	Transport Cask #17 Reload	Place STAD #17 in Vault
Railbay #1	STAD #10 Transfer to VB	Transport Cask #10 Reload	Place STAD #10 in Vault	Transport Cask #14 Unload	STAD #14 Transfer to VB	Transport Cask #14 Reload	Place STAD #14 in Vault	Transport Cask #18 Unload	STAD #18 Transfer to VB	Transport Cask #18 Reload
Railbay #2	Transport Cask #11 Unload	STAD #11 Transfer to VB	Transport Cask #11 Reload	Place STAD #11 in Vault	Transport Cask #15 Unload	STAD #15 Transfer to VB	Transport Cask #15 Reload	Place STAD #15 in Vault	Transport Cask #19 Unload	STAD #19 Transfer to VB
Railbay #2	Place STAD #8 in Vault	Transport Cask #12 Unload	STAD #12 Transfer to VB	Transport Cask #12 Reload	Place STAD #12 in Vault	Transport Cask #16 Unload	STAD #16 Transfer to VB	Transport Cask #16 Reload	Place STAD #16 in Vault	Transport Cask #20 Unload

NOTES*:*

1. The highlighted boxes show the critical path activity in the Railbays. Note that work is always on going in the railbays.
2. The railcars are removed after the work crews are done with them and replaced by the next railcar to be processed.
3. The cycle is four shifts long.
4. This process is the same for all STAD canister sizes.
5. The standalone CHB design can process 20 STAD canisters in four weeks; averaging 5 a week

C4-3.0 ISF Construction

The ISF will consist of a number of features and structures that will need to be constructed for the facility to operate. They include:

1. ISF Site (with access road and utilities)
2. Railroad spur and yard
3. Vault with integral or standalone Cask Handling Building
4. Protected Area (security boundary, cameras, intrusion detection and lighting)
5. Administration building
6. Security/access control building
7. Warehouse/maintenance facilities

C4-3.1 ISF Site

The ISF site is assumed to be placed on approximately one square mile of property. Not all of the land will require construction, only the area for the ISF. An access road and electrical utilities will need to be constructed into the property. The site access road will consist of an asphalt paved 2 lane road from the nearest highway into the ISF. The location of the site will determine if mechanical utilities (domestic water, wastewater, natural gas) can be supplied from local means or if these will need to be self-contained. A remote site requiring self-contained utilities can use water wells or trucked-in tanks of water depending on the underground water capability. Wastewater can be discharged through drain fields. Propane gas can be supplied if no natural gas lines are near the site.

The site will require an Owner Controlled Area (OCA) fence which will likely consist of a chain link fence to discourage trespassers from entering the site and keep animals out. The fence requires minimal construction and establishes a good facility boundary. Just inside the fence a gravel security road can be constructed to enable guard patrols around the site.

The purpose of the OCA is to establish the portion of the property that maintains a level of secured control. Within this boundary, security maintains control and patrols for unauthorized individuals. In addition, 10 CFR 72.106 requires that all SNF storage and handling operations be maintained at least 100 meters from the OCA boundary. All CSF functions are contained within this boundary.

C4-3.2 Railroad Spur and Yard

The ISF will need railroad tracks from the mainline to receive incoming train consists and prepare for outgoing train consists. A rail portal at the Protected Area boundary and a rail yard near the storage area will also be required.

The purpose for the rail yard is to provide adequate railcar storage for incoming and outgoing SNF train consists, and access to the CHB. The rail yard must be designed to allow flexibility for maneuvering yard switchers, railcars, buffer cars, and escort cars.

It is assumed that the rail yard will consist of at least 4 tracks – 2 tracks to receive inbound trains and 2 tracks for staging outbound trains. The yard includes a runaround track to permit the yard switchers access around the tracks. The yard also includes a lead line and a spur off the lead line accessing the CHB.

Construction of the rail yards will involve excavation, structural fill, and potential geotextile materials to maintain soil stability, gradation to establish various elevations to ease railcar movements, heavy steel rail, ties, several rail turnouts, ballast placement, lighting, and other minor railroad related features.

C4-3.3 Storage Area

The storage area resides within the reinforced concrete storage vault whose floor is at grade elevation. The storage hall above the shielded storage area is a steel framed structure. The vault will be a long, open bay approximately 100 ft. wide by 800 ft. long.

The base of the vault and the operating floor will house a thick reinforced concrete slab approximately 60 inches thick, which will house the STAD canisters. The S-AGV will utilize a natural cooling method of passing outside air directly across the canisters within the vault and up through the vault's chimney, creating a natural air flow based on the heat generated by the STAD canisters and the height of the chimney. The vault will be designed to ensure adequate safety and to mitigate the effects of site environmental conditions, natural phenomena, security events, and accidents including stability and liquefaction caused by earthquake conditions over the life of the facility.

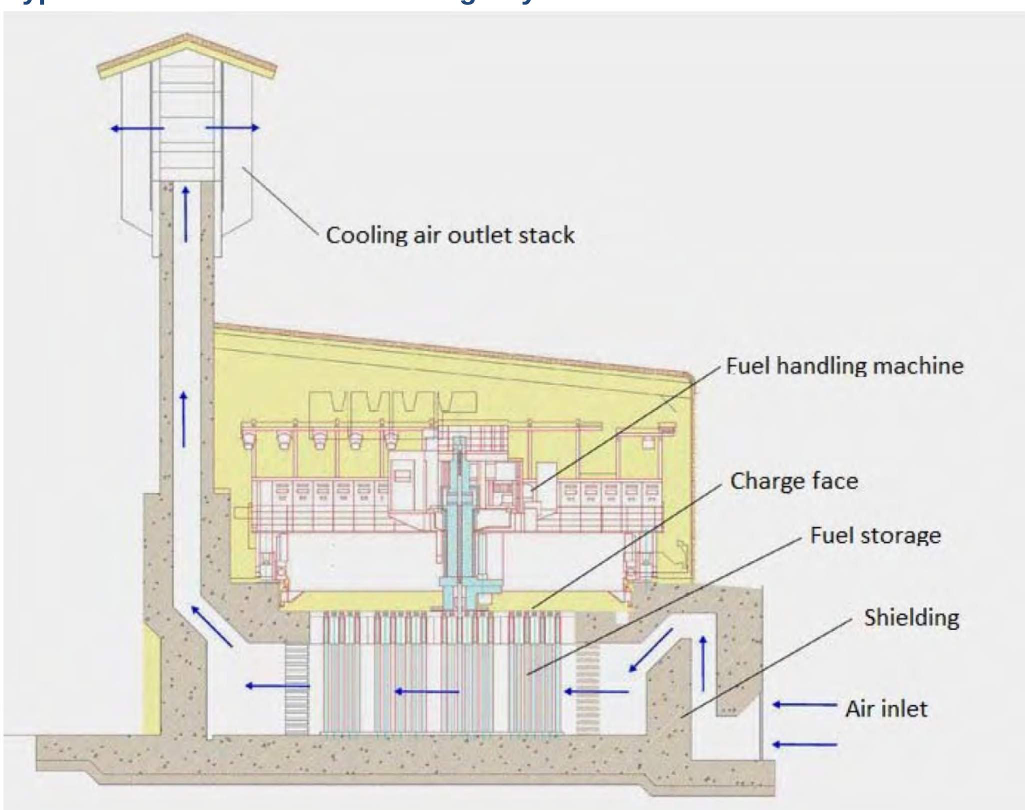
A vault design holds spent fuel in individual STAD canisters vertically within a concrete structure forming the vault. The STAD canisters would be transferred from the transportation cask and placed within a cell of the vault with a shield plug placed on top. The tops of the shield plugs would be level and integrated within the operating floor. The vault itself is located below the operating floor and has a concrete floor that the STAD canisters rest on and inlet and outlet air cooling ducts. The ceiling of the vault (also the operating floor) would be a composite steel and concrete structure. This ceiling and the floor of the vault would maintain the array of STAD canisters since the canisters would be sitting within a receiver on the vault floor and within one on the vault ceiling to ensure complete capture of the DPC and ensure no movement during a seismic event, sub-criticality, and efficient cooling.

Cooling air will enter through an inlet vent at grade elevation, pass around a labyrinth to prevent radiation streaming, enter the vault, and exit through the chimney. The passive cooling system is self-regulating, driven by natural buoyancy of warm air, and is naturally immune to partial blockage of the inlet or outlet vents as the air velocity will increase to account for the blockage. This affords the ISF several days to clear the vent in the unlikely event of a blockage.

Since the vault is a massive concrete structure, there will be little to no radiation dose outside of the vault structure. Even on the operating floor, as long as the shield plugs are in place, there will be less than a 1mrem/hr dose rate.

A typical above grade vault configuration storing up to 5,000 MTHM of SNF for the ISF will need to store up to 450 STAD canisters as shown on **Figure C4-14**.

Figure C4-14
Typical Above Grade Vault Storage System – Elevation View



C4-3.4 Cask Handling Building

The purpose of the CHB is threefold; 1) receive SNF shipments; 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 building cell and transfer canisters from the transport casks to storage overpacks for vertical systems. The building is designed to provide physical protection for the canisters and radiation shielding to the workers.

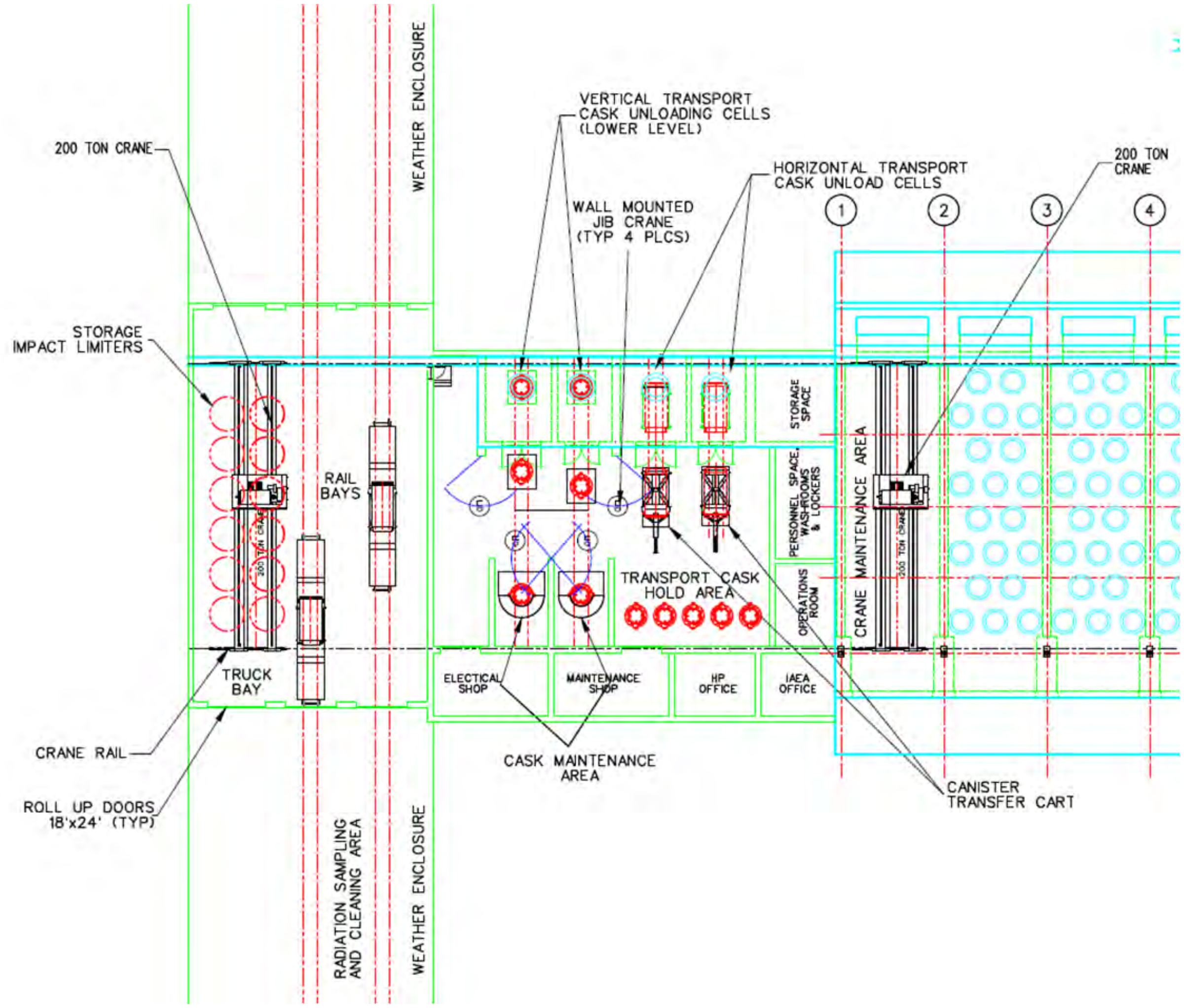
The CHB for this report has been designed with 2 rail bays, 2 truck bays, 4 vertical canister transfer cells, 2 - 200 ton single-failure-proof overhead bridge cranes, laydown area for impact limiters and other Transport Cask equipment, staging area for transport casks and office area. The CHB would be a reinforced concrete structure with thick walls to protect all Transport Casks, STAD canister, overpacks, and cask-handling equipment from the effects of earthquakes, tornado winds, tornado-generated missiles, fire, and explosions. The throughput would be 3,000 MTHM/yr with one shift per day, 5 days per week.

The CHB would be a reinforced concrete structure with thick walls to protect all SNF casks, canisters, overpacks, and cask-handling equipment from the effects of earthquakes, tornado winds, tornado-generated missiles, fire, and explosions.

The CHB is designed to provide radiological shielding during canister transfer operations. Four vertical type canister transfer cells with reinforced concrete walls shield workers from dose intensive operations.

Figure C4-15 shows a plan view of the CHB for the a vault using an integral CHB.

Figure C4-15
Cask Handling Building for an Integral CHB



C4-3.5 Protected Area

The PA is an area within the OCA large enough to encompass the ISF rail yards, CHB, and S-AGV. The PA consists of two physical barriers: (1) a security fence and (2) a nuisance fence separated by a 20-foot wide isolation zone. Within the isolation zone is an intrusion detection system that provides ground surveillance to detect any unauthorized entry into the PA. Assessment of unauthorized intruders is provided by illumination along the PA perimeter and throughout the storage area and a CCTV system, consisting of both fixed and pan-tilt-zoom cameras to monitor activities around the PA boundary from the security building.

The PA is surrounded by a passive vehicle barrier system (VBS) that is constructed of large concrete blocks to prevent any vehicles from getting near the PA boundary. The VBS is physically placed at a distance so that a pressure wave from a vehicle-born improvised explosive device cannot affect the storage containers or cask handling activities. Active VBSs are placed at large gates that accommodate railcars loaded with SNF transport casks or vehicles to prevent any unauthorized entry. These VBSs can be lowered once the railcar or vehicles are inspected and cleared for entry.

Security equipment is typically powered from normal off-site power supplies. However, in the event of a loss of off-site power, an Uninterruptable Power System (UPS) consisting of batteries would be used to provide seamless power to all electronic security equipment. The UPS and site lighting would be backed up by an emergency diesel-powered generator located within the PA.

Bullet resistant enclosures would be situated at strategic locations within the PA to provide protected locations for security force personnel during a security event.

C4-3.6 Site Support Buildings

The ISF will need to include a number of support buildings. An administration building will need to be constructed to house managers, admin staff, engineers, document storage, licensing records, health physics personnel, radiological records, training rooms, etc.

A security/access control building will need to be constructed to house security personnel, security managers, the Central Alarm Station, safeguards information, etc. The building can be sited at the PA boundary to provide access control for personnel entering the storage area. This most likely would include a badging station, explosion detectors, metal detector to monitor persons entering the secured area, x-ray machines to monitor materials brought onsite, and turnstiles delineating the PA boundary.

A warehouse/maintenance building will need to be constructed to stockpile materials shipped to the ISF for overpack fabrication, pad construction, inspection equipment, general supplies, etc. This structure could also double as a maintenance building for general maintenance activities as well as transporter and canister handling equipment maintenance.

The ISF would also include a number of other features such as fire protection, potable water, sanitary drains, electrical power and distribution, and communications.

C4-4.0 ISF Expansion

C4-4.1 Storage Area Impact

ISF expansion of another 5,000 MTHM would require constructing another vault building. Construction of the second 5,000 MTHM storage area should be performed outside of the ISF PA to facilitate construction activities without stressing security. Once the new vault is constructed, the PA would be expanded to encompass it. Of course, this type of construction would mean that a significant corridor would need to be placed between vaults to ensure that construction workers receive as low as reasonably achievable (ALARA) radiation dose from the existing loaded storage units.

The PA would be expanded in size as required to accommodate the new vault including fencing, intrusion detection system equipment, number of CCTV cameras and yard illumination.

Electrical power would need to increase to accommodate a larger ISF to account for the additional security, lighting and temperature monitoring equipment. The Uninterruptable Power System (UPS) and security backup emergency diesel-powered generator would need to be able to accommodate the new loads of the larger site.

C4-4.2 Increased Throughput Impact

The CHB constructed for the ISF has a throughput capacity of 3,000 MTHM/yr which may be adequate for an expanded ISF. Even if the throughput requirements are increased to 4,500 MTHM/yr, the CHB would not need to be enlarged. Rather, adding a second shift would effectively double the throughput of the building to 6,000 MTHM.

To expand the ISF, the rail yards, Administration Building Warehouse/Maintenance Building, Security/Access Control Building and other site infrastructure utilities may not require many modifications. Backup electrical power service for illumination and security of the larger storage area, additional security guards, increased CCTV and intrusion detection equipment are a few modifications that may be required to accommodate the expanded ISF. For example, these additions may require a larger Security/Access Control Building for the additional security personnel as well as a larger CAS for the increased CCTV coverage. However, if the ISF is designed with the understanding of the expanded ISF that doubles the vault storage area, then these items could easily be included in the initial design.

C4-4.3 Modular Expansion Impact

For vault storage, the only modular construction would be the construction of an additional, attached vault. No other changes in the ISF would be modular type design.

C4-5.0 Performance of Structures, Systems and Components

C4-5.1 Structural and Seismic Evaluation

Structural evaluations of storage alternatives must be performed to demonstrate compliance with the applicable requirements given in 10CFR72, sections 72.122 and 72.236. These sections specify structural performance requirements for facilities and storage systems to maintain the confinement, subcriticality, radiation shielding, and retrievability of the SNF under normal operations, off-normal conditions, accident scenarios, and design basis natural phenomena conditions. For all dual purpose canister storage systems associated with the NPP's, the STAD canister is designated as the confinement boundary. The types of structural loading that the STAD canister must be qualified to withstand at the ISF include deadweight, internal pressure, and thermal expansion under normal and off-normal environmental conditions, handling loads, drops and tip-over events, explosive overpressure events, and design basis natural phenomena events including fires, floods, tornado winds, and earthquakes. NUREG-1536 (Reference C4-5) provides guidance for the types of structural modeling, structural analysis methods, NRC-approved design codes and standards for different storage system components, loading conditions and combinations, and acceptance criteria for performing the structural analyses required to meet the functional requirements described above.

Structural evaluations of the above grade meet the requirements described above will be performed and documented in safety analysis reports accepted by the NRC during licensing. The environmental, accident and natural phenomena loading conditions, structural models, material properties, and displacement, force, and stress-strain results documented in these evaluations are used as a basis of comparison, to make judgments regarding the seismic performance of storage and transportation systems under the general loading conditions defined for the expanded ISFs.

The below and above grade vaults are long, narrow concrete structures, which house bare STAD canisters inside ventilated, shielded concrete storage bays. The design of the two vaults are identical, except the above grade vault has the top of its base slab located at grade, and the below grade vault has the top of the operating floor located at grade. The seismic response of the below grade vault will be less than that of the above ground vault, due to the building embedment. Parametric studies of similar structures indicate that partial embedment on the order of 0.2 times the building width reduces the peak seismic demands by as much as 67%. Therefore, the results from the seismic analysis of the above ground vault envelops the loads the below grade case and will be used as representative of the seismic performance of the below grade vault, accounting for the reduced demand by decreasing the reinforcing bar by 10%. Also, there are five optional floor plans for each vault, which are differentiated based on storage orientation (all vertical, all horizontal, and both vertical and horizontal) and transport cask unloading location (integral to vault, and in a separate CHB). In order to limit the number of evaluations to something manageable, the vault with the highest projected cost - the above ground vault with all vertical storage and a separate CHB for cask unloading – will be seismically evaluated, and the results will be used to develop the base cost estimate. Approximate costs for other options will be determined by accounting for the design differences between options, where significant.

C4-5.2 Thermal Evaluation

Thermal evaluations of storage alternatives must be performed to demonstrate compliance with the applicable requirements given in 10CFR72, sections 72.122 and 72.236. The basic thermal performance requirement is for the storage system to provide adequate passive cooling capacity to maintain the temperatures of storage system materials below their allowable limits. NUREG-1536 provides guidance for the types of thermal modeling, the basic heat transfer considerations, the environmental conditions and accident scenarios, and temperature acceptance criteria for the fuel cladding that the thermal evaluations must address.

Thermal evaluations of the vault storage meet the requirements described above and will have been performed in Safety Analysis Reports accepted by the NRC during the licensing process. The environmental conditions, thermal models, and temperature results documented in these evaluations are used in this report as a basis of comparison, to make judgments regarding the thermal performance of storage and transportation systems under the conditions defined for the expanded ISFs.

In the Above Grade Vault, vertical STAD canisters and horizontal STAD canisters in lift frames are stored standing up on the base slab which forms the floor of the vault. The vault storage area is isolated from the occupied portions of the building one floor above by the five foot thick operating floor. Shield plugs in the operating floor can be removed to provide access for placement and retrieval of STAD canisters using an overhead crane, but when installed, isolate the atmosphere in the vault storage area from the area above the operating floor. The vault storage area is separated into individual bays which span the width of the building by concrete walls which isolate one bay from the next. A concrete stack runs the length of the storage area along one side of the building. Each bay has an air intake on one side of the building and is open to the stack on the other side. When STAD canisters are placed in a bay and the shield plugs are re-installed, the decay heat from the STAD canisters warms the air in the bay which exhausts upward through the stack. The air exiting the stack is replaced by air flowing into the bay through the air intake on the opposite side of the bay. Thus, a self-sustaining cross flow develops which passively removes the decay heat from the bay. The amount of airflow through the bay is a function of the heat generated in the bay, the stack height and flow area, and the frictional losses along the flow path. Since the stack height and flow area are fixed parameters, the airflow reaches an equilibrium state where the differential pressure due to the stack effect is balanced by the frictional losses along the flow path. After equilibrium is reached, the flow is self-regulating, in that any decrease in the decay heat generated will reduce the driving pressure due to the stack effect, which reduces the flow and associated frictional losses until the system reaches a new equilibrium state at a lower value of flow. Therefore, the thermal performance of a vault is evaluated by determining if the decay heat generated induces sufficient airflow to maintain STAD canister temperature limits within their allowable values.

A computational fluid dynamics (CFD) analysis of the proposed design for the vault has been performed to verify whether or not the vault design meets required thermal performance criteria. In the analysis, a thermal model of a representative section through a vault bay was developed, including the air intake, the vault storage area with the base slab Above and operating floor above, a row of (8) STAD canisters, and the exhaust stack. Appropriate (symmetric) boundary conditions were coded along the cut faces of the model. Adiabatic boundary conditions were coded on concrete surfaces, which is a good first approximation since concrete is a rather poor conductor of heat. Each STAD canister was assigned a decay heat generation rate of 25kW, which is conservative with respect to the maximum heat load for SNF from any plant. The heat from each STAD canister was distributed to the model as a uniform heat flux over the STAD canister sides and top. This uniform distribution is conservative compared to the actual STAD canister heat flux distribution, where a shield plug at the top of the STAD canister blocks almost all heat transfer through the top, directing it preferentially out the sides. The environmental temperature considered in the analysis was the extreme accident temperature of 120°F, given in section.

The CFD solver calculated the steady-state temperature distribution, the airflow rates, and the heat fluxes throughout the model, based on the input geometry, the constitutive properties of air, and the applied heat loading described above. Both convection and radiation heat transfer mechanisms were considered in solving the model. Temperature contour plots of the model were generated, as well as tabular results, including the projected maximum centerline cladding temperature, maximum stainless steel temperatures, and maximum concrete temperatures. These results are discussed in the following sections.

C4-5.3 Radiological Evaluation

The exposures to radiation for the workers in this study are based on historical radiological source terms from dry storage systems at commercial nuclear plants. They demonstrate differences among the various options rather predict actual doses. STAD canisters would be licensed for newer spent fuel with different source terms that are yet to be determined. Therefore, doses from STAD canisters were not calculated for this study. However, some factors are noteworthy:

1. Due to self-shielding within the STAD canister, the contact dose rate for any size STAD should be within a few percent of the contact dose rate for other size STAD canister

containing the same SNF. Since worker dose rates are determined by a few activities that involve close contact with the canister, the worker exposures for the different STAD canisters are based primarily on the handling activities required not the STAD type.

2. The activities necessary to transfer a STAD canister from a rail car to the storage location are assumed in this report to be similar to the commercial DPC processes in order to provide a comparison of the different storage alternatives. STAD canisters and their associated transport, transfer casks or storage units can be designed to remove or reduce dose intensive activities. For example, attaching and removing lifting lugs to DPCs is major contributor to dose rates. An integral lifting means on the STAD canister will remove considerable worker dose.

3. STAD transport casks, transfer casks and storage units can be designed with improved shielding. STAD canisters are smaller and lighter than commercial DPCs, so the various shielding casks can be heavier without impact shipping or lifting infrastructure. This can reduce worker dose without changes to rolling stock or cask handling equipment.

4. STAD handling systems can be designed with more automated features reducing manual activities next to the canister. Commercial systems were developed as temporary expedients to address fuel pool capacity and life extension issues. STAD canisters can be designed to improve performance based on industry experience.

5. Study #1 determined that worker doses are fairly consistent for all alternative storage methods. Study #2 determined that the method used to process incoming shipments has a greater effect on worker dose than the storage method – more automation can substantially reduce worker doses versus manual handling. Similar results are likely to be the same with STAD canisters.

6. Offsite doses to the public are expected to be very similar to commercial systems. Offsite dose is a function of shielding and distance. Doses to the public can be reduced with additional system or building shielding and/or by increasing the distance from the storage area to the Owner Controlled Area boundary. The exposures to radiation for the workers due to STAD canister processing at the ISF cannot be assessed at this time since they are still conceptual. It is very difficult to predict what overall dose would be received for each canister transfer let alone the dose each worker receives.

C4-5.4 Design Life, Aging and Maintenance Evaluation

Currently, storage systems may be designed for 40 to 100 years but are only permitted to be licensed for a period of up to 40 years. Prior to February 16, 2011, when 10 CFR 72.42, Duration of License; Renewal (for specific licenses) and 10 CFR 72.240, Conditions for Spent Fuel Storage Cask Renewal (for CoCs for general licenses) were revised to permit 40 year license durations, licenses and CoCs for storage systems had a duration of 20 years. Therefore, most of the storage systems currently in place at ISFSIs are only licensed for 20 years. In order to renew the license and extend the storage license, NUREG-1927, Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance (Reference C4-6) requires that an applicant demonstrate that the effects of aging will be adequately managed so that the intended safety function(s) of SSCs identified in the scope of license renewal will be maintained consistent with the current licensing basis for the period of extended operation. The NRC requires that an Aging Management Review (AMR) be performed that consists of identifying ISFSI components relied on for safety, susceptible materials in those components, environments to which susceptible materials are exposed, aging effects, and development of an aging management program to manage aging effects and protect against degradation of age-sensitive components (such as by performing inspections of age-sensitive components and replacing components that have a life expectancy of less than the license renewal period being requested in the anticipated environment). For purposes of this section, it is assumed that the original license has a duration of 20 years and a 40 year license extension is requested, so the licensee will need to demonstrate the in-scope component materials will withstand the anticipated environment for a total of 60 years, or provide a plan for replacing age-sensitive components at acceptable analyzed intervals. If the initial license was for a 40 year duration, and a 40 year license extension is requested, then the licensee would need to demonstrate the in-scope components are acceptable for 80 years in the storage environment.

The AMR identifies susceptible materials of subcomponents in the in-scope SSCs that are exposed to environments that could cause age-related degradation. The functions required to be performed by the individual subcomponents of these in-scope SCCs (determined in previous section) are identified in applicable tables in this AMR section of the application for ISFSI license renewal.

The NRC's Draft Revision 1 of NUREG-1927, Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel (Reference C4-7 explains the purpose of the AMR as follows:

> "The purpose of the aging management review (AMR) is to assess the proposed aging management activities (AMAs) for structures, systems, and components (SSCs)

determined to be within the scope of renewal. The AMR addresses aging mechanisms and effects[1] that could adversely affect the ability of the SSCs (and associated subcomponents) from performing their intended functions during the period of extended operation. The reviewer should verify that the renewal application includes specific information that clearly describes the AMR performed on SSCs within the scope of renewal."

Footnote 1 in this quotation states: "In order to effectively manage an aging effect, it is necessary to determine the aging mechanisms that are potentially at work for a given material and environment application. Therefore, the aging management review process identifies both the aging effects and the associated aging mechanisms that cause them."

The license application needs to include an Aging Management Review (AMR) that is comprised of four major steps that are summarized as follows:

1) Identification of In-Scope Subcomponents Requiring AMR

Structures, Systems and Components (SSCs) within scope of the aging evaluation are identified as those that are 1) classified as important to safety (ITS), and 2) classified as not important to safety but whose failure could prevent an ITS function from being fulfilled. SSCs within scope are determined based on review of the ISFSI Materials License, ISFSI SAR, ISFSI Tech Specs, NRC's SER for the ISFSI and docketed licensing correspondence related to the ISFSI.

2) Identification of Susceptible Materials and Applicable Environmental Conditions

For the subcomponents of in-scope SSCs that require AMR, the next step is identification of materials of construction susceptible to aging and the environments (e.g., temperature, pressure, radiation, wet vs. dry, etc.) that these materials normally experience.

3) Identification of Aging Mechanisms and Effects Requiring Management

Aging mechanisms potentially at work on susceptible materials in given environments (corrosion, cyclic stress fatigue, radiation embrittlement, etc.) are determined. Aging effects (manifestation of aging mechanisms) of material / environment combinations are compiled from industry and plant operating experience through use of industry standards and reference materials, including metallurgical literary references. During this process, the question is asked, are the potential aging effects credible given the identified materials and environmental conditions of storage?

4) Determination of Activities Required to Manage Aging Effects (Aging Management Program)

The final step in the AMR process involves the determination of activities necessary to manage the effects of aging. If the aging review determines that certain materials may not be able to support a 60 year life in the environment that they are normally exposed to, then an Aging Management Program needs to be established for those subcomponents to extend the life of the storage system to 60 years (such as by performing inspections of vulnerable subcomponents to determine their continued adequacy, or replacing the associated subcomponent at specified intervals).

Each of the four above steps of the AMR process are discussed in more detail in the following paragraphs.

C4-5.4.1 Aging Management Review (AMR)

Identification of In-Scope Components Requiring AMR

During this first step in the AMR process, the in-scope SSCs are further reviewed to identify and describe the subcomponents that support the SSC intended function. Intended functions of interest in the AMR are sub-criticality control, pressure boundary integrity (confinement of fission products), heat transfer, structural support (protection against environmental phenomena) and shielding. The subcomponents and associated intended functions are identified by reviewing the applicable current licensing basis (CLB) documentation sources.

SSCs and associated subcomponents within the scope of renewal fall into the following scoping categories:

(1) They are classified as important to safety (ITS), as they are relied on to do one of the following functions:

i. Maintain the conditions required by the regulations, specific license, or CoC to store spent fuel safely;

ii. Prevent damage to the spent fuel during handling and storage; or

iii. Provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

These SSCs ensure that important safety functions are met for (1) confinement, (2) radiation shielding, (3) sub-criticality control, (4) heat-removal capability, (5) structural integrity, and (6) retrievability of the spent fuel.

(2) They are classified as not important to safety but, according to the design bases, their failure could prevent fulfillment of a function that is important to safety.

Subcomponents that perform or support any one of the identified intended functions will require an AMR. Those components that do not support an intended function can be excluded from further evaluation in the AMR with supporting justification. The SSCs within the scope of renewal are screened to identify and describe the subcomponents with intended functions. It should be recognized that SSC subcomponents may degrade by different modes, or have different criteria for evaluation from the overall component (i.e., different materials or environments). SSC subcomponents may also have different performance requirements for support of safety functions.

Typically, the application for ISFSI license renewal tabulates the results of the AMR, including a listing of subcomponents and the intended function provided by each subcomponent, material group, environment, aging effects requiring management and aging management activity required. The AMR results tables also identify subcomponents that did not support the SSC intended function and are not subject to AMR, with justification for their exclusion.

Identification of Materials and Environments

The second step of the AMR process requires the identification of materials of construction and the environments to which these materials are exposed, for the in-scope ISFSI subcomponents that require an AMR. Environmental data may include: temperature, wind, relative humidity, relevant atmospheric pollutants and deposits, exposure to precipitation, marine fog, salt, or water exposure, radiation field (gamma and neutron), the service environment (e.g., embedded, sheltered, or outdoor), and gas compositions (e.g., external: air; internal: inert gas such as helium).

The environments to which components are exposed play a critical role in the determination of potential aging mechanisms and effects. A documentation review is required to quantify the environmental conditions to which the in-scope ISFSI SSCs are continuously or frequently exposed (conditions known to exist on a recurring basis). As noted in the next section, normal operating conditions are evaluated and not accident conditions.

The storage system FSAR is typically used to determine the intended functions and materials of construction for cask subcomponents that are in-scope of ISFSI license renewal. Additional documentation, drawings and technical reports should also be reviewed during the AMR process as required to obtain clarifications of the intended materials of construction and functions performed by in-scope ISFSI subcomponents.

The specific materials of construction for the cask and fuel assembly subcomponents requiring aging management review are identified and evaluated for the renewal period.

Identification of Aging Mechanisms and Effects Requiring Management

The third step in the AMR process is to identify the aging mechanisms and effects requiring management. A Material Aging Effects Report (MAER) is typically prepared for the storage system in question. This report needs to include aging mechanisms and effects that theoretically occur as well those that have actually occurred based on industry operating experience and the ISF operating experience for the appropriate material and environmental conditions. Aging effects are presented in this report in terms of material / environment combinations.

The environments considered in the evaluation are the environments that the subcomponents normally experience. Environmental stressors that are conditions not normally experienced, such as accident conditions, or that may be caused by a design problem, are considered event-driven situations and are not characterized as sources of aging. Such event-driven situations would be evaluated at the time of event, with corrective actions taken as necessary.

To effectively manage an aging effect, it is necessary to determine the aging mechanisms that are potentially at work for a given material and environment application. Therefore, the AMR process needs to address both the aging mechanisms as well as the aging effects. Selective mechanisms are only applicable under certain environmental conditions, such as high temperature or moisture. The identified aging mechanisms need to be characterized by a set of applicable conditions that must be met for the mechanism to occur and/or propagate. The application for ISFSI license renewal should identify aging effects based on the aging mechanisms potentially at work in given environments on susceptible subcomponent materials (e.g., general corrosion of carbon steel, stress corrosion cracking and crevice and pitting corrosion of stainless steel, cyclic stress fatigue, radiation embrittlement, boron depletion of neutron absorber due to neutron flux, etc.). Aging effects (manifestation of aging mechanisms) of material / environment combinations are compiled from industry and plant operating experience through use of industry standards and reference materials, including metallurgical literary references. The majority of aging mechanisms will be extracted from industry documents (including NRC and EPRI) for the applicable material/environmental combinations. For instance, the EPRI Dry Cask Characterization Project final report (Reference C4-8) is a primary source for fuel assembly and dual purpose canister internals aging mechanism evaluations. During the process of identifying aging effects the question is asked, are the potential aging effects credible given the identified materials and environmental conditions of storage?

Appendix D, Table D-1, of NUREG-1927 lists potential aging effects and possible aging mechanisms that should be considered. This information is also available from a table in Appendix C to NUREG-1557 (Reference C4-9). Section 3.4 of the NRC's Draft Revision 1 of NUREG-1927 lists the following sources of information that should be used to identify applicable aging mechanisms and effects:

- site maintenance, repair, and modification records;
- corrective action reports, including root cause evaluations;
- lead system inspection results ;
- maintenance and inspection records from ISFSI sites with similar SSC materials and operating environments;
- industry records;
- applicable operating experience outside the nuclear industry;
- applicable consensus codes and standards;
- NRC reports;
- other applicable guidance for determining if an aging mechanism or effect should be managed for the period of extended operation.

Section 3.4 of the NRC's Draft Revision 1 of NUREG-1927 gives the following examples of potential aging mechanisms and effects that may be identified by reviewing the above sources of information:

> "(1) cracking or loss of strength as a result of cement aggregate reactions in the concrete, (2) cracking or loss of material as a result of freeze-thaw degradation of the concrete (requires the presence of moisture combined with temperatures below freezing), (3) reinforcement corrosion and concrete cracking as a result of chloride ingress, (4) accelerated corrosion of steel structures and components and stress corrosion cracking of austenitic stainless steels as a result of atmospheric deposition of chloride salts."

Other possible aging effects are settlement, change in dimension and change in material properties. The applicant for renewal of an ISFSI specific license is not required to take further action if an SSC is determined to be within the scope of renewal but is found to have no potential aging effects for the period of extended operation.

The AMR defines two methods for addressing potential aging mechanisms and effects: TLAA and AMP, both of which are discussed below.

Time-Limited Aging Analyses to Identify Aging Effects

Time-Limited Aging Analyses (TLAAs) are calculations performed to evaluate the life of subcomponents of interest. TLAAs are defined in Section 3.5 of the NRC's Draft Revision 1 of NUREG 1927, as those licensee calculations and analyses that meet all of the following criteria:

1. Involve SSCs important to safety within the scope of the specific-license renewal, as delineated in Subpart F of 10 CFR Part 72;
2. Consider the effects of aging;
3. Involve time-limited assumptions defined by the current operating term;
4. Were determined to be relevant by the specific licensee or certificate holder in making a safety determination;
5. Involve conclusions or provide the basis of conclusions related to the capability of SSCs to perform their intended safety functions (analyses that do not affect the intended functions of the SSCs are not considered TLAAs); and
6. Are contained or incorporated by reference in the design bases.

The defined operating term should be explicit in the analyses. Simply asserting that the SSC is designed for a service life or ISFSI life is not sufficient. The assertions must be supported by a calculation, analyses, or testing that explicitly include a time limit.

Examples of TLAAs described in the past applications for license renewal are: 1) cracking of the dual purpose canister (DPC) shell due to fatigue from thermal cycling; 2) change in material properties of epoxy seal in DPC penetration (for temperature monitoring) due to exposure to ionizing radiation; and 3) canister basket poison plate depletion of boron due to increase in neutron exposure for 60 year life of ISFSI; change in properties of boron-polyethylene front access cover plate due to increased radiation exposure over 60 year life of ISFSI.

Operating Experience Review for Process Confirmation

Typically, the potential aging effects for the ISFSI material and environment combinations are compiled from common industry and plant operating experience through the use of accepted industry standards and reference materials, including various metallurgical literary references relating specific materials and environments to aging effects and mechanisms.

A further review of industry and plant specific operating experience for the ISFSI should also be performed in order to confirm the applicability of previously identified potential aging mechanisms/effects and to identify any aging effects not previously addressed.

The application for ISFSI license renewal will need to address the various observations resulting from ISFSI operating experience with the storage systems. This information should address items specific to the subcomponents. As an example; Dominion identified corrosion of lid bolts and outer metallic lid seals on some of the TN-32 casks stored at the Surrey ISFSI. The corrosion was most prevalent on the down-slope side of the cask lid. As part of the investigation, the bolt torque was checked and it was determined that there had been no torque relaxation. The corrosion of the lid bolts and outer metallic seal was the result of external water intrusion in the vicinity of the lid bolts and outer metallic seal. It was determined that the connector seal for the electrical connector in the cask protective cover was leaking due to improper installation of the connectors. Therefore, this degradation was not related to aging.

Activities Required to Manage Aging Effects (Aging Management Program)

The fourth and final step in the AMR process involves the determination of the aging management activities or Aging Management Programs (AMPs) to be credited or developed for managing the effects of aging. Section 3.6 of Draft Revision 1 of NUREG-1927 states the following regarding AMPs:

> "Aging management programs (AMPs) monitor and control the degradation of SSCs within the scope of renewal so that aging effects will not result in a loss of intended functions during the period of extended operation. An AMP includes all activities that are credited for managing aging mechanisms or effects for specific SSCs. An effective AMP prevents, mitigates, or detects the aging effects and provides for the prediction of the extent of the effects of aging and timely corrective actions before there is a loss of intended function."
>
> "Aging management programs should be informed, and enhanced when necessary, based on the ongoing review of both site-specific and industry-wide operating experience. Operating experience provides direct confirmation of the effectiveness of an AMP and critical feedback for the need for improvement. As new knowledge and data become available from new analyses, experiments, and operating experience, licensees and CoC holders should revise existing AMPs (or pertinent procedures for AMP implementation) to address program improvements or aging issues."

Section 3.6.1 of the NRC's Draft Revision 1 of NUREG-1927 indicates that an AMP should contain the following elements:

1. Scope of Program,
2. Preventive actions,
3. Parameters monitored or inspected,
4. Detection of aging effects,
5. Monitoring and trending,
6. Acceptance criteria,
7. Corrective actions,
8. Confirmation process,
9. Administrative controls, and
10. Operating experience.

To the extent practical, existing ISFSI programs and/or activities are credited for the management of aging effects that could cause a loss of component intended function during the license renewal period. If the aging review determines that certain materials cannot support the required life in the environment that they are normally exposed to, then an AMP needs to be established for those subcomponents to extend the life of the storage system for the duration of the license renewal period (such as by performing inspections of vulnerable subcomponents to determine their continued adequacy, or replacing the associated subcomponent at specified intervals). The application for ISFSI license renewal will need to discuss development of AMPs to address subcomponents whose materials are susceptible to age-related degradation. AMPs for ISFSIs typically include visual inspections of cask external surfaces to look for signs of deterioration due to corrosion (general corrosion for carbon steel subcomponents due to moist atmospheric environments, and crevice and/or pitting corrosion for stainless steel surfaces that are subject to wetting), and monitoring area radiation levels, airborne and smearable contamination levels at selected areas of the ISFSI. Increased radiation / radioactivity levels could indicate reduction in shielding, breach of the SFA cladding or loss of cask confinement. Inspection intervals are established at frequencies that provide confidence the subcomponents of interest will not experience age-related adverse effects that could prevent them from performing their intended functions.

C4-5.5 Postulated Accident Evaluation

The accident descriptions to follow refer to "Design Event" levels given in ANSI/ANS 57.9, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)" (Reference C4-10). As explained in NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" (Reference C4-11): "Off-normal events are those expected to occur with moderate frequency or once per calendar year. ANSI/ANS 57.9 refers to these events as Design Event II. Accident events are considered to occur infrequently, if ever, during the lifetime of the facility. ANSI/ANS 57.9 subdivides this class of accidents into Design Event III, a set of infrequent events that could be expected to occur during the lifetime of the ISFSI, and Design Event IV, events that are postulated because they establish a conservative design basis for SSCs important to safety. The effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches, are considered to be accident events."

Section 15.4 of NUREG-1567 identifies acceptance criteria for accidents, including the following:

> Criticality: 10 CFR 72.124(a) requires that the spent fuel must be maintained in a subcritical condition (i.e., keff $\leq$ 0.95), and at least two unlikely, independent and concurrent or sequential changes must be postulated to occur in the conditions essential to nuclear criticality safety before a nuclear criticality accident is possible (double contingency).
>
> Confinement: 10 CFR 72.128(a)(3) requires that the systems important to safety must be evaluated, using appropriate tests or by other means acceptable to the Commission, to demonstrate that they will reasonably keep radioactive material confined under credible accident conditions. NUREG-1567 states that “A breach of a confinement barrier is not acceptable for any accident event.”
>
> Retrievability: 10 CFR 72.122(l) requires that “Storage systems must be designed to allow ready retrieval of spent fuel, high-level radioactive waste, and reactor-related GTCC waste for further processing or disposal.” The definition for Important to Safety SSCs in 10 CFR 72.3 includes those features whose function is to “provide reasonable assurance that spent fuel, high-level radioactive waste, or reactor-related GTCC waste can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.”
>
> Instrumentation: 10 CFR 72.122(i) states in part: “Instrumentation systems for dry storage casks must be provided in accordance with cask design requirements to monitor conditions that are important to safety over anticipated ranges for normal conditions and off-normal conditions. Systems that are required under accident conditions must be identified in the Safety Analysis Report.”
>
> Radiological Dose: 10 CFR 72.104 requires that for off-normal events, annual dose equivalent to any individual located beyond the controlled area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as a result of exposure to planned discharges to the general environment, direct radiation

from operations of the ISFSI, and cumulative radiation from uranium fuel cycle operations in the area. 10 CFR 72.106(b) requires that any individual located at or beyond the nearest controlled area boundary must not receive a dose greater than 5 rem to the whole body or any organ from any design basis accident.

C4-5.5.1 Earthquake

An earthquake is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. Earthquakes are associated with faults in the upper crust of the earth's surface. SSCs classified as Important to Safety are required to be designed to resist the effects of the design basis ground motion in accordance with the requirements of 10 CFR 72.122(b).

10 CFR Part 72.103, "Geological and Seismological Characteristics for Applications for Dry Cask Modes of Storage on or after October 16, 2003," gives requirements for determining Design Earthquake Ground Motion (DE) at sites for spent fuel storage, and NRC Regulatory Guide 3.73 "Site Evaluations and Design Earthquake Ground Motion for Dry Cask Independent Spent Fuel Storage and Monitored Retrievable Storage Installations" (Reference C4-12) provides guidance on applying the rules in Part 72.103 to arrive at an acceptable DE that satisfies the requirements of Part 72. In general, Part 72.103 allows use of a standardized DE described by an appropriate response spectrum anchored at 0.25 g for sites in non-seismically-active areas east of the Rocky Mountain Front and requires a seismic evaluation elsewhere. For the ISF, a probabilistically-derived horizontal ground acceleration design value of 0.75 g is used to provide a bounding value for all potential ISF sites.

Depending on the specific storage system, the acceptance criteria for seismic design may include some or all of the following:

i. The loaded overpacks will not impact each other during the DE event.
ii. The loaded overpack will not slide excessively.
iii. The loaded overpack will not tip over.
iv. The confinement boundary will not be breached.

C4-5.5.2 Tornado Winds and Missiles

The storage system is designed to withstand loads associated with the most severe meteorological conditions, including extreme winds, pressure differentials, and missiles generated by a tornado. The extreme design basis wind is derived from the design basis tornado. Extreme wind is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. The design basis tornado loading is defined for a given region (identified in NRC Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear

Power Plants" (Reference C4-13). It is conservatively assumed that Region I design basis tornado loading applies to the ISF. The design basis tornado wind loading for this region is defined as a tornado with a maximum wind speed of 230 mph and a 1.2 psi pressure drop occurring at a rate of 0.5 psi/sec.

In addition, the ISF is designed to withstand the effects of tornado-generated missiles that could be created by the passage of the tornado as identified in Regulatory Guide 1.76, Rev. 1, and discussed in Sections 3.3.2 (Tornado Loadings) and 3.5.1.4 (Missiles Generated by Extreme Winds) of NUREG 0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, (Reference C4-14). Tornado-driven missiles, identified in the following table, are assumed to impact a storage system in a manner that produces maximum damage. Regulatory Guide 1.76, Rev. 1, identifies the following design basis missiles for Region I:

Missile Description	Total Mass (lbs)	Velocity (mph)
Automobile	4000	92
Schedule 40 Pipe (6. 625 inch-diameter), 15 ft long	287	92
Solid Sphere (1-inch-diameter)	0.147	17.7

Alternatively, there are other spectrums of tornado missiles that have been accepted by the NRC (for which spent fuel storage systems have been qualified) that could be reviewed for potential use at the ISF.

The combination of tornado winds with the most massive missile, a 4,000 lb automobile traveling at 92 mph, needs to be evaluated in accordance with Section 3 of NUREG-0800, since it tests storage system stability. The wind tip-over moment is applied to the cask at its maximum rotation position following the worst-case missile strike. The schedule 40 pipe missile tests the capacity of the storage system to resist penetration, and the small solid steel sphere missile tests barrier openings. Canister tip-over potential and reduction in shielding from tornado-borne projectile strikes are evaluated.

C4-5.5.3 Flood

Flooding is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9. 10 CFR 72.122(b)(2) requires that SSCs Important to Safety must be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lighting, hurricanes, floods, tsunami, and seiches, without impairing their capability to perform safety functions.

The probable maximum flood (PMF) is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions.

Other potential sources of flooding considered include effects from an upstream dam breach, seismically induced flooding due to landslides in the site area, occurrence of the PMF with superposition of wind-wave activity on nearby water bodies, flooding due to tsunamis and ice conditions, and flooding from local intense precipitation.

The storage system is designed to withstand severe flooding, including pressure and water forces associated with deep and moving flood waters. Resultant loads on the storage system consist of buoyancy effects, static pressure loads, and velocity pressure due to water velocity. The flood is assumed to deeply submerge the storage system without the canisters collapsing, buckling, or allowing water in-leakage under the hydrostatic pressure from the flood; and, where applicable, without sliding and cask tip-over occurring. Full blockage of the air inlets by submergence in water is addressed by emergency action planning based on the individual storage device's capabilities. For more information on blockage of air inlets, refer to "Loss of Cooling Accident."

C4-5.5.4 Fire

Fire is classified as a human-induced Design Event IV as defined in ANSI/ANS-57.9. The storage system must withstand elevated temperatures due to a fire event. Credible fires from various sources such as buildings, fuel spills, and other combustible materials are analyzed for heat flux using standard analysis techniques from NFPA and compared with acceptance criteria for the storage system. Possible effects from wildfires are also evaluated, addressing fire magnitude, duration, propagation, and heat generation.

Fires analyzed include those that could occur during transfer operations and those affecting stored fuel. Canister integrity during smaller fire events is qualified by heat flux comparison with a bounding fire for which an approved canister analysis has been performed. Fires affecting structures in which transfer operations and storage of fuel occur have been analyzed to ensure continued reliability.

Based on the analyses, the canister storage and transfer systems meet the general design criteria of 10 CFR 72.122(c), which states that SSCs Important to Safety must be designed and located so that they can continue to perform their safety functions effectively under credible fire exposure conditions. A fire at the ISF (or a wildfire adjacent to the ISF

Protected Area) would not cause a radioactive release, even if no credit were taken for firefighting by personnel or for automatic fire detection/suppression systems.

C4-5.5.5 Explosion

Explosion is classified as a human-induced Design Event IV as defined in ANSI/ANS-57.9. The ISF storage system must withstand loads due to an explosion. Potential onsite (internal and external) and offsite explosions are investigated.

NRC Regulatory Guide 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plants" (Reference C4-15) provides guidance for calculating safe distances from transportation routes, based on calculated overpressures at various distances created by postulated explosions from accidents. The Regulatory Guide indicates that overpressures which do not exceed 1 psi at the storage site would not cause significant damage and states:

> under these conditions, a detailed review of the transport of explosives on these transportation routes would not be required.

In lieu of the 1 psi overpressure selected in the Regulatory Guide, the overpressure for which the storage system is qualified (e.g., 3 psi, 5 psi, 10 psi) is used to determine the safe standoff distance from the source of the potential explosion.

There are no credible internal explosive events since the canister is comprised of non-explosive materials, it is filled with an inert gas, and materials are compatible with the operating environment. Likewise, the mandatory use of the protective measures at the ISF site to prevent fires and explosions and the absence of any need for an explosive material during canister loading, transfer, and unloading operations eliminates the scenario of an onsite explosion as a credible event, except during canister movement, which requires investigation of any nearby onsite-specific potential explosive sources.

Any design basis overpressure from an offsite explosion (e.g., from a truck, rail car, barge, fuel storage tank, munition depot, chemical processing plant, petroleum refinery, natural gas facility, etc.) must be investigated and, if credible, analyzed.

Based on the analyses, the canister storage and transfer systems meet the general design criteria of 10 CFR 72.122(c), which states that SSCs Important to Safety must be designed and located so that they can continue to perform their safety functions effectively under credible explosion exposure conditions.

C4-5.5.6 Canister Drop Accident

NUREG-1567 considers both off-normal cask drops and more severe cask drop accidents. With regards to an off-normal event involving a cask drop that is less than the design allowable lift height, Section 15.5.1.1 of NUREG-1567 states:

> The drop of the confinement cask at less than design allowable height is one of the hypothetical off-normal scenarios that the applicant must evaluate. The evaluation must show that the cask integrity and fuel spacing geometry are not compromised if the cask is dropped from a relatively low height. It must also show that the cask will continue to store fuel safely after such a drop.

For accident conditions, the hypothetical drop of a storage canister is classified as Design Event IV as defined by ANSI/ANS-57.9.

With regards to a cask drop accident, Section 15.5.2.2 of NUREG-1567 identifies the key items to be evaluated assuming a cask drop, including decelerations, evaluation of calculated stress intensities against the allowable stresses identified in the applicable code, evaluation of buckling stability for each component of the cask confinement subjected to compressive loading, and evaluation of deformation of cask internal members that could contribute to fuel assembly spacing geometry (for criticality concerns). While this guidance may apply to transport casks that do provide a confinement boundary, it may not be directly applicable to the transfer casks that are used to transfer canisters from transport casks to storage overpacks. In addition, in the event the spent fuel cask handling systems meet the NRC criteria for “single-failure-proof” (discussed in Section 9.1.5 of NUREG-0800, "Overhead Heavy Load Handling Systems”), the NRC does not require a cask drop accident to be postulated nor its consequences to be analyzed.

Within the alternative storage systems, there are two basic drop situations, with certain potential drop accidents that necessitate analysis and/or operational restrictions, as identified below:

(1) Handling inside the transport cask receiving structure and canister transfer facility:

- A drop of the transport cask with its impact limiters removed prior to being handled by the single-failure-proof crane requires analysis and operational restrictions.

- Transport cask drop accidents (other than above) and transfer cask drop accidents are precluded by the use of a single-failure-proof handling system, consisting of an overhead crane whose main hoist meets the NRC criteria for a single-failure-proof crane (i.e., NUREG-0554, "Single-Failure-Proof Cranes for Nuclear Power Plants," (Reference C4-16) or ASME NOG-1, "Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)" (Reference C4-17)).

(2) Handling outside the transport cask receiving structure and canister transfer facility (i.e., during cask transfer to the storage area):

- For some transport systems, it is required to assume a cask drop and, therefore, the lift height is limited to a height that has been fully analyzed for the assumed cask drop accident (e.g., TransNuclear transfer casks and NAC storage casks).

- For other systems (e.g., Holtec Vertical Cask Transporter), the lifting apparatus is required to meet ANSI N14.6 "American National Standard for Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10 000 Pounds (4500 kg) or More" (Reference C4-18) criteria for allowable stresses and to have redundant drop protection features. For these systems, no height restriction is required for cask transfer.

- For potential drops when a canister is being handled, lifts of canisters loaded with spent nuclear fuel are performed using single-failure-proof equipment and lifting devices that comply with the stress limits of ANSI N14.6 and have redundant drop protection to render an uncontrolled lowering of the payload non-credible, so a canister drop accident need not be postulated.

C4-5.5.7 Loss of Cooling Accident (LOCA)

The various spent fuel storage system alternatives all use passive air cooling of the dry storage canisters. The cooling air flow is driven by natural convection with cool air at ambient temperature entering the canister storage area near the bottom of the canister(s), rising as it is heated by the relatively hot outer surface of the canister(s), and exiting the canister storage area by outlet vents above the canisters.

It is credible that various types of debris or materials such as plastic sheets could blow into the canister storage area and block some of the air vents, thus reducing air flow and causing canister temperatures and spent fuel cladding temperatures to increase. Complete blockage of the air inlet ducts is classified as a Design Event IV accident condition as defined by ANSI/ANS-57.9. In addition, partial blockage of the cooling air vents is also analyzed as an off-normal condition, such as by assuming that one-half of the area of the air inlet vents is blocked. Thermal analyses are required to be performed to determine storage system temperatures, including canister and spent fuel cladding temperatures. The resulting temperatures are compared with the applicable temperature limits for off-normal (partial vent blockage) and accident or faulted conditions (complete blockage of air inlets).

Typically, the thermal analysis of partial blockage determines final steady-state temperatures of the storage system that result from the reduced air flow rates and these are compared to the maximum allowable temperatures of the various components to demonstrate the storage system can acceptably withstand this partial blockage with no operator actions.

For the accident condition involving postulated complete blockage of the air inlet vents, a transient thermal analysis is performed that determines the time at which temperatures of storage system components that are classified as Important to Safety exceed their maximum allowable temperatures for accident conditions, such as spent fuel cladding, canister confinement or canister basket material temperatures. This time is then used to establish a conservative required frequency of inspection or temperature monitoring of the storage system that ensures temperature limits will not be exceeded. This inspection frequency is then incorporated into the Technical Specifications that govern operations of the spent fuel storage facility. With regard to this inspection frequency requirement, Section 6.5.1.1 of NUREG-1567 recommends the following paragraph be incorporated into the Technical Specifications, based on results of the accident analysis that assumes complete blockage of air inlet vents:

> Surveillance requirement: Periodic surveillance will be performed to ensure that there is no blockage of cooling air flow in the heat removal system. This surveillance [typically based on the minimum time for stored material cladding or other material Important to Safety (e.g., shielding) to reach a threshold temperature in the event of a complete blockage occurring immediately following the prior surveillance.

Surveillance of cooling air vents for blockage can either be performed by visual inspection of the air inlet and outlet vents or by checking temperature readings of the temperature monitoring system to verify temperatures for each storage system are within allowable limits. ISFSIs frequently use temperature detectors mounted in the outlet vents to assess the performance of the natural convection air cooling system, since blockage of cooling air vents will result in reduced airflow with consequent increased air outlet temperatures. For ISFSIs with a relatively large number of storage systems, temperature monitoring is used to ensure worker doses are ALARA, since significant dose can be accrued by workers performing routine inspections of storage system air vents (typically, daily inspections are required), which requires the inspector to be in the near vicinity of the spent fuel storage systems.

C4-5.5.8 Off-Normal and Extreme Environmental Temperature

Ambient environmental temperatures must be evaluated for periods during which handling operations take place and also for the long time period over which spent fuel storage will occur. The various cask vendors have analyzed their products for intended use typically to cover all ISFSI sites in the continental U.S.

Minimum short-term temperature limitations are specified to ensure a sufficient safety margin against brittle fracture during handling. A typical operational limitation would be around 0°F, so it is likely that operational temperature restrictions imposed for other reasons may be more stringent (e.g., the minimum allowable temperature for crane operation). The lower bound off-normal temperature limit, applicable to long-term storage, is typically about -40°F.

Storage systems are designed for upper bound off-normal temperatures in the range of about 100°F, which is assumed to persist for a sufficient duration to allow the system to reach thermal equilibrium. The accident condition extreme ambient environmental temperature is typically around 125°F. Upper bound limitations are based on analyses that determine the storage system's ability to properly convey heat away from the spent fuel. Extreme environmental temperature is classified as a natural phenomenon Design Event IV as defined in ANSI/ANS-57.9.

C4-5.5.9 Lightning

Lightning is classified as a natural phenomenon Design Event III as defined in ANSI/ANS-57.9. Because a direct lightning strike of a storage SSC is a credible occurrence, the ISF storage system must withstand loads due to lightning, with the canister retaining its confinement integrity, and thereby preventing release of radioactivity. The lightning path to ground will vary, depending on the storage system alternative; but for each alternative, the canister will be protected from the effects of a lightning strike. (For example, for above-ground vertical cask storage, the steel shell of the overpack will convey the lightning to ground and the lightning will not pass through the canister, which is surrounded by the cask steel, so the strike will not affect the canister integrity.) Therefore, no offsite doses would result from this accident.

C4-5.5.10 C4 Alternative Applicability

Each of the previously discussed design basis accidents for each alternative will be slightly different since each of the alternatives' design handles each of the accidents differently. The Above list summarizes the applicability of the accidents with regard to Alternative C4 (S-AGV):

1. Seismic (C4-5.5.1)

   The S-AGV will be designed to adhere fully to the requirements discussed in C4-5.5.1. A site-specific seismic analysis will be performed to ensure all components of the S-AGV are qualified for the chosen ISF site's seismic input. Since the vault is underground, the seismic input will be reduced.

2. Tornado Winds / Missiles (C4-5.5.2)

   The S-AGV will be qualified to the NRC's tornado winds and missile criteria as discussed in C4-5.5.2. While the vault itself and the exhaust stack will be required to withstand the tornado wind forces, the building around the vault will employ blow-off panels to reduce the wind forces on the superstructure. The vault structure and exhaust chimney will be analyzed to withstand the design basis tornado missiles as discussed in C4-5.5.2

3. Flooding (C4-5.5.3)

   The S-AGV will comply with all flooding requirements discussed in C4-5.5.3. Flooding is of particular concern with an underground vault system as the air inlet vent is Above grade and will thus be required to have a drain system in order to preclude the vent from being completely blocked by water.

4. Fire (C4-5.5.4)

   The S-AGV will comply with all fire protection requirements discussed in C4-5.5.4, including fire sources from nearby buildings, fuel spills, combustibles, and wildfires. This will also include internal fuel spills as the cask handling building will be integral with the vault and will required to be analyzed to ensure the STAD canisters' shell temperature is not exceeded during a design basis fire.

5. Explosion (C4-5.5.5)

   The S-AGV will comply with all explosion requirements from NRC Reg Guide 1.91 as discussed in C4-5.5.5. Since the vault would be underground, the exposure of the STAD canisters to an explosion risk is minimal.

6. Canister Drop Accident (C4-5.5.6)

   The S-AGV system will comply with all canister drop requirements from NUREG-1567 as discussed in C4-5.5.6. All material handling systems will be classified as Single-Failure-Proof as and thus does not require postulation of a dropped STAD canister.

7. Loss of Cooling Accident (LOCA) (C4-5.5.7)

   The S-AGV will comply with all LOCA requirements discussed in C4-5.5.7. The S-AGV alternative will use passive air cooling of the STAD canisters through an underground vault. The cooling air flow is driven by natural convection with cool air at ambient temperature entering the vault near grade level, passing through the vault, and rising as it is heated by the relatively hot outer surface of the canisters, and exiting the vault by outlet vents through a building chimney.

8. Off-Normal and Extreme Environmental Temperature (C4-5.5.8)

   The S-AGV will comply with all off-normal and extreme environment temperature requirements discussed in C4-5.5.8 based on the environmental minimum and maximum temperatures at the ISF site.

9. Lightning (C4-5.5.9)

   The S-AGV will comply with all lightning requirements discussed in C4-5.5.9.

C4-5.6 Licensing Evaluation

C4-5.6.1 Overview

10 CFR Part 72 governs ISFSI licensing. There are two options for licensing an ISFSI: (1) a specific license and (2) a general license. However, 10 CFR 72.210 only authorizes the use of a general license at a power reactor site with a 10 CFR Part 50 or 10 CFR Part 52 license. Since it is not anticipated that the ISF would be located at the site of a nuclear power plant, the ISF would be governed by a 10 CFR Part 72 specific license.

The process for obtaining a specific ISFSI license is similar to that for obtaining a license for a fuel cycle facility under 10 CFR Part 70 (Reference C4-19). The applicant submits a License Application (LA) in accordance with 10 CFR 72.16 that includes the information required by 10 CFR 72.22 through 10 CFR 72.28. The primary documents comprising the LA are as follows:

- Safety Analysis Report (SAR) that assesses safety of the storage system and the ISFSI facility (used as basis for NRC preparation of the Safety Evaluation Report)
- Environmental Report (used as basis for NRC preparation of the Environment Impact Statement)
- Proposed Technical Specifications
- Quality Assurance (QA) program
- Decommissioning Plan
- Emergency Plan
- Security Plan

C4-5.6.2 Licensing Process

Upon receipt of the application, the NRC establishes a docket number and reviews the application for completeness. If the application is deemed complete, the NRC prepares and publishes a notice of docketing in the Federal Register (FR). The notice of docketing identifies the site of the ISF and includes either a notice of hearing or a notice of proposed action and opportunity for hearing pursuant to 10 CFR 72.46. 10 CFR 72.46 provides the regulations governing the hearing process with references to 10 CFR Part 2 (Reference C4-20), as appropriate.

The NRC will request a hearing upon the notice of docketing if a statute specifically requires it, or if they believe it to be in the public interest, notwithstanding any requests for hearing submitted by parties who believe they having standing in the licensing action. 10 CFR 2.105(a)(7) specifies that if the NRC is not required by statute to conduct a hearing and does not find that a hearing is in the public interest, a notice of proposed action is instead published in the FR.

The notice of proposed action includes the time frame for any person whose interest may be affected by the proceeding to file a request for a hearing or a petition for leave to intervene if a hearing has already been requested. A request for hearing on a 10 CFR Part 72 License Application must be submitted, with the contentions upon which the hearing would be litigated, within 60 days of the notice of docketing. It is worth noting that if the 10 CFR Part 72 specific license applicant is incorporating design information pertaining to a previously NRC-certified spent fuel storage cask design by reference into the application, any hearing held to consider the application will not include any cask design issues pursuant to 10 CFR 72.46(e).

If any requests for hearing are received on the notice or proposed action, the NRC will establish an Atomic Safety Licensing Board (ASLB) to review the hearing requests and contentions for admittance. For the ASLB to admit a contention and grant a hearing, the requestor needs to have standing in the proceeding per 10 CFR 2.309(d), and at least one contention must meet the criteria in 10 CFR 2.309(f). The NRC may also permit discretionary intervention of someone not having standing under the strict requirements of 10 CFR 2.309(e).

Admitted contentions are litigated through a review of documents submitted by the petitioner and may require court testimony and/or documents to be submitted by the applicant, at the discretion of the ASLB. Hearings would take place after issuance of the Final Environmental Impact Statement (EIS). The ASLB may decide to start the hearings prior to completion of the NRC staff Safety Evaluation Report (SER). A license would not be granted until all hearings are completed and the contentions resolved in favor of the applicant. At that point, the Director of the Office of Nuclear Material Safety and Safeguards would request Commission authorization to issue the license pursuant to 10 CFR 72.46(d). While petitioners may appeal the resolution of contentions in the courts, the license would likely be issued without awaiting resolution of those court appeals.

The NRC reviews the application for a specific license, and generally there are several rounds of requests for additional information.

10 CFR 72.42, Duration of License; Renewal, paragraph (a) states the following:

> Each license issued under this part must be for a fixed period of time to be specified in the license. The license term for an ISFSI must not exceed 40 years from the date of issuance. The license term for an MRS must not exceed 40 years from the date of issuance. Licenses for either type of installation may be renewed by the Commission at the expiration of the license term upon application by the licensee for a period not to exceed 40 years and under the requirements of this rule.

C4-5.6.3 License Application

NUREG-1571, "NRC Information Handbook on Independent Spent Fuel Storage Installations," (Reference C3-21) summarizes key requirements for a specific license application, as follows:

- Siting Evaluation Factors (10 CFR 72 Subpart E)—The site characteristics, including external, natural, and manmade events, that may directly affect the safety or the environmental impact of the ISFSI.

- General Design Criteria (10 CFR 72 Subpart F)—Applies to the design, fabrication, construction, testing, maintenance, and performance requirements for structures, systems, and components important to safety.

- Quality Assurance (10 CFR 72 Subpart G)—The planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service as applied to design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, modification, and decommissioning.

- Physical Protection (10 CFR 72 Subpart H)—The detailed plans for ISFSI security.

- Personnel Training (10 CFR 72 Subpart I)—The program for training, proficiency testing, and certification of ISFSI personnel who operate equipment or controls important to safety.

The NRC will review the specific license application and complete an evaluation of potential environmental impacts of the ISFSI in accordance with the National Environmental Policy Act of 1969 (NEPA), as amended (Reference C4-22). The NRC will prepare an EIS in accordance with 10 CFR Part 51 (Reference C4-23). Following its safety review and resolution of comments, the NRC issues a Materials License along with its SER and final EIS. The SER describes the conclusions of the staff's safety review based on the applicant's SAR and assesses the technical adequacy of the ISFSI and the spent fuel storage system(s).

Safety Analysis Report

The level of effort associated with preparation of the ISFSI SAR for a specific license can be reduced considerably by taking advantage of the permission granted in 10 CFR 72.46(e) to select storage systems with SARs that have been reviewed and approved by the NRC (with Certificate of Compliances [CoC] having been issued for the storage systems), or storage systems that are currently undergoing NRC review per 10 CFR 72, Subpart L. 10 CFR 72.46(e) states: "If an application for (or an amendment to) a specific license issued under this part incorporates by reference information on the design of a spent fuel storage cask for which NRC approval pursuant to subpart L of this part has been issued or is being sought, the scope of any public hearing held to consider the application will not include any cask design issues." With this approach, the NRC will focus its review on site-specific issues and storage system/site interface issues. This helps streamline the specific licensing process. Should the applicant select a storage system that has neither been reviewed and approved by the NRC nor is currently undergoing NRC review, the NRC must review information associated with the proposed spent fuel storage system as part of the specific license application, which would extend the review time.

Detailed guidance as to information that needs to be included in the ISFSI SAR that is submitted with the license application is provided by Regulatory Guide 3.48, "Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage)" (Reference C3-24). Additional information to enable the NRC staff review in accordance with NUREG-1567 should also be included in the SAR, along with information from any applicable NRC Interim Staff Guidance (ISG). The SAR for the ISF will need to identify and evaluate each of the storage systems that will be used at the ISF to store SNF. For each individual system, the ISF SAR will need to address the following key topics specified in the NUREG-1567 Standard Review Plan:

- General description of the storage system
- Design criteria
- Structural evaluation

- Thermal evaluation
- Shielding evaluation
- Criticality evaluation
- Confinement evaluation
- Material evaluation
- Operating procedures
- Acceptance tests and maintenance program
- Radiation protection (occupational exposures, public exposures, ALARA measures)
- Accident analyses
- Operating controls (technical specifications)
- Quality assurance
- Decommissioning

The previous topics are addressed in the storage system vendors' SARs that have been approved by the NRC for general and specific ISFSI licenses; these documents can be incorporated by reference into the ISF SAR. It is envisioned that the ISF SAR will have a main body that describes and analyzes the ISF design and generic operations, with a separate appendix that serves as the SAR for each individual storage system. The ISF SAR will benefit in that it will primarily use SNF storage systems that have already been licensed under the provisions of 10 CFR Part 72, Subpart K, and have existing Final Safety Analysis Reports (FSARs) that have been approved by the NRC and can be referenced. A specific revision of the vendors' FSARs would need to be chosen for incorporation into the ISF ISFSI SAR. Changes to the vendors' FSARs thereafter would not automatically be incorporated by reference into the ISF SAR, but would require evaluation by the ISF license applicant for incorporation.

The SAR would include descriptions of the safety analyses and other technical evaluations for the ISFSI in each SAR chapter, incorporating by reference any required information for the storage system designs. The format and content would coincide with the chapters of the SRP in NUREG-1567 and any applicable Interim Staff Guidance documents amending that guidance. Formatting the ISFSI SAR in this manner sets the stage for a more efficient NRC technical review because the SRP establishes the format and content template for the NRC's SER.

Environmental Report

The Environmental Report (ER) that is submitted with the License Application is prepared to address the requirements of Subpart E of 10 CFR Part 72, Siting Evaluation Factors, and Subpart A of 10 CFR Part 51, National Environmental Policy Act - Regulations

Implementing Section 102(2), using the guidance provided in NRC NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs," (Reference C4-25). The ER contains the following key topics:

- General description of the proposed activities and discussion of need for the facility
- Site interfaces with the environment, including geography, demography, land use, ecology, climatology, hydrology, geology and seismology, historical and cultural features, and background radiation levels.
- Description of the facility, including appearance, construction, operations and effluent control
- Environmental effects of facility construction and operation, including transportation of radioactive material, and effects of decontamination and decommissioning
- Environmental effects of accidents involving radioactive materials, including transportation accidents
- Proposed environmental monitoring programs
- Economic and social effects of facility construction and operation, including cost benefit analysis
- Facility siting (site selection process) and design alternatives
- Environmental approvals including federal, state, and local regulations and permits

As noted above, the NRC will need to prepare a complete EIS for the ISF based on the ER submitted by the licensee, in accordance with 10 CFR Part 51 requirements.

Upon receipt of would be required in the License Application are discussed in the following paragraphs.

Alternative 4, Above Grade Vault Storage

Like Alternative 3, the use of a vault does away with pad storage and places each STAD canister into a large self-contained vault module structure. The ISFSI at the former Fort St. Vrain (FSV) reactor site in Colorado uses the Modular Vault Dry Store (MVDS) system in an above grade vault. The FSV MVDS has a specific license (Materials License No. SNM-2504), so has its own SAR and Technical Specification, with analyses specific to the FSV site. Vaults are designed as robust, hardened reinforced concrete structures. The vaults are typically laid out so that the STAD canisters can be hung from a concrete floor much like a test tube rack, with a support stool at the bottom of each canister that the canister bottom rests upon. An overhead bridge crane can access the entire vault storage area and provides the means to move STAD canisters from the unloading point where STAD canisters are removed from transport casks to the STAD canister's designated storage position. At the FSV MVDS, a canister handling machine is used for movement of a STAD canister between the transport cask unload port and the port on the operating floor through which the canister is lowered into its storage vault. Following loading of a STAD canister into its storage vault, a large shield plug is placed in the port in the operating floor to provide radiation shielding above the top of the canister, to attenuate dose rates so workers can walk across the operating floor and not receive significant doses. Cooling of the STAD canisters is accomplished by means of passive chimney stack effect from an inlet vent in the front of the vault through the STAD canister storage area to a chimney where air exits from the back of a vault, with chimney height designed to draw the desired air flow. The entire facility is enclosed with walls and a roof. The vault width is typically limited to the span of the bridge crane and can be of various lengths to accommodate the desired storage capacity.

The above grade vault would be designed so that the bottom slab of the storage area would be at ground level and the STAD canister storage area would be above grade. The above grade vault positions the STAD canisters so that direct radiation from the sides of STAD canisters must be shielded by the vault walls.

All operations such as STAD canister offload from a transport cask, STAD canister transfer from the transport cask to the canister handling machine and from the canister handling machine into the STAD canister storage vault, are performed within the MVDS structure if the CHB is integral to the vault or performed in the CHB if it is a standalone structure.

There are significant licensing challenges with Alternative 4 since vault storage for large commercial STAD canisters is still conceptual, unlike other storage methods. In order to store 450 STAD canisters, a vault 100 ft in width would need to be about 800 ft long increasing the complexity of the structure. The canisters (fuel storage containers) at FSV are carbon steel cylinders one-half inch thick, 16 ft long but only 18 inches diameter, so designed for a single column of fuel (which at FSV consists of 6 graphite blocks stacked end-to-end). The FSV canister lid is 1.5 inches thick bolted to the body of the canister by means of 24 one-half inch diameter steel bolts sealed with double metal O-rings. For this type of canister closure, leakage of the gas inside the canister to atmosphere is a credible event, so the FSV SAR assumes leakage of fission products past the O-ring seals in what is termed the "Maximum Credible Accident in the FSV SAR." For storage of commercial STAD canisters with their redundant seal welded closure lids, accidents involving leakage of STAD canisters are not credible and not required to be postulated or analyzed in the ISF SAR.

Canisters stored in the existing FSV vaults do not have the increased performance issues such as weight and thermal loading characteristic of commercial STAD canisters. Since the performance capability of a vault is unknown, rigorous analyses will need to be performed to show that the STAD canisters could be safely stored in a vault, the vault could perform as desired, and the results of these analyses described in the ISF SAR. These analyses would include structural, thermal and radiation shielding analyses of the STAD canisters in vault storage. In addition, it is considered that criticality analyses will be necessary since there is potential for neutrons from one STAD canister reaching adjacent STAD canisters due to the relatively close packing of canisters stored in vaults with no intervening materials that would shield and attenuate the neutron flux.

Most STAD canisters in existing dry fuel storage systems will have a much higher decay heat release rate than the FSV canisters. When canisters were initially loaded into the FSV MVDS, a canister containing average decay heat fuel elements would have 330 watts total decay heat. In contrast, a single commercial STAD canister could have up to 100 times this heat release rate, or on the order of 33 kW. The thermal study performed by CB&I for this task order determined that heat removal using the chimney stack effect for natural convection cooling in a vault is limited to thermal outputs much less than the licensed limits in existing commercial STAD canister storage methods. STAD canisters with hotter SNF may not be able to be adequately cooled in a vault which would require longer pool cooling prior to storage. This would need to be addressed in the ISF SAR and the ISF licensing process.

Design and licensing tasks would be extensive and involve significantly more time than the other storage methods. As noted above, the FSV MVDS is operated under a specific ISFSI license and the FSV SAR cannot be referenced under as is the case for FSARs associated with an ISFSI general license. In addition, the NRC has never licensed a vault system for storing large commercial STAD canisters. The performance characteristics of a vault would need to be licensed as part of the ISF Specific License which would require considerable development in the ISF SAR costing more NRC review time.

C4-5.7 Security Evaluation

The purpose of security at an interim storage facility is to protect the SNF against acts of radiological sabotage and theft or diversion that could lead to an unreasonable risk to the health and safety of the public. The ISF must meet the requirements of 10 CFR 73 (Reference C4-26). In order to accomplish this task the ISF will need to establish and maintain a physical protection system which consists of the following:

- Controlled access
- Visual surveillance

- Detection and assessment of unauthorized individuals
- Adversary response
- Measures to resistance to explosive devices

The physical security systems must be designed to protect against loss of control of the ISF.

Controlled Access

Controlled access is maintaining control of a clearly demarcated area and isolation of the material or persons within it. The features at the ISF that afford controlled access include a fenced Owner Controlled Area (OCA) typically established at the property boundaries, vehicular access gates into the property where security personnel can verify the identification and authorization of all persons and vehicles entering the site, a Protected Area (PA) with two physical barriers (fences or structures) designed to thwart physical intrusion, and personnel and vehicle access barriers into the PA. All of these features are required of the ISF regardless of the storage system utilized. However, the area required may vary depending on the storage alternative used thus affecting the OCA and PA boundary distances.

For S-AGV storage, the PA will need to be approximately 250 acres in size which would require a perimeter fence roughly 2- 3 miles in length.

Visual Surveillance

Visual surveillance is establishing security guards around the PA who maintain an unobstructed view of the PA at all times. This may be performed from bullet resistant enclosures (BREs) placed around the PA which are occupied by security guards, closed circuit TV (CCTV) cameras that are viewed by security guards at the Central Alarm Station (CAS) or secondary Alarm Station (SAS) or security guards patrolling the site. BREs are situated at strategic locations within the PA to provide protected locations for security force personnel during a security event.

Vault storage has a major advantage in that few exterior and interior BREs or cameras are required to maintain line of sight around and within the vault storage area. Since all storage is within a secured building, there are very few security risks to the canisters.

Detection and assessment of unauthorized individuals

Detection of unauthorized individuals is maintained by establishing an intrusion detection system that can detect unauthorized penetration through the isolation zone located between the PA boundary fences and tamper devices on doors and equipment that send an alarm to alert security staff when the PA or security equipment is breached. Assessment of unauthorized individual is established by illuminating the PA with sufficient lighting that security guards can adequately determine the nature of the intrusion either visually or by the CCTV system. The intrusion and CCTV systems are monitored continually by security staff at the CAS and SAS.

S-AGV storage will not affect the detection and assessment capabilities as the initial PA will encompass the size of the expanded S-AGV.

Adversary Response

Adversary response is the ability to prevent or delay the attempted theft of SNF or radiological sabotage by armed response personnel. Adversary response also includes the ability to provide timely communication to a designated response force such as the local law enforcement agency whenever necessary.

S-AGV storage will not affect adversary response since this is primarily a function of the vault building, security staff and communication equipment.

Measures to resistance to explosive devices

Resistance to explosive devices intended to disable security personnel or radiological sabotage is maintained by establishing engineered barriers that prevent such explosions from damaging SNF storage containers or disabling security personnel. Engineered barriers consist of access points designed to slow the speed of approaching vehicles by turns, speed humps, or a serpentine design and a vehicle barrier system (VBS) made of thick reinforce concrete walls or heavy steel portal gates that are installed at a prescribed distance from the SNF or cask handling activities. The VBS prevents entry of vehicle-borne explosive devices. Its distance from the storage area minimizes the impact of an explosion if one were to occur.

Resistance to explosive devices is also maintained by passing persons through explosive and metal detectors, checking all hand-carried items by X-ray machines and inspecting all vehicles and deliveries by security personnel.

Since the entire system is within an Above-Grade Vault within a secured building, the S-AGV storage system has excellent resistance to high explosion pressure waves. This ability enables the VBS to be placed much closer to the PA which effectively reduces the overall footprint of the PA.

C4-6.0 Summary

In general, the use of STAD canisters offers a standardized method of SNF storage. Use of a single storage system simplifies handling equipment and operations. Only one storage overpack and concrete storage pad design is required which reduces analyses, design and licensing time.

There are also dry cask storage industry issues that can be resolved with STAD canisters. Elimination of the need to affix a temporary lifting lug to the top of the STAD canister would significantly reduce dose rates. Also the transport cask could be designed with lids on either end so that traditional canister transfer is eliminated and the canister could be directly transferred into a storage unit from the transport cask.

STAD canisters represent a marked increase in the number of units required due to the reduced capacity from current commercial storage systems. This increase will affect the cost as a whole. The size of the STAD canister also factors into the cost – the more canisters required, the higher the costs. The use of a 4-pack container for the small STAD canisters helps defray some of the storage issues as well as cost. STAD canisters contain fewer assemblies than a current DPCs being used in the industry. This means that for a given amount of effort less MTHM will be placed into storage. Instead of 450 overpacks as in other commercial alternatives, the STAD canister forces the use of between 500 and 1000 overpacks, depending on the size STAD canister ultimately selected. The storage pad would need to be substantially larger for STAD canister alternatives and the cost could be a significant penalty.

STAD canisters do not currently exist and no design standard has been accepted. Moreover, the NRC has not reviewed STAD canisters yet in any licensing application, so it is not clear what the final configuration of STAD canisters will be. Likewise, there eventually will need to be a transfer system developed that takes SNF assemblies out of their NRC-licensed canisters and to repackage them in STAD canisters. The process for doing this is undefined, it is not licensed, and there are no facilities available to make this exchange.

In summary, the pros and cons of this alternative in comparison with the other alternative using STAD canisters is listed from the highest most significant impact to the lowest least significant impact are as follows:

<u>Pros</u>

- Since the STAD canister storage is effectively indoors, the vault alternative may provide a more controlled environment than other Alternatives. The STAD canisters are stored within the building largely away from the effects of weather (although there is some effect since the cooling air is drawn into the building past the STAD canisters. The STAD canisters would likely feel humidity changes during wetter weather and temperature changes between summer and winter).

- A vault shields STAD canisters from view, easing security concerns.
- A vault removes the possibility of STAD canister tipover caused by an earthquake or other postulated accidence since the STAD canisters are locked into position within the vault.

Cons

- A vault is a large nuclear structure impacted by potential seismic, construction, cost issues typically associated with large nuclear projects. In order to store 500 to 1,000 STAD canisters, a vault 100 feet in width would need to be between 1,000 and 2,000 feet long increasing the complexity of the structure.
- The thermal characteristics of STAD canisters are unknown. FSV canisters have relatively low energy densities compared to STAD canisters containing much hotter newer SNF. The study performed by CB&I determined that heat removal using stack effect in a vault is limited. Newer STAD canisters with hotter SNF may not be able to be adequately cooled in a vault which would require longer pool cooling prior to storage.
- The Above Grade Vault positions the STAD canisters so that direct radiation from the sides of STAD canisters must be shielded by thicker concrete walls.
- Higher structure and crane height from S-BGV requires increased strength to resist seismic loading.
- Vault throughput is limited due to cask handling congestion in the storage hall.

C4-7.0 References

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2. Transportation, Aging, and Disposal Canister System Performance Specification, DOE/RW-0585, US Department of Energy, Office of Civilian Waste Management, Revision 1/ICN 1, March, 2008.
3. 10 CFR 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste.
4. 10 CFR 71, Packaging and Transportation of Radioactive Material.
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6. NRC NUREG-1927, Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance, March 2011.
7. Draft Report for Comment, NRC NUREG-1927, Revision 1, Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel, 2015.
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12. NRC Regulatory Guide 3.73 Site Evaluations and Design Earthquake Ground Motion for Dry Cask Independent Spent Fuel Storage and Monitored Retrievable Storage Installations, October 2003.
13. NRC Regulatory Guide 1.76, Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants, Rev. 1, March 2007.

14. NRC NUREG 0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition.

15. NRC Regulatory Guide 1.91, Evaluations of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plants, Rev. 1, February 1978.

16. NRC NUREG-0554, Single-Failure-Proof Cranes for Nuclear Power Plants, May 1979.

17. ASME NOG-1, Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder), 2007.

18. ANSI N14.6 American National Standard for Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10 000 Pounds (4500 kg) or More, 1993.

19. 10 CFR 70, Domestic Licensing of Special Nuclear Material.

20. 10 CFR 2, Agency Rules of Practice and Procedure.

21. NUREG-1571, NRC Information Handbook on Independent Spent Fuel Storage Installations, December 1996.

22. National Environmental Policy Act of 1969 (NEPA), as amended.

23. 10 CFR 51, Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.

24. NRC Regulatory Guide 3.48, Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage), Rev. 1, 1989.

25. NRC NUREG-1748, Environmental Review Guidance for Licensing Actions Associated with NMSS Programs, August 2003.

26. 10 CFR 73, Physical Protection of Plants and Materials.

APPENDIX C5-1

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 1 - S-PAD 21P/44B, PILOT, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 21P/44B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB
Annual Escalation Factor 1.90%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$895,142,433*					*$895,142,433*
Operations & Maintenance (40 Year Life)		*$566,213,291*				*$566,213,291*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$96,490,672		*$96,490,672*
Escalation					$734,570,255	*$734,570,255*
Total Costs (40 year Life)						*$2,330,925,339*
Present Value						*$1,333,221,314*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$895,142,433*					*$895,142,433*
Operations & Maintenance (80 Year Life)		*$1,031,946,410*				*$1,031,946,410*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$96,490,672		*$96,490,672*
Escalation					$2,359,372,031	*$2,359,372,031*
Total Costs (80 Year Life)						*$4,421,460,234*
Present Value						$1,534,274,415

APPENDIX C5-1

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 1 - S-PAD 21P/44B, PILOT, LOW SEISMIC

CAPITAL COST SUMMARIES

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 21P/44B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-PAD EX 01			Interim Storage Facility and transportation Project		
	C-PAD EX 01.01		Pilot ISF Facility	$559,989,827	
		C-PAD EX 01.01.01	Storage Pads		$0
		C-PAD EX 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-PAD EX 01.01.03	Horizontal Dry Storage Modules		$131,695,971
		C-PAD EX 01.01.04	Vertical Dry Storage Module		$133,978,975
		C-PAD EX 01.01.05	Storage Cask Fabrication Facility		$0
		C-PAD EX 01.01.06	Cask Maintenance Facility		$0
		C-PAD EX 01.01.07	Concrete Batch Plant		$1,850,000
		C-PAD EX 01.01.08	Visitor Center/ Auditorium		$0
		C-PAD EX 01.01.09	Administration Building		$3,140,000
		C-PAD EX 01.01.10	Security		$24,148,975
		C-PAD EX 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-PAD EX 01.01.12	Utilities		$18,682,150
		C-PAD EX 01.01.13	Roads		$18,212,737
		C-PAD EX 01.01.14	Parking		$735,000
		C-PAD EX 01.01.15	Site Work		$23,417,500
		C-PAD EX 01.01.16	Warehouse		$10,200,000
		C-PAD EX 01.01.17	Maintenance Facility		$0
		C-PAD EX 01.01.18	Waste management Facility		$0
		C-PAD EX 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-PAD EX 01.02		Expanded Interim Storage Facility	$0	
		C-PAD EX 01.02.01	Expanded Storage Pads and Dry Cask Storage Systems		$0
		C-PAD EX 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-PAD EX 01.02.03	Horizontal Dry Storage Modules		$0
		C-PAD EX 01.02.04	Vertical Dry Storage Casks		$0
		C-PAD EX 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-PAD EX 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-PAD EX 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-PAD EX 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-PAD EX 01.02.09	Administration Building (Expanded if needed)		$0
		C-PAD EX 01.02.10	Security (Expanded)		$0
		C-PAD EX 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-PAD EX 01.02.12	Utilities Expanded as needed)		$0
		C-PAD EX 01.02.13	Roads (Expanded)		$0
		C-PAD EX 01.02.14	Parking (Expanded as needed)		$0
		C-PAD EX 01.02.15	Site Work (Expanded)		$0
		C-PAD EX 01.02.16	Warehouse (Expanded if Needed)		$0
		C-PAD EX 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-PAD EX 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-PAD EX 01.02.19	Hot Cell / Laboratories		$0
		C-PAD EX 01.02.20	Pool Packaging Facility		$0
		C-PAD EX 01.02.21	Standardized Storage System		$0
		C-PAD EX 01.02.22	Standardized Disposal Canister		$0
		C-PAD EX 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-PAD EX 01.03		Transportation Equipment	$0	
		C-PAD EX 01.03.01	Transportation Casks		$0
		C-PAD EX 01.03.02	Rail Equipment		$0
		C-PAD EX 01.03.03	Rail Maintenance Facility		$0
		C-PAD EX 01.03.04	Transportation Systems Services		$0
	C-PAD EX 01.04		Pre-Construction Capitalized Costs	$60,265,000	
		C-PAD EX 01.04.01	Land or Land Leases		$1,920,000
		C-PAD EX 01.04.02	Site permits		$200,000
		C-PAD EX 01.04.03	Site Licensing		$6,240,000
		C-PAD EX 01.04.05	Plant Permits		$0
		C-PAD EX 01.04.06	Planning and Alternative Studies		$750,000

	C-PAD EX 01.04.07	Research and Development		$0
	C-PAD EX 01.04.08	Design		$23,955,000
	C-PAD EX 01.04.09	Other Pre-construction Costs		$17,200,000
	C-PAD EX 01.04.10	Pre-construction contingencies		$10,000,000
	C-PAD EX 01.04.xx	(Add Further Breakdown as needed)		$0
C-PAD EX 01.05		Indirect Capitalized Costs	$63,180,000	
	C-PAD EX 01.05.01	Project Management		$2,700,000
	C-PAD EX 01.05.02	Construction Management		$3,600,000
	C-PAD EX 01.05.03	Field indirect services		$11,880,000
	C-PAD EX 01.05.o4	Design Services in support of Construction		$5,400,000
	C-PAD EX 01.05.05	QA/QC		$12,600,000
	C-PAD EX 01.05.06	Commissioning and Startup		$1,200,000
	C-PAD EX 01.05.07	Home office Engineering support to Construction		$7,200,000
	C-PAD EX 01.05.08	Document Control		$2,700,000
	C-PAD EX 01.05.09	Project Controls		$3,600,000
	C-PAD EX 01.05.10	Construction Testing		$2,700,000
	C-PAD EX 01.05.11	Inspections		$3,600,000
	C-PAD EX 01.05.12	Startup and Testing		$3,000,000
	C-PAD EX 01.05.13	Commissioning		$3,000,000
C-PAD EX 01.06		Site Selection	$0	
	C-PAD EX 01.06.01	Site Selection		$0
	C-PAD EX 01.06.02	Public Information Process		$0
C-PAD EX 01.07		Decontamination and Deconstruction	$0	
	C-PAD EX 01.07.01	Decommissioning		$0
	C-PAD EX 01.07.02	Decontamination		$0
	C-PAD EX 01.07.03	Deconstruction		$0
	C-PAD EX 01.07.04			$0
	C-PAD EX 01.07.05			$0
C-PAD EX 01.08		Project Financial Costs	$91,580,267	
	C-PAD EX 01.08.01	Contractor Fees		$54,674,786
	C-PAD EX 01.08.02	Escalation Costs		$36,905,481
	C-PAD EX 01.08.03	Interest Payments		$0
	C-PAD EX 01.08.04	Indirect costs to support shipments to repository		$0
	C-PAD EX 01.08.05			$0
	C-PAD EX 01.08.xx	(Add Further Breakdown as needed)		$0
C-PAD EX 01.09		Project Contingencies	$120,127,339	
	C-PAD EX 01.09.01	Management Reserve - Contractor Held		$38,750,755
	C-PAD EX 01.09.02	Contingency - DOE held		$81,376,585
C-PAD EX 01.10				
	C-PAD EX 01.10.01	Other Direct Costs	$0	
	C-PAD EX 01.10.02	DOE Project Operations		$0
	C-PAD EX 01.10.03	DOE TM&E		$0
	C-PAD EX 01.10.04	Host site Operational Costs Miscellaneous		$0
	C-PAD EX 01.10.05	Miscellaneous ODC		$0
C-PAD EX 01.11		Operational Costs	0	
	C-PAD EX 01.11.01	Operations Costs		$0
	C-PAD EX 01.11.02	Transportation Costs		$0
	C-PAD EX 01.11.03	Escalation (Operations/Transportation)		$0

Project Total

TEC	(All Direct & indirect Costs, MR, Escalation)	$813,765,848
TPC	(TEC plus Contingency, ODCs)	$895,142,433
LCC	All Capitol, Operation, Transportation, Escalation	$895,142,433

APPENDIX C5-1

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 1 - S-PAD 21P/44B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 21P/44B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

Annual Escalation	1.90%
Discount Rate	3.00%

40 Year Operating life

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 28,054,945	$ -	$ -	$ 42,096,410	$ 270,151,354	$ 642,131,376
10	$ 367,254,034	$ 26,453,185	$ -	$ -	$ 81,535,222	$ 475,242,441	$ 1,117,373,816
11		$ 26,967,342	$ 12,836,230	$ -	$ 9,156,052	$ 48,959,623	$ 1,166,333,439
12	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 10,086,284	$ 49,889,856	$ 1,216,223,295
13	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 11,034,192	$ 50,837,763	$ 1,267,061,059
14	$ -	$ 11,643,328	$ -	$ -	$ 3,510,268	$ 15,153,596	$ 1,282,214,655
15	$ -	$ 11,643,328	$ -	$ -	$ 3,798,186	$ 15,441,514	$ 1,297,656,169
16	$ -	$ 11,643,328	$ -	$ -	$ 4,091,575	$ 15,734,903	$ 1,313,391,072
17	$ -	$ 11,643,328	$ -	$ -	$ 4,390,538	$ 16,033,866	$ 1,329,424,939
18	$ -	$ 11,643,328	$ -	$ -	$ 4,695,182	$ 16,338,510	$ 1,345,763,449
19	$ -	$ 11,643,328	$ -	$ -	$ 5,005,614	$ 16,648,942	$ 1,362,412,390
20	$ -	$ 11,643,328	$ -	$ -	$ 5,321,943	$ 16,965,271	$ 1,379,377,661
21	$ -	$ 11,643,328	$ -	$ -	$ 5,644,284	$ 17,287,612	$ 1,396,665,273
22	$ -	$ 11,643,328	$ -	$ -	$ 5,972,748	$ 17,616,076	$ 1,414,281,349
23	$ -	$ 11,643,328	$ -	$ -	$ 6,307,454	$ 17,950,782	$ 1,432,232,131
24	$ -	$ 11,643,328	$ -	$ -	$ 6,648,518	$ 18,291,846	$ 1,450,523,977
25	$ -	$ 11,643,328	$ -	$ -	$ 6,996,064	$ 18,639,392	$ 1,469,163,369
26	$ -	$ 11,643,328	$ -	$ -	$ 7,350,212	$ 18,993,540	$ 1,488,156,909
27	$ -	$ 11,643,328	$ -	$ -	$ 7,711,089	$ 19,354,417	$ 1,507,511,326
28	$ -	$ 11,643,328	$ -	$ -	$ 8,078,823	$ 19,722,151	$ 1,527,233,477
29	$ -	$ 11,643,328	$ -	$ -	$ 8,453,544	$ 20,096,872	$ 1,547,330,349
30	$ -	$ 11,643,328	$ -	$ -	$ 8,835,385	$ 20,478,713	$ 1,567,809,062
31	$ -	$ 11,643,328	$ -	$ -	$ 9,224,480	$ 20,867,808	$ 1,588,676,870
32	$ -	$ 11,643,328	$ -	$ -	$ 9,620,969	$ 21,264,297	$ 1,609,941,167
33	$ -	$ 11,643,328	$ -	$ -	$ 10,024,990	$ 21,668,318	$ 1,631,609,485
34	$ -	$ 11,643,328	$ -	$ -	$ 10,436,688	$ 22,080,016	$ 1,653,689,501
35	$ -	$ 11,643,328	$ -	$ -	$ 10,856,209	$ 22,499,537	$ 1,676,189,038
36	$ -	$ 11,643,328	$ -	$ -	$ 11,283,700	$ 22,927,028	$ 1,699,116,065
37	$ -	$ 11,643,328	$ -	$ -	$ 11,719,313	$ 23,362,641	$ 1,722,478,707
38	$ -	$ 11,643,328	$ -	$ -	$ 12,163,203	$ 23,806,531	$ 1,746,285,238
39	$ -	$ 11,643,328	$ -	$ -	$ 12,615,528	$ 24,258,856	$ 1,770,544,094
40	$ -	$ 11,643,328	$ -	$ -	$ 13,076,446	$ 24,719,774	$ 1,795,263,867
41	$ -	$ 11,643,328	$ -	$ -	$ 13,546,121	$ 25,189,449	$ 1,820,453,317
42	$ -	$ 11,643,328	$ -	$ -	$ 14,024,721	$ 25,668,049	$ 1,846,121,366
43	$ -	$ 11,643,328	$ -	$ -	$ 14,512,414	$ 26,155,742	$ 1,872,277,108
44	$ -	$ 11,643,328	$ -	$ -	$ 15,009,373	$ 26,652,701	$ 1,898,929,809
45	$ -	$ 11,643,328	$ -	$ -	$ 15,515,774	$ 27,159,102	$ 1,926,088,911
46	$ -	$ 11,643,328	$ -	$ -	$ 16,031,797	$ 27,675,125	$ 1,953,764,037
47	$ -	$ 11,643,328	$ -	$ -	$ 16,557,625	$ 28,200,953	$ 1,981,964,989
48	$ -	$ 11,643,328	$ -	$ -	$ 17,093,443	$ 28,736,771	$ 2,010,701,760
49	$ -	$ 11,643,328	$ -	$ -	$ 17,639,441	$ 29,282,769	$ 2,039,984,530
50	$ -	$ 11,643,328	$ -	$ -	$ 18,195,814	$ 29,839,142	$ 2,069,823,672
51	$ -	$ -	$ -	$ 21,175,000	$ 34,122,666	$ 55,297,666	$ 2,125,121,338
52	$ -	$ -	$ -	$ 22,750,000	$ 37,789,519	$ 60,539,519	$ 2,185,660,857
53	$ -	$ -	$ -	$ 17,521,891	$ 29,991,138	$ 47,513,029	$ 2,233,173,886
54	$ -	$ -	$ -	$ 17,521,891	$ 30,893,886	$ 48,415,776	$ 2,281,589,662
55	$ -	$ -	$ -	$ 17,521,891	$ 31,813,786	$ 49,335,676	$ 2,330,925,339
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,330,925,339
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,330,925,339
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,330,925,339
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,330,925,339
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,330,925,339

Total Design/Const	Total O&M		Total D&D	Total Escalation	Total Life Cycle
$ 895,142,433	$ 566,213,291	$ 38,508,689	$ 96,490,672	$ 734,570,255	$ 2,330,925,339

APPENDIX C5-1

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 1 - S-PAD 21P/44B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 21P/44B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

80 Year Operating Life

Annual Escalation	Discount Rate
1.90%	3.00%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	\	$ -	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 28,054,945	$ -	$ -	$ 42,096,410	$270,151,354	$642,131,376
10	$ 367,254,034	$ 26,453,185	$ -	$ -	$ 81,535,222	$475,242,441	$1,117,373,816
11		$ 26,967,342	$ 12,836,230	$ -	$ 9,156,052	$48,959,623	$1,166,333,439
12	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 10,086,284	$49,889,856	$1,216,223,295
13	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 11,034,192	$50,837,763	$1,267,061,059
14	$ -	$ 11,643,328	$ -	$ -	$ 3,510,268	$15,153,596	$1,282,214,655
15	$ -	$ 11,643,328	$ -	$ -	$ 3,798,186	$15,441,514	$1,297,656,169
16	$ -	$ 11,643,328	$ -	$ -	$ 4,091,575	$15,734,903	$1,313,391,072
17	$ -	$ 11,643,328	$ -	$ -	$ 4,390,538	$16,033,866	$1,329,424,939
18	$ -	$ 11,643,328	$ -	$ -	$ 4,695,182	$16,338,510	$1,345,763,449
19	$ -	$ 11,643,328	$ -	$ -	$ 5,005,614	$16,648,942	$1,362,412,390
20	$ -	$ 11,643,328	$ -	$ -	$ 5,321,943	$16,965,271	$1,379,377,661
21	$ -	$ 11,643,328	$ -	$ -	$ 5,644,284	$17,287,612	$1,396,665,273
22	$ -	$ 11,643,328	$ -	$ -	$ 5,972,748	$17,616,076	$1,414,281,349
23	$ -	$ 11,643,328	$ -	$ -	$ 6,307,454	$17,950,782	$1,432,232,131
24	$ -	$ 11,643,328	$ -	$ -	$ 6,648,518	$18,291,846	$1,450,523,977
25	$ -	$ 11,643,328	$ -	$ -	$ 6,996,064	$18,639,392	$1,469,163,369
26	$ -	$ 11,643,328	$ -	$ -	$ 7,350,212	$18,993,540	$1,488,156,909
27	$ -	$ 11,643,328	$ -	$ -	$ 7,711,089	$19,354,417	$1,507,511,326
28	$ -	$ 11,643,328	$ -	$ -	$ 8,078,823	$19,722,151	$1,527,233,477
29	$ -	$ 11,643,328	$ -	$ -	$ 8,453,544	$20,096,872	$1,547,330,349
30	$ -	$ 11,643,328	$ -	$ -	$ 8,835,385	$20,478,713	$1,567,809,062
31	$ -	$ 11,643,328	$ -	$ -	$ 9,224,480	$20,867,808	$1,588,676,870
32	$ -	$ 11,643,328	$ -	$ -	$ 9,620,969	$21,264,297	$1,609,941,167
33	$ -	$ 11,643,328	$ -	$ -	$ 10,024,990	$21,668,318	$1,631,609,485
34	$ -	$ 11,643,328	$ -	$ -	$ 10,436,688	$22,080,016	$1,653,689,501
35	$ -	$ 11,643,328	$ -	$ -	$ 10,856,209	$22,499,537	$1,676,189,038
36	$ -	$ 11,643,328	$ -	$ -	$ 11,283,700	$22,927,028	$1,699,116,065
37	$ -	$ 11,643,328	$ -	$ -	$ 11,719,313	$23,362,641	$1,722,478,707
38	$ -	$ 11,643,328	$ -	$ -	$ 12,163,203	$23,806,531	$1,746,285,238
39	$ -	$ 11,643,328	$ -	$ -	$ 12,615,528	$24,258,856	$1,770,544,094
40	$ -	$ 11,643,328	$ -	$ -	$ 13,076,446	$24,719,774	$1,795,263,867
41	$ -	$ 11,643,328	$ -	$ -	$ 13,546,121	$25,189,449	$1,820,453,317
42	$ -	$ 11,643,328	$ -	$ -	$ 14,024,721	$25,668,049	$1,846,121,366
43	$ -	$ 11,643,328	$ -	$ -	$ 14,512,414	$26,155,742	$1,872,277,108
44	$ -	$ 11,643,328	$ -	$ -	$ 15,009,373	$26,652,701	$1,898,929,809
45	$ -	$ 11,643,328	$ -	$ -	$ 15,515,774	$27,159,102	$1,926,088,911
46	$ -	$ 11,643,328	$ -	$ -	$ 16,031,797	$27,675,125	$1,953,764,037
47	$ -	$ 11,643,328	$ -	$ -	$ 16,557,625	$28,200,953	$1,981,964,989
48	$ -	$ 11,643,328	$ -	$ -	$ 17,093,443	$28,736,771	$2,010,701,760
49	$ -	$ 11,643,328	$ -	$ -	$ 17,639,441	$29,282,769	$2,039,984,530
50	$ -	$ 11,643,328	$ -	$ -	$ 18,195,814	$29,839,142	$2,069,823,672
51	$ -	$ 11,643,328	$ -	$ -	$ 18,762,758	$30,406,086	$2,100,229,757
52	$ -	$ 11,643,328	$ -	$ -	$ 19,340,473	$30,983,801	$2,131,213,559
53	$ -	$ 11,643,328	$ -	$ -	$ 19,929,166	$31,572,494	$2,162,786,052
54	$ -	$ 11,643,328	$ -	$ -	$ 20,529,043	$32,172,371	$2,194,958,423
55	$ -	$ 11,643,328	$ -	$ -	$ 21,140,318	$32,783,646	$2,227,742,069
56	$ -	$ 11,643,328	$ -	$ -	$ 21,763,207	$33,406,535	$2,261,148,605
57	$ -	$ 11,643,328	$ -	$ -	$ 22,397,931	$34,041,259	$2,295,189,864
58	$ -	$ 11,643,328	$ -	$ -	$ 23,044,715	$34,688,043	$2,329,877,908
59	$ -	$ 11,643,328	$ -	$ -	$ 23,703,788	$35,347,116	$2,365,225,024

60	$ -	$ 11,643,328	$ -	$ -	$ 24,375,383	$36,018,711	$2,401,243,735
61	$ -	$ 11,643,328	$ -	$ -	$ 25,059,739	$36,703,067	$2,437,946,802
62	$ -	$ 11,643,328	$ -	$ -	$ 25,757,097	$37,400,425	$2,475,347,228
63	$ -	$ 11,643,328	$ -	$ -	$ 26,467,705	$38,111,033	$2,513,458,261
64	$ -	$ 11,643,328	$ -	$ -	$ 27,191,815	$38,835,143	$2,552,293,404
65	$0	$ 11,643,328	$ -	$ -	$ 27,929,683	$39,573,011	$2,591,866,414
66	$0	$ 11,643,328	$ -	$ -	$ 28,681,570	$40,324,898	$2,632,191,312
67	$0	$ 11,643,328	$ -	$ -	$ 29,447,743	$41,091,071	$2,673,282,383
68	$0	$ 11,643,328	$ -	$ -	$ 30,228,473	$41,871,801	$2,715,154,185
69	$0	$ 11,643,328	$ -	$ -	$ 31,024,038	$42,667,366	$2,757,821,550
70	$0	$ 11,643,328	$ -	$ -	$ 31,834,717	$43,478,045	$2,801,299,595
71	$0	$ 11,643,328	$ -	$ -	$ 32,660,800	$44,304,128	$2,845,603,724
72	$0	$ 11,643,328	$ -	$ -	$ 33,502,579	$45,145,907	$2,890,749,631
73	$0	$ 11,643,328	$ -	$ -	$ 34,360,351	$46,003,679	$2,936,753,310
74	$0	$ 11,643,328	$ -	$ -	$ 35,234,421	$46,877,749	$2,983,631,058
75	$0	$ 11,643,328	$ -	$ -	$ 36,125,098	$47,768,426	$3,031,399,485
76	$0	$ 11,643,328	$ -	$ -	$ 37,032,698	$48,676,026	$3,080,075,511
77	$0	$ 11,643,328	$ -	$ -	$ 37,957,543	$49,600,871	$3,129,676,381
78	$0	$ 11,643,328	$ -	$ -	$ 38,899,959	$50,543,287	$3,180,219,669
79	$0	$ 11,643,328	$ -	$ -	$ 39,860,282	$51,503,610	$3,231,723,278
80	$0	$ 11,643,328	$ -	$ -	$ 40,838,850	$52,482,178	$3,284,205,457
81	$0	$ 11,643,328	$ -	$ -	$ 41,836,012	$53,479,340	$3,337,684,796
82	$0	$ 11,643,328	$ -	$ -	$ 42,852,119	$54,495,447	$3,392,180,243
83	$0	$ 11,643,328	$ -	$ -	$ 43,887,533	$55,530,861	$3,447,711,104
84	$0	$ 11,643,328	$ -	$ -	$ 44,942,619	$56,585,947	$3,504,297,051
85	$0	$ 11,643,328	$ -	$ -	$ 46,017,752	$57,661,080	$3,561,958,131
86	$0	$ 11,643,328	$ -	$ -	$ 47,113,312	$58,756,640	$3,620,714,772
87	$0	$ 11,643,328	$ -	$ -	$ 48,229,689	$59,873,017	$3,680,587,788
88	$0	$ 11,643,328	$ -	$ -	$ 49,367,276	$61,010,604	$3,741,598,392
89	$0	$ 11,643,328	$ -	$ -	$ 50,526,477	$62,169,805	$3,803,768,198
90	$0	$ 11,643,328	$ -	$ -	$ 51,707,704	$63,351,032	$3,867,119,229
91			$ -	$ 21,175,000	$ 96,226,640	$117,401,640	$3,984,520,869
92			$ -	$ 22,750,000	$ 105,780,539	$128,530,539	$4,113,051,409
93			$ -	$ 17,521,891	$ 83,352,303	$100,874,194	$4,213,925,602
94			$ -	$ 17,521,891	$ 85,268,913	$102,790,803	$4,316,716,406
95			$ -	$ 17,521,891	$ 87,221,938	$104,743,829	$4,421,460,234
96				$ -	$ -	$0	$4,421,460,234
97				$ -	$ -	$0	$4,421,460,234
98					$ -	$0	$4,421,460,234
99					$ -	$0	$4,421,460,234
100					$ -	$0	$4,421,460,234

Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation	Total Life Cycle
$895,142,433	$1,031,946,410	$38,508,689	$96,490,672	$2,359,372,031	$4,421,460,234

APPENDIX C5-2

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 2 - S-PAD 12P/32B, PILOT, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 12P/32B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB
Annual Escalation Factor 1.90%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$1,153,173,619*					*$1,153,173,619*
Operations & Maintenance (40 Year Life)		*$566,213,291*				*$566,213,291*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$122,726,856		*$122,726,856*
Escalation					$833,552,661	*$833,552,661*
Total Costs (40 year Life)						*$2,714,175,116*
Present Value						*$1,579,761,718*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$1,153,173,619*					*$1,153,173,619*
Operations & Maintenance (80 Year Life)		*$1,031,946,410*				*$1,031,946,410*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$122,726,856		*$122,726,856*
Escalation					$2,538,970,979	*$2,538,970,979*
Total Costs (80 Year Life)						*$4,885,326,554*
Present Value						$1,775,654,801

APPENDIX C5-2

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 2 - S-PAD 12P/32B, PILOT, LOW SEISMIC

CAPITAL COST SUMMARY

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 12P/32B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-PAD EX 01			Interim Storage Facility and transportation Project		
	C-PAD EX 01.01		Pilot ISF Facility	$756,994,787	
		C-PAD EX 01.01.01	Storage Pads		$0
		C-PAD EX 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-PAD EX 01.01.03	Horizontal Dry Storage Modules		$229,347,514
		C-PAD EX 01.01.04	Vertical Dry Storage Module		$233,332,393
		C-PAD EX 01.01.05	Storage Cask Fabrication Facility		$0
		C-PAD EX 01.01.06	Cask Maintenance Facility		$0
		C-PAD EX 01.01.07	Concrete Batch Plant		$1,850,000
		C-PAD EX 01.01.08	Visitor Center/ Auditorium		$0
		C-PAD EX 01.01.09	Administration Building		$3,140,000
		C-PAD EX 01.01.10	Security		$24,148,975
		C-PAD EX 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-PAD EX 01.01.12	Utilities		$18,682,150
		C-PAD EX 01.01.13	Roads		$18,212,737
		C-PAD EX 01.01.14	Parking		$735,000
		C-PAD EX 01.01.15	Site Work		$23,417,500
		C-PAD EX 01.01.16	Warehouse		$10,200,000
		C-PAD EX 01.01.17	Maintenance Facility		$0
		C-PAD EX 01.01.18	Waste management Facility		$0
		C-PAD EX 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-PAD EX 01.02		Expanded Interim Storage Facility	$0	
		C-PAD EX 01.02.01	Expanded Storage Pads and Dry Cask Storage Systems		$0
		C-PAD EX 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-PAD EX 01.02.03	Horizontal Dry Storage Modules		$0
		C-PAD EX 01.02.04	Vertical Dry Storage Casks		$0
		C-PAD EX 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-PAD EX 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-PAD EX 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-PAD EX 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-PAD EX 01.02.09	Administration Building (Expanded if needed)		$0
		C-PAD EX 01.02.10	Security (Expanded)		$0
		C-PAD EX 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-PAD EX 01.02.12	Utilities Expanded as needed)		$0
		C-PAD EX 01.02.13	Roads (Expanded)		$0
		C-PAD EX 01.02.14	Parking (Expanded as needed)		$0
		C-PAD EX 01.02.15	Site Work (Expanded)		$0
		C-PAD EX 01.02.16	Warehouse (Expanded if Needed)		$0
		C-PAD EX 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-PAD EX 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-PAD EX 01.02.19	Hot Cell / Laboratories		$0
		C-PAD EX 01.02.20	Pool Packaging Facility		$0
		C-PAD EX 01.02.21	Standardized Storage System		$0
		C-PAD EX 01.02.22	Standardized Disposal Canister		$0
		C-PAD EX 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-PAD EX 01.03		Transportation Equipment	$0	
		C-PAD EX 01.03.01	Transportation Casks		$0
		C-PAD EX 01.03.02	Rail Equipment		$0
		C-PAD EX 01.03.03	Rail Maintenance Facility		$0
		C-PAD EX 01.03.04	Transportation Systems Services		$0
	C-PAD EX 01.04		Pre-Construction Capitalized Costs	$60,265,000	
		C-PAD EX 01.04.01	Land or Land Leases		$1,920,000
		C-PAD EX 01.04.02	Site permits		$200,000
		C-PAD EX 01.04.03	Site Licensing		$6,240,000
		C-PAD EX 01.04.05	Plant Permits		$0
		C-PAD EX 01.04.06	Planning and Alternative Studies		$750,000

		C-PAD EX 01.04.07	Research and Development		$0
		C-PAD EX 01.04.08	Design		$23,955,000
		C-PAD EX 01.04.09	Other Pre-construction Costs		$17,200,000
		C-PAD EX 01.04.10	Pre-construction contingencies		$10,000,000
		C-PAD EX 01.04.xx	(Add Further Breakdown as needed)		$0
	C-PAD EX 01.05		Indirect Capitalized Costs	$63,180,000	
		C-PAD EX 01.05.01	Project Management		$2,700,000
		C-PAD EX 01.05.02	Construction Management		$3,600,000
		C-PAD EX 01.05.03	Field indirect services		$11,880,000
		C-PAD EX 01.05.o4	Design Services in support of Construction		$5,400,000
		C-PAD EX 01.05.05	QA/QC		$12,600,000
		C-PAD EX 01.05.06	Commissioning and Startup		$1,200,000
		C-PAD EX 01.05.07	Home office Engineering support to Construction		$7,200,000
		C-PAD EX 01.05.08	Document Control		$2,700,000
		C-PAD EX 01.05.09	Project Controls		$3,600,000
		C-PAD EX 01.05.10	Construction Testing		$2,700,000
		C-PAD EX 01.05.11	Inspections		$3,600,000
		C-PAD EX 01.05.12	Startup and Testing		$3,000,000
		C-PAD EX 01.05.13	Commissioning		$3,000,000
	C-PAD EX 01.06		Site Selection	$0	
		C-PAD EX 01.06.01	Site Selection		$0
		C-PAD EX 01.06.02	Public Information Process		$0
	C-PAD EX 01.07		Decontamination and Deconstruction	$0	
		C-PAD EX 01.07.01	Decommissioning		$0
		C-PAD EX 01.07.02	Decontamination		$0
		C-PAD EX 01.07.03	Deconstruction		$0
		C-PAD EX 01.07.04			$0
		C-PAD EX 01.07.05			$0
	C-PAD EX 01.08		Project Financial Costs	$117,978,931	
		C-PAD EX 01.08.01	Contractor Fees		$70,435,183
		C-PAD EX 01.08.02	Escalation Costs		$47,543,748
		C-PAD EX 01.08.03	Interest Payments		$0
		C-PAD EX 01.08.04	Indirect costs to support shipments to repository		$0
		C-PAD EX 01.08.05			$0
		C-PAD EX 01.08.xx	(Add Further Breakdown as needed)		$0
	C-PAD EX 01.09		Project Contingencies	$154,754,901	
		C-PAD EX 01.09.01	Management Reserve - Contractor Held		$49,920,936
		C-PAD EX 01.09.02	Contingency - DOE held		$104,833,965
	C-PAD EX 01.10				
		C-PAD EX 01.10.01	Other Direct Costs	$0	
		C-PAD EX 01.10.02	DOE Project Operations		$0
		C-PAD EX 01.10.03	DOE TM&E		$0
		C-PAD EX 01.10.04	Host site Operational Costs Miscellaneous		$0
		C-PAD EX 01.10.05	Miscellaneous ODC		$0
	C-PAD EX 01.11		Operational Costs	0	
		C-PAD EX 01.11.01	Operations Costs		$0
		C-PAD EX 01.11.02	Transportation Costs		$0
		C-PAD EX 01.11.03	Escalation (Operations/Transportation)		$0
Project Total					

TEC	(All Direct & indirect Costs, MR, Escalation)	$1,048,339,654
TPC	(TEC plus Contingency, ODCs)	$1,153,173,619
LCC	All Capitol, Operation, Transportation, Escalation	$1,153,173,619

APPENDIX C5-2

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 2 - S-PAD 12P/32B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 12P/32B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

Annual Escalation: 1.90%
Discount Rate: 3.00%

40 Year Operating life

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 28,054,945	$ -	$ -	$ 42,096,410	$ 270,151,354	$ 642,131,376
10	$ 625,285,220	$ 26,453,185	$ -	$ -	$ 134,972,470	$ 786,710,875	$ 1,428,842,250
11		$ 26,967,342	$ 12,836,230	$ -	$ 9,156,052	$ 48,959,623	$ 1,477,801,873
12	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 10,086,284	$ 49,889,856	$ 1,527,691,729
13	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 11,034,192	$ 50,837,763	$ 1,578,529,493
14	$ -	$ 11,643,328	$ -	$ -	$ 3,510,268	$ 15,153,596	$ 1,593,683,089
15	$ -	$ 11,643,328	$ -	$ -	$ 3,798,186	$ 15,441,514	$ 1,609,124,603
16	$ -	$ 11,643,328	$ -	$ -	$ 4,091,575	$ 15,734,903	$ 1,624,859,506
17	$ -	$ 11,643,328	$ -	$ -	$ 4,390,538	$ 16,033,866	$ 1,640,893,373
18	$ -	$ 11,643,328	$ -	$ -	$ 4,695,182	$ 16,338,510	$ 1,657,231,883
19	$ -	$ 11,643,328	$ -	$ -	$ 5,005,614	$ 16,648,942	$ 1,673,880,824
20	$ -	$ 11,643,328	$ -	$ -	$ 5,321,943	$ 16,965,271	$ 1,690,846,096
21	$ -	$ 11,643,328	$ -	$ -	$ 5,644,284	$ 17,287,612	$ 1,708,133,707
22	$ -	$ 11,643,328	$ -	$ -	$ 5,972,748	$ 17,616,076	$ 1,725,749,783
23	$ -	$ 11,643,328	$ -	$ -	$ 6,307,454	$ 17,950,782	$ 1,743,700,565
24	$ -	$ 11,643,328	$ -	$ -	$ 6,648,518	$ 18,291,846	$ 1,761,992,411
25	$ -	$ 11,643,328	$ -	$ -	$ 6,996,064	$ 18,639,392	$ 1,780,631,803
26	$ -	$ 11,643,328	$ -	$ -	$ 7,350,212	$ 18,993,540	$ 1,799,625,343
27	$ -	$ 11,643,328	$ -	$ -	$ 7,711,089	$ 19,354,417	$ 1,818,979,760
28	$ -	$ 11,643,328	$ -	$ -	$ 8,078,823	$ 19,722,151	$ 1,838,701,911
29	$ -	$ 11,643,328	$ -	$ -	$ 8,453,544	$ 20,096,872	$ 1,858,798,784
30	$ -	$ 11,643,328	$ -	$ -	$ 8,835,385	$ 20,478,713	$ 1,879,277,496
31	$ -	$ 11,643,328	$ -	$ -	$ 9,224,480	$ 20,867,808	$ 1,900,145,304
32	$ -	$ 11,643,328	$ -	$ -	$ 9,620,969	$ 21,264,297	$ 1,921,409,601
33	$ -	$ 11,643,328	$ -	$ -	$ 10,024,990	$ 21,668,318	$ 1,943,077,919
34	$ -	$ 11,643,328	$ -	$ -	$ 10,436,688	$ 22,080,016	$ 1,965,157,935
35	$ -	$ 11,643,328	$ -	$ -	$ 10,856,209	$ 22,499,537	$ 1,987,657,472
36	$ -	$ 11,643,328	$ -	$ -	$ 11,283,700	$ 22,927,028	$ 2,010,584,499
37	$ -	$ 11,643,328	$ -	$ -	$ 11,719,313	$ 23,362,641	$ 2,033,947,141
38	$ -	$ 11,643,328	$ -	$ -	$ 12,163,203	$ 23,806,531	$ 2,057,753,672
39	$ -	$ 11,643,328	$ -	$ -	$ 12,615,528	$ 24,258,856	$ 2,082,012,528
40	$ -	$ 11,643,328	$ -	$ -	$ 13,076,446	$ 24,719,774	$ 2,106,732,301
41	$ -	$ 11,643,328	$ -	$ -	$ 13,546,121	$ 25,189,449	$ 2,131,921,751
42	$ -	$ 11,643,328	$ -	$ -	$ 14,024,721	$ 25,668,049	$ 2,157,589,800
43	$ -	$ 11,643,328	$ -	$ -	$ 14,512,414	$ 26,155,742	$ 2,183,745,542
44	$ -	$ 11,643,328	$ -	$ -	$ 15,009,373	$ 26,652,701	$ 2,210,398,243
45	$ -	$ 11,643,328	$ -	$ -	$ 15,515,774	$ 27,159,102	$ 2,237,557,345
46	$ -	$ 11,643,328	$ -	$ -	$ 16,031,797	$ 27,675,125	$ 2,265,232,471
47	$ -	$ 11,643,328	$ -	$ -	$ 16,557,625	$ 28,200,953	$ 2,293,433,423
48	$ -	$ 11,643,328	$ -	$ -	$ 17,093,443	$ 28,736,771	$ 2,322,170,194
49	$ -	$ 11,643,328	$ -	$ -	$ 17,639,441	$ 29,282,769	$ 2,351,452,964
50	$ -	$ 11,643,328	$ -	$ -	$ 18,195,814	$ 29,839,142	$ 2,381,292,106
51	$ -	$ -	$ -	$ 21,175,000	$ 34,122,666	$ 55,297,666	$ 2,436,589,772
52	$ -	$ -	$ -	$ 29,800,000	$ 49,500,118	$ 79,300,118	$ 2,515,889,890
53	$ -	$ -	$ -	$ 23,917,285	$ 40,937,740	$ 64,855,026	$ 2,580,744,915
54	$ -	$ -	$ -	$ 23,917,285	$ 42,169,986	$ 66,087,271	$ 2,646,832,186
55	$ -	$ -	$ -	$ 23,917,285	$ 43,425,644	$ 67,342,929	$ 2,714,175,116
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,714,175,116
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,714,175,116
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,714,175,116
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,714,175,116
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,714,175,116
	Total Design/Const	Total O&M		Total D&D	Total Escalation		Total Life Cycle
	$ 1,153,173,619	$ 566,213,291	$ 38,508,689	$ 122,726,856	$ 833,552,661		$ 2,714,175,116

APPENDIX C5-2

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 2 - S-PAD 12P/32B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 12P/32B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

80 Year Operating Life

Annual Escalation	Discount Rate
1.90%	3.00%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	\	$ -	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 28,054,945	$ -	$ -	$ 42,096,410	$270,151,354	$642,131,376
10	$ 625,285,220	$ 26,453,185	$ -	$ -	$ 134,972,470	$786,710,875	$1,428,842,250
11		$ 26,967,342	$ 12,836,230	$ -	$ 9,156,052	$48,959,623	$1,477,801,873
12	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 10,086,284	$49,889,856	$1,527,691,729
13	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 11,034,192	$50,837,763	$1,578,529,493
14	$ -	$ 11,643,328	$ -	$ -	$ 3,510,268	$15,153,596	$1,593,683,089
15	$ -	$ 11,643,328	$ -	$ -	$ 3,798,186	$15,441,514	$1,609,124,603
16	$ -	$ 11,643,328	$ -	$ -	$ 4,091,575	$15,734,903	$1,624,859,506
17	$ -	$ 11,643,328	$ -	$ -	$ 4,390,538	$16,033,866	$1,640,893,373
18	$ -	$ 11,643,328	$ -	$ -	$ 4,695,182	$16,338,510	$1,657,231,883
19	$ -	$ 11,643,328	$ -	$ -	$ 5,005,614	$16,648,942	$1,673,880,824
20	$ -	$ 11,643,328	$ -	$ -	$ 5,321,943	$16,965,271	$1,690,846,096
21	$ -	$ 11,643,328	$ -	$ -	$ 5,644,284	$17,287,612	$1,708,133,707
22	$ -	$ 11,643,328	$ -	$ -	$ 5,972,748	$17,616,076	$1,725,749,783
23	$ -	$ 11,643,328	$ -	$ -	$ 6,307,454	$17,950,782	$1,743,700,565
24	$ -	$ 11,643,328	$ -	$ -	$ 6,648,518	$18,291,846	$1,761,992,411
25	$ -	$ 11,643,328	$ -	$ -	$ 6,996,064	$18,639,392	$1,780,631,803
26	$ -	$ 11,643,328	$ -	$ -	$ 7,350,212	$18,993,540	$1,799,625,343
27	$ -	$ 11,643,328	$ -	$ -	$ 7,711,089	$19,354,417	$1,818,979,760
28	$ -	$ 11,643,328	$ -	$ -	$ 8,078,823	$19,722,151	$1,838,701,911
29	$ -	$ 11,643,328	$ -	$ -	$ 8,453,544	$20,096,872	$1,858,798,784
30	$ -	$ 11,643,328	$ -	$ -	$ 8,835,385	$20,478,713	$1,879,277,496
31	$ -	$ 11,643,328	$ -	$ -	$ 9,224,480	$20,867,808	$1,900,145,304
32	$ -	$ 11,643,328	$ -	$ -	$ 9,620,969	$21,264,297	$1,921,409,601
33	$ -	$ 11,643,328	$ -	$ -	$ 10,024,990	$21,668,318	$1,943,077,919
34	$ -	$ 11,643,328	$ -	$ -	$ 10,436,688	$22,080,016	$1,965,157,935
35	$ -	$ 11,643,328	$ -	$ -	$ 10,856,209	$22,499,537	$1,987,657,472
36	$ -	$ 11,643,328	$ -	$ -	$ 11,283,700	$22,927,028	$2,010,584,499
37	$ -	$ 11,643,328	$ -	$ -	$ 11,719,313	$23,362,641	$2,033,947,141
38	$ -	$ 11,643,328	$ -	$ -	$ 12,163,203	$23,806,531	$2,057,753,672
39	$ -	$ 11,643,328	$ -	$ -	$ 12,615,528	$24,258,856	$2,082,012,528
40	$ -	$ 11,643,328	$ -	$ -	$ 13,076,446	$24,719,774	$2,106,732,301
41	$ -	$ 11,643,328	$ -	$ -	$ 13,546,121	$25,189,449	$2,131,921,751
42	$ -	$ 11,643,328	$ -	$ -	$ 14,024,721	$25,668,049	$2,157,589,800
43	$ -	$ 11,643,328	$ -	$ -	$ 14,512,414	$26,155,742	$2,183,745,542
44	$ -	$ 11,643,328	$ -	$ -	$ 15,009,373	$26,652,701	$2,210,398,243
45	$ -	$ 11,643,328	$ -	$ -	$ 15,515,774	$27,159,102	$2,237,557,345
46	$ -	$ 11,643,328	$ -	$ -	$ 16,031,797	$27,675,125	$2,265,232,471
47	$ -	$ 11,643,328	$ -	$ -	$ 16,557,625	$28,200,953	$2,293,433,423
48	$ -	$ 11,643,328	$ -	$ -	$ 17,093,443	$28,736,771	$2,322,170,194
49	$ -	$ 11,643,328	$ -	$ -	$ 17,639,441	$29,282,769	$2,351,452,964
50	$ -	$ 11,643,328	$ -	$ -	$ 18,195,814	$29,839,142	$2,381,292,106
51	$ -	$ 11,643,328	$ -	$ -	$ 18,762,758	$30,406,086	$2,411,698,191
52	$ -	$ 11,643,328	$ -	$ -	$ 19,340,473	$30,983,801	$2,442,681,993
53	$ -	$ 11,643,328	$ -	$ -	$ 19,929,166	$31,572,494	$2,474,254,486
54	$ -	$ 11,643,328	$ -	$ -	$ 20,529,043	$32,172,371	$2,506,426,857
55	$ -	$ 11,643,328	$ -	$ -	$ 21,140,318	$32,783,646	$2,539,210,503
56	$ -	$ 11,643,328	$ -	$ -	$ 21,763,207	$33,406,535	$2,572,617,039
57	$ -	$ 11,643,328	$ -	$ -	$ 22,397,931	$34,041,259	$2,606,658,298
58	$ -	$ 11,643,328	$ -	$ -	$ 23,044,715	$34,688,043	$2,641,346,342

59	$ -	$ 11,643,328	$ -	$ -	$ 23,703,788	$35,347,116	$2,676,693,458
60	$ -	$ 11,643,328	$ -	$ -	$ 24,375,383	$36,018,711	$2,712,712,169
61	$ -	$ 11,643,328	$ -	$ -	$ 25,059,739	$36,703,067	$2,749,415,236
62	$ -	$ 11,643,328	$ -	$ -	$ 25,757,097	$37,400,425	$2,786,815,662
63	$ -	$ 11,643,328	$ -	$ -	$ 26,467,705	$38,111,033	$2,824,926,695
64	$ -	$ 11,643,328	$ -	$ -	$ 27,191,815	$38,835,143	$2,863,761,838
65	$0	$ 11,643,328	$ -	$ -	$ 27,929,683	$39,573,011	$2,903,334,848
66	$0	$ 11,643,328	$ -	$ -	$ 28,681,570	$40,324,898	$2,943,659,746
67	$0	$ 11,643,328	$ -	$ -	$ 29,447,743	$41,091,071	$2,984,750,817
68	$0	$ 11,643,328	$ -	$ -	$ 30,228,473	$41,871,801	$3,026,622,619
69	$0	$ 11,643,328	$ -	$ -	$ 31,024,038	$42,667,366	$3,069,289,984
70	$0	$ 11,643,328	$ -	$ -	$ 31,834,717	$43,478,045	$3,112,768,030
71	$0	$ 11,643,328	$ -	$ -	$ 32,660,800	$44,304,128	$3,157,072,158
72	$0	$ 11,643,328	$ -	$ -	$ 33,502,579	$45,145,907	$3,202,218,065
73	$0	$ 11,643,328	$ -	$ -	$ 34,360,351	$46,003,679	$3,248,221,744
74	$0	$ 11,643,328	$ -	$ -	$ 35,234,421	$46,877,749	$3,295,099,492
75	$0	$ 11,643,328	$ -	$ -	$ 36,125,098	$47,768,426	$3,342,867,919
76	$0	$ 11,643,328	$ -	$ -	$ 37,032,698	$48,676,026	$3,391,543,945
77	$0	$ 11,643,328	$ -	$ -	$ 37,957,543	$49,600,871	$3,441,144,815
78	$0	$ 11,643,328	$ -	$ -	$ 38,899,959	$50,543,287	$3,491,688,103
79	$0	$ 11,643,328	$ -	$ -	$ 39,860,282	$51,503,610	$3,543,191,712
80	$0	$ 11,643,328	$ -	$ -	$ 40,838,850	$52,482,178	$3,595,673,891
81	$0	$ 11,643,328	$ -	$ -	$ 41,836,012	$53,479,340	$3,649,153,230
82	$0	$ 11,643,328	$ -	$ -	$ 42,852,119	$54,495,447	$3,703,648,678
83	$0	$ 11,643,328	$ -	$ -	$ 43,887,533	$55,530,861	$3,759,179,538
84	$0	$ 11,643,328	$ -	$ -	$ 44,942,619	$56,585,947	$3,815,765,485
85	$0	$ 11,643,328	$ -	$ -	$ 46,017,752	$57,661,080	$3,873,426,565
86	$0	$ 11,643,328	$ -	$ -	$ 47,113,312	$58,756,640	$3,932,183,206
87	$0	$ 11,643,328	$ -	$ -	$ 48,229,689	$59,873,017	$3,992,056,222
88	$0	$ 11,643,328	$ -	$ -	$ 49,367,276	$61,010,604	$4,053,066,826
89	$0	$ 11,643,328	$ -	$ -	$ 50,526,477	$62,169,805	$4,115,236,632
90	$0	$ 11,643,328	$ -	$ -	$ 51,707,704	$63,351,032	$4,178,587,663
91			$ -	$ 21,175,000	$ 96,226,640	$117,401,640	$4,295,989,303
92			$ -	$ 29,800,000	$ 138,560,882	$168,360,882	$4,464,350,186
93			$ -	$ 23,917,285	$ 113,775,440	$137,692,725	$4,602,042,911
94			$ -	$ 23,917,285	$ 116,391,602	$140,308,887	$4,742,351,798
95			$ -	$ 23,917,285	$ 119,057,471	$142,974,756	$4,885,326,554
96				$ -	$ -	$0	$4,885,326,554
97				$ -	$ -	$0	$4,885,326,554
98					$ -	$0	$4,885,326,554
99					$ -	$0	$4,885,326,554
100					$ -	$0	$4,885,326,554

Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation	Total Life Cycle
$1,153,173,619	$1,031,946,410	$38,508,689	$122,726,856	$2,538,970,979	$4,885,326,554

APPENDIX C5-3

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 3 - S-PAD 4P/9B, PILOT, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 4P/9B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB
Annual Escalation Factor 1.90%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$962,462,783*					*$962,462,783*
Operations & Maintenance (40 Year Life)		*$566,213,291*				*$566,213,291*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$170,370,939		*$170,370,939*
Escalation					$875,316,961	*$875,316,961*
Total Costs (40 year Life)						*$2,612,872,663*
Present Value						*$1,435,475,816*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$962,462,783*					*$962,462,783*
Operations & Maintenance (80 Year Life)		*$1,031,946,410*				*$1,031,946,410*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$170,370,939		*$170,370,939*
Escalation					$2,725,505,246	*$2,725,505,246*
Total Costs (80 Year Life)						*$4,928,794,068*
Present Value						$1,621,938,532

APPENDIX C5-3

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 3 - S-PAD 4P/9B, PILOT, LOW SEISMIC

CAPITAL COST SUMMARY

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 4P/9B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-PAD EX 01			Interim Storage Facility and transportation Project		
	C-PAD EX 01.01		Pilot ISF Facility	$611,388,431	
		C-PAD EX 01.01.01	Storage Pads		$0
		C-PAD EX 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-PAD EX 01.01.03	Horizontal Dry Storage Modules		$0
		C-PAD EX 01.01.04	Vertical Dry Storage Module		$317,073,551
		C-PAD EX 01.01.05	Storage Cask Fabrication Facility		$0
		C-PAD EX 01.01.06	Cask Maintenance Facility		$0
		C-PAD EX 01.01.07	Concrete Batch Plant		$1,850,000
		C-PAD EX 01.01.08	Visitor Center/ Auditorium		$0
		C-PAD EX 01.01.09	Administration Building		$3,140,000
		C-PAD EX 01.01.10	Security		$24,148,975
		C-PAD EX 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-PAD EX 01.01.12	Utilities		$18,682,150
		C-PAD EX 01.01.13	Roads		$18,212,737
		C-PAD EX 01.01.14	Parking		$735,000
		C-PAD EX 01.01.15	Site Work		$23,417,500
		C-PAD EX 01.01.16	Warehouse		$10,200,000
		C-PAD EX 01.01.17	Maintenance Facility		$0
		C-PAD EX 01.01.18	Waste management Facility		$0
		C-PAD EX 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-PAD EX 01.02		Expanded Interim Storage Facility	$0	
		C-PAD EX 01.02.01	Expanded Storage Pads and Dry Cask Storage Systems		$0
		C-PAD EX 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-PAD EX 01.02.03	Horizontal Dry Storage Modules		$0
		C-PAD EX 01.02.04	Vertical Dry Storage Casks		$0
		C-PAD EX 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-PAD EX 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-PAD EX 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-PAD EX 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-PAD EX 01.02.09	Administration Building (Expanded if needed)		$0
		C-PAD EX 01.02.10	Security (Expanded)		$0
		C-PAD EX 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-PAD EX 01.02.12	Utilities Expanded as needed)		$0
		C-PAD EX 01.02.13	Roads (Expanded)		$0
		C-PAD EX 01.02.14	Parking (Expanded as needed)		$0
		C-PAD EX 01.02.15	Site Work (Expanded)		$0
		C-PAD EX 01.02.16	Warehouse (Expanded if Needed)		$0
		C-PAD EX 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-PAD EX 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-PAD EX 01.02.19	Hot Cell / Laboratories		$0
		C-PAD EX 01.02.20	Pool Packaging Facility		$0
		C-PAD EX 01.02.21	Standardized Storage System		$0
		C-PAD EX 01.02.22	Standardized Disposal Canister		$0
		C-PAD EX 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-PAD EX 01.03		Transportation Equipment	$0	
		C-PAD EX 01.03.01	Transportation Casks		$0
		C-PAD EX 01.03.02	Rail Equipment		$0
		C-PAD EX 01.03.03	Rail Maintenance Facility		$0
		C-PAD EX 01.03.04	Transportation Systems Services		$0
	C-PAD EX 01.04		Pre-Construction Capitalized Costs	$60,265,000	
		C-PAD EX 01.04.01	Land or Land Leases		$1,920,000
		C-PAD EX 01.04.02	Site permits		$200,000
		C-PAD EX 01.04.03	Site Licensing		$6,240,000
		C-PAD EX 01.04.05	Plant Permits		$0
		C-PAD EX 01.04.06	Planning and Alternative Studies		$750,000

		C-PAD EX 01.04.07	Research and Development		$0
		C-PAD EX 01.04.08	Design		$23,955,000
		C-PAD EX 01.04.09	Other Pre-construction Costs		$17,200,000
		C-PAD EX 01.04.10	Pre-construction contingencies		$10,000,000
		C-PAD EX 01.04.xx	(Add Further Breakdown as needed)		$0
	C-PAD EX 01.05		Indirect Capitalized Costs	$63,180,000	
		C-PAD EX 01.05.01	Project Management		$2,700,000
		C-PAD EX 01.05.02	Construction Management		$3,600,000
		C-PAD EX 01.05.03	Field indirect services		$11,880,000
		C-PAD EX 01.05.o4	Design Services in support of Construction		$5,400,000
		C-PAD EX 01.05.05	QA/QC		$12,600,000
		C-PAD EX 01.05.06	Commissioning and Startup		$1,200,000
		C-PAD EX 01.05.07	Home office Engineering support to Construction		$7,200,000
		C-PAD EX 01.05.08	Document Control		$2,700,000
		C-PAD EX 01.05.09	Project Controls		$3,600,000
		C-PAD EX 01.05.10	Construction Testing		$2,700,000
		C-PAD EX 01.05.11	Inspections		$3,600,000
		C-PAD EX 01.05.12	Startup and Testing		$3,000,000
		C-PAD EX 01.05.13	Commissioning		$3,000,000
	C-PAD EX 01.06		Site Selection	$0	
		C-PAD EX 01.06.01	Site Selection		$0
		C-PAD EX 01.06.02	Public Information Process		$0
	C-PAD EX 01.07		Decontamination and Deconstruction	$0	
		C-PAD EX 01.07.01	Decommissioning		$0
		C-PAD EX 01.07.02	Decontamination		$0
		C-PAD EX 01.07.03	Deconstruction		$0
		C-PAD EX 01.07.04			$0
		C-PAD EX 01.07.05			$0
	C-PAD EX 01.08		Project Financial Costs	$98,467,680	
		C-PAD EX 01.08.01	Contractor Fees		$58,786,674
		C-PAD EX 01.08.02	Escalation Costs		$39,681,005
		C-PAD EX 01.08.03	Interest Payments		$0
		C-PAD EX 01.08.04	Indirect costs to support shipments to repository		$0
		C-PAD EX 01.08.05			$0
		C-PAD EX 01.08.xx	(Add Further Breakdown as needed)		$0
	C-PAD EX 01.09		Project Contingencies	$129,161,672	
		C-PAD EX 01.09.01	Management Reserve - Contractor Held		$41,665,056
		C-PAD EX 01.09.02	Contingency - DOE held		$87,496,617
	C-PAD EX 01.10				
		C-PAD EX 01.10.01	Other Direct Costs	$0	
		C-PAD EX 01.10.02	DOE Project Operations		$0
		C-PAD EX 01.10.03	DOE TM&E		$0
		C-PAD EX 01.10.04	Host site Operational Costs Miscellaneous		$0
		C-PAD EX 01.10.05	Miscellaneous ODC		$0
	C-PAD EX 01.11		Operational Costs	0	
		C-PAD EX 01.11.01	Operations Costs		$0
		C-PAD EX 01.11.02	Transportation Costs		$0
		C-PAD EX 01.11.03	Escalation (Operations/Transportation)		$0
Project Total					

TEC	(All Direct & indirect Costs, MR, Escalation)	$874,966,167
TPC	(TEC plus Contingency, ODCs)	$962,462,783
LCC	All Capitol, Operation, Transportation, Escalation	$962,462,783

APPENDIX C5-3

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 3 - S-PAD 4P/9B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 4P/9B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB

40 Year Operating life

Annual Escalation: 1.90%

Discount Rate: 3.00%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 28,054,945	$ -	$ -	$ 42,096,410	$ 270,151,354	$ 642,131,376
10	$ 434,574,384	$ 26,453,185	$ -	$ -	$ 95,477,003	$ 556,504,572	$ 1,198,635,948
11		$ 26,967,342	$ 12,836,230	$ -	$ 9,156,052	$ 48,959,623	$ 1,247,595,571
12	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 10,086,284	$ 49,889,856	$ 1,297,485,427
13	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 11,034,192	$ 50,837,763	$ 1,348,323,190
14	$ -	$ 11,643,328	$ -	$ -	$ 3,510,268	$ 15,153,596	$ 1,363,476,786
15	$ -	$ 11,643,328	$ -	$ -	$ 3,798,186	$ 15,441,514	$ 1,378,918,300
16	$ -	$ 11,643,328	$ -	$ -	$ 4,091,575	$ 15,734,903	$ 1,394,653,204
17	$ -	$ 11,643,328	$ -	$ -	$ 4,390,538	$ 16,033,866	$ 1,410,687,070
18	$ -	$ 11,643,328	$ -	$ -	$ 4,695,182	$ 16,338,510	$ 1,427,025,580
19	$ -	$ 11,643,328	$ -	$ -	$ 5,005,614	$ 16,648,942	$ 1,443,674,521
20	$ -	$ 11,643,328	$ -	$ -	$ 5,321,943	$ 16,965,271	$ 1,460,639,793
21	$ -	$ 11,643,328	$ -	$ -	$ 5,644,284	$ 17,287,612	$ 1,477,927,404
22	$ -	$ 11,643,328	$ -	$ -	$ 5,972,748	$ 17,616,076	$ 1,495,543,480
23	$ -	$ 11,643,328	$ -	$ -	$ 6,307,454	$ 17,950,782	$ 1,513,494,262
24	$ -	$ 11,643,328	$ -	$ -	$ 6,648,518	$ 18,291,846	$ 1,531,786,109
25	$ -	$ 11,643,328	$ -	$ -	$ 6,996,064	$ 18,639,392	$ 1,550,425,500
26	$ -	$ 11,643,328	$ -	$ -	$ 7,350,212	$ 18,993,540	$ 1,569,419,040
27	$ -	$ 11,643,328	$ -	$ -	$ 7,711,089	$ 19,354,417	$ 1,588,773,457
28	$ -	$ 11,643,328	$ -	$ -	$ 8,078,823	$ 19,722,151	$ 1,608,495,609
29	$ -	$ 11,643,328	$ -	$ -	$ 8,453,544	$ 20,096,872	$ 1,628,592,481
30	$ -	$ 11,643,328	$ -	$ -	$ 8,835,385	$ 20,478,713	$ 1,649,071,193
31	$ -	$ 11,643,328	$ -	$ -	$ 9,224,480	$ 20,867,808	$ 1,669,939,001
32	$ -	$ 11,643,328	$ -	$ -	$ 9,620,969	$ 21,264,297	$ 1,691,203,298
33	$ -	$ 11,643,328	$ -	$ -	$ 10,024,990	$ 21,668,318	$ 1,712,871,616
34	$ -	$ 11,643,328	$ -	$ -	$ 10,436,688	$ 22,080,016	$ 1,734,951,632
35	$ -	$ 11,643,328	$ -	$ -	$ 10,856,209	$ 22,499,537	$ 1,757,451,169
36	$ -	$ 11,643,328	$ -	$ -	$ 11,283,700	$ 22,927,028	$ 1,780,378,197
37	$ -	$ 11,643,328	$ -	$ -	$ 11,719,313	$ 23,362,641	$ 1,803,740,838
38	$ -	$ 11,643,328	$ -	$ -	$ 12,163,203	$ 23,806,531	$ 1,827,547,369
39	$ -	$ 11,643,328	$ -	$ -	$ 12,615,528	$ 24,258,856	$ 1,851,806,225
40	$ -	$ 11,643,328	$ -	$ -	$ 13,076,446	$ 24,719,774	$ 1,876,525,999
41	$ -	$ 11,643,328	$ -	$ -	$ 13,546,121	$ 25,189,449	$ 1,901,715,448
42	$ -	$ 11,643,328	$ -	$ -	$ 14,024,721	$ 25,668,049	$ 1,927,383,497
43	$ -	$ 11,643,328	$ -	$ -	$ 14,512,414	$ 26,155,742	$ 1,953,539,239
44	$ -	$ 11,643,328	$ -	$ -	$ 15,009,373	$ 26,652,701	$ 1,980,191,940
45	$ -	$ 11,643,328	$ -	$ -	$ 15,515,774	$ 27,159,102	$ 2,007,351,042
46	$ -	$ 11,643,328	$ -	$ -	$ 16,031,797	$ 27,675,125	$ 2,035,026,168
47	$ -	$ 11,643,328	$ -	$ -	$ 16,557,625	$ 28,200,953	$ 2,063,227,120
48	$ -	$ 11,643,328	$ -	$ -	$ 17,093,443	$ 28,736,771	$ 2,091,963,891
49	$ -	$ 11,643,328	$ -	$ -	$ 17,639,441	$ 29,282,769	$ 2,121,246,661
50	$ -	$ 11,643,328	$ -	$ -	$ 18,195,814	$ 29,839,142	$ 2,151,085,803
51	$ -	$ -	$ -	$ 21,175,000	$ 34,122,666	$ 55,297,666	$ 2,206,383,469
52	$ -	$ -	$ -	$ 56,750,000	$ 94,266,164	$ 151,016,164	$ 2,357,399,633
53	$ -	$ -	$ -	$ 30,815,313	$ 52,744,669	$ 83,559,982	$ 2,440,959,615
54	$ -	$ -	$ -	$ 30,815,313	$ 54,332,309	$ 85,147,622	$ 2,526,107,237
55	$ -	$ -	$ -	$ 30,815,313	$ 55,950,113	$ 86,765,426	$ 2,612,872,663
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,612,872,663
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,612,872,663
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,612,872,663
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,612,872,663
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,612,872,663

	Total Design/Const	Total O&M		Total D&D	Total Escalation		Total Life Cycle
	$ 962,462,783	$ 566,213,291	$ 38,508,689	$ 170,370,939	$ 875,316,961		$ 2,612,872,663

APPENDIX C5-3

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 3 - S-PAD 4P/9B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-PAD Pilot (5,000 MTU) 4P/9B
PILOT Project - S-PAD 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB

80 Year Operating Life

Annual Escalation 1.90% | Discount Rate 3.00%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	\	$ -	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 28,054,945	$ -	$ -	$ 42,096,410	$270,151,354	$642,131,376
10	$ 434,574,384	$ 26,453,185	$ -	$ -	$ 95,477,003	$556,504,572	$1,198,635,948
11		$ 26,967,342	$ 12,836,230	$ -	$ 9,156,052	$48,959,623	$1,247,595,571
12	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 10,086,284	$49,889,856	$1,297,485,427
13	$ -	$ 26,967,342	$ 12,836,230	$ -	$ 11,034,192	$50,837,763	$1,348,323,190
14	$ -	$ 11,643,328	$ -	$ -	$ 3,510,268	$15,153,596	$1,363,476,786
15	$ -	$ 11,643,328	$ -	$ -	$ 3,798,186	$15,441,514	$1,378,918,300
16	$ -	$ 11,643,328	$ -	$ -	$ 4,091,575	$15,734,903	$1,394,653,204
17	$ -	$ 11,643,328	$ -	$ -	$ 4,390,538	$16,033,866	$1,410,687,070
18	$ -	$ 11,643,328	$ -	$ -	$ 4,695,182	$16,338,510	$1,427,025,580
19	$ -	$ 11,643,328	$ -	$ -	$ 5,005,614	$16,648,942	$1,443,674,521
20	$ -	$ 11,643,328	$ -	$ -	$ 5,321,943	$16,965,271	$1,460,639,793
21	$ -	$ 11,643,328	$ -	$ -	$ 5,644,284	$17,287,612	$1,477,927,404
22	$ -	$ 11,643,328	$ -	$ -	$ 5,972,748	$17,616,076	$1,495,543,480
23	$ -	$ 11,643,328	$ -	$ -	$ 6,307,454	$17,950,782	$1,513,494,262
24	$ -	$ 11,643,328	$ -	$ -	$ 6,648,518	$18,291,846	$1,531,786,109
25	$ -	$ 11,643,328	$ -	$ -	$ 6,996,064	$18,639,392	$1,550,425,500
26	$ -	$ 11,643,328	$ -	$ -	$ 7,350,212	$18,993,540	$1,569,419,040
27	$ -	$ 11,643,328	$ -	$ -	$ 7,711,089	$19,354,417	$1,588,773,457
28	$ -	$ 11,643,328	$ -	$ -	$ 8,078,823	$19,722,151	$1,608,495,609
29	$ -	$ 11,643,328	$ -	$ -	$ 8,453,544	$20,096,872	$1,628,592,481
30	$ -	$ 11,643,328	$ -	$ -	$ 8,835,385	$20,478,713	$1,649,071,193
31	$ -	$ 11,643,328	$ -	$ -	$ 9,224,480	$20,867,808	$1,669,939,001
32	$ -	$ 11,643,328	$ -	$ -	$ 9,620,969	$21,264,297	$1,691,203,298
33	$ -	$ 11,643,328	$ -	$ -	$ 10,024,990	$21,668,318	$1,712,871,616
34	$ -	$ 11,643,328	$ -	$ -	$ 10,436,688	$22,080,016	$1,734,951,632
35	$ -	$ 11,643,328	$ -	$ -	$ 10,856,209	$22,499,537	$1,757,451,169
36	$ -	$ 11,643,328	$ -	$ -	$ 11,283,700	$22,927,028	$1,780,378,197
37	$ -	$ 11,643,328	$ -	$ -	$ 11,719,313	$23,362,641	$1,803,740,838
38	$ -	$ 11,643,328	$ -	$ -	$ 12,163,203	$23,806,531	$1,827,547,369
39	$ -	$ 11,643,328	$ -	$ -	$ 12,615,528	$24,258,856	$1,851,806,225
40	$ -	$ 11,643,328	$ -	$ -	$ 13,076,446	$24,719,774	$1,876,525,999
41	$ -	$ 11,643,328	$ -	$ -	$ 13,546,121	$25,189,449	$1,901,715,448
42	$ -	$ 11,643,328	$ -	$ -	$ 14,024,721	$25,668,049	$1,927,383,497
43	$ -	$ 11,643,328	$ -	$ -	$ 14,512,414	$26,155,742	$1,953,539,239
44	$ -	$ 11,643,328	$ -	$ -	$ 15,009,373	$26,652,701	$1,980,191,940
45	$ -	$ 11,643,328	$ -	$ -	$ 15,515,774	$27,159,102	$2,007,351,042
46	$ -	$ 11,643,328	$ -	$ -	$ 16,031,797	$27,675,125	$2,035,026,168
47	$ -	$ 11,643,328	$ -	$ -	$ 16,557,625	$28,200,953	$2,063,227,120
48	$ -	$ 11,643,328	$ -	$ -	$ 17,093,443	$28,736,771	$2,091,963,891
49	$ -	$ 11,643,328	$ -	$ -	$ 17,639,441	$29,282,769	$2,121,246,661
50	$ -	$ 11,643,328	$ -	$ -	$ 18,195,814	$29,839,142	$2,151,085,803
51	$ -	$ 11,643,328	$ -	$ -	$ 18,762,758	$30,406,086	$2,181,491,889
52	$ -	$ 11,643,328	$ -	$ -	$ 19,340,473	$30,983,801	$2,212,475,690
53	$ -	$ 11,643,328	$ -	$ -	$ 19,929,166	$31,572,494	$2,244,048,184
54	$ -	$ 11,643,328	$ -	$ -	$ 20,529,043	$32,172,371	$2,276,220,555
55	$ -	$ 11,643,328	$ -	$ -	$ 21,140,318	$32,783,646	$2,309,004,201
56	$ -	$ 11,643,328	$ -	$ -	$ 21,763,207	$33,406,535	$2,342,410,736
57	$ -	$ 11,643,328	$ -	$ -	$ 22,397,931	$34,041,259	$2,376,451,995
58	$ -	$ 11,643,328	$ -	$ -	$ 23,044,715	$34,688,043	$2,411,140,039
59	$ -	$ 11,643,328	$ -	$ -	$ 23,703,788	$35,347,116	$2,446,487,155
60	$ -	$ 11,643,328	$ -	$ -	$ 24,375,383	$36,018,711	$2,482,505,867
61	$ -	$ 11,643,328	$ -	$ -	$ 25,059,739	$36,703,067	$2,519,208,933

62	$ -	$ 11,643,328	$ -	$ -	$ 25,757,097	$37,400,425	$2,556,609,359
63	$ -	$ 11,643,328	$ -	$ -	$ 26,467,705	$38,111,033	$2,594,720,392
64	$ -	$ 11,643,328	$ -	$ -	$ 27,191,815	$38,835,143	$2,633,555,535
65	$0	$ 11,643,328	$ -	$ -	$ 27,929,683	$39,573,011	$2,673,128,546
66	$0	$ 11,643,328	$ -	$ -	$ 28,681,570	$40,324,898	$2,713,453,444
67	$0	$ 11,643,328	$ -	$ -	$ 29,447,743	$41,091,071	$2,754,544,514
68	$0	$ 11,643,328	$ -	$ -	$ 30,228,473	$41,871,801	$2,796,416,316
69	$0	$ 11,643,328	$ -	$ -	$ 31,024,038	$42,667,366	$2,839,083,681
70	$0	$ 11,643,328	$ -	$ -	$ 31,834,717	$43,478,045	$2,882,561,727
71	$0	$ 11,643,328	$ -	$ -	$ 32,660,800	$44,304,128	$2,926,865,855
72	$0	$ 11,643,328	$ -	$ -	$ 33,502,579	$45,145,907	$2,972,011,762
73	$0	$ 11,643,328	$ -	$ -	$ 34,360,351	$46,003,679	$3,018,015,441
74	$0	$ 11,643,328	$ -	$ -	$ 35,234,421	$46,877,749	$3,064,893,190
75	$0	$ 11,643,328	$ -	$ -	$ 36,125,098	$47,768,426	$3,112,661,616
76	$0	$ 11,643,328	$ -	$ -	$ 37,032,698	$48,676,026	$3,161,337,642
77	$0	$ 11,643,328	$ -	$ -	$ 37,957,543	$49,600,871	$3,210,938,513
78	$0	$ 11,643,328	$ -	$ -	$ 38,899,959	$50,543,287	$3,261,481,800
79	$0	$ 11,643,328	$ -	$ -	$ 39,860,282	$51,503,610	$3,312,985,410
80	$0	$ 11,643,328	$ -	$ -	$ 40,838,850	$52,482,178	$3,365,467,588
81	$0	$ 11,643,328	$ -	$ -	$ 41,836,012	$53,479,340	$3,418,946,928
82	$0	$ 11,643,328	$ -	$ -	$ 42,852,119	$54,495,447	$3,473,442,375
83	$0	$ 11,643,328	$ -	$ -	$ 43,887,533	$55,530,861	$3,528,973,235
84	$0	$ 11,643,328	$ -	$ -	$ 44,942,619	$56,585,947	$3,585,559,182
85	$0	$ 11,643,328	$ -	$ -	$ 46,017,752	$57,661,080	$3,643,220,262
86	$0	$ 11,643,328	$ -	$ -	$ 47,113,312	$58,756,640	$3,701,976,903
87	$0	$ 11,643,328	$ -	$ -	$ 48,229,689	$59,873,017	$3,761,849,919
88	$0	$ 11,643,328	$ -	$ -	$ 49,367,276	$61,010,604	$3,822,860,523
89	$0	$ 11,643,328	$ -	$ -	$ 50,526,477	$62,169,805	$3,885,030,329
90	$0	$ 11,643,328	$ -	$ -	$ 51,707,704	$63,351,032	$3,948,381,361
91			$ -	$ 21,175,000	$ 96,226,640	$117,401,640	$4,065,783,001
92			$ -	$ 56,750,000	$ 263,870,136	$320,620,136	$4,386,403,137
93			$ -	$ 30,815,313	$ 146,589,622	$177,404,936	$4,563,808,072
94			$ -	$ 30,815,313	$ 149,960,316	$180,775,629	$4,744,583,702
95			$ -	$ 30,815,313	$ 153,395,053	$184,210,366	$4,928,794,068
96				$ -	$ -	$0	$4,928,794,068
97				$ -	$ -	$0	$4,928,794,068
98					$ -	$0	$4,928,794,068
99					$ -	$0	$4,928,794,068
100					$ -	$0	$4,928,794,068

Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation	Total Life Cycle
$962,462,783	$1,031,946,410	$38,508,689	$170,370,939	$2,725,505,246	$4,928,794,068

APPENDIX C5-4

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 4 - S-UGS 21P/44B, PILOT, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 21P/44B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

Annual Escalation Factor	1.90%	Discount Rate	3.40%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$890,507,700*					*$890,507,700*
Operations & Maintenance (40 Year Life)		*$532,356,575*				*$532,356,575*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$110,238,910		*$110,238,910*
Escalation					$738,016,091	*$738,016,091*
Total Costs (40 year Life)						*$2,309,627,964*
Present Value						*$1,233,153,963*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$890,507,700*					*$890,507,700*
Operations & Maintenance (80 Year Life)		*$978,129,829*				*$978,129,829*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$110,238,910		*$110,238,910*
Escalation					$2,347,982,407	*$2,347,982,407*
Total Costs (80 Year Life)						*$4,365,367,535*
Present Value						$1,372,021,300

APPENDIX C5-4

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 4 - S-UGS 21P/44B, PILOT, LOW SEISMIC

CAPITAL COST SUMMARY

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 21P/44B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate
CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-UGS 01			Interim Storage Facility and transportation Project		
	C-UGS 01.01		Pilot ISF Facility	$559,686,539	
		C-UGS 01.01.01	Storage Pads		$0
		C-UGS 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-UGS 01.01.03	Horizontal Dry Storage Modules		$0
		C-UGS 01.01.04	Vertical Dry Storage Module		$265,371,659
		C-UGS 01.01.05	Storage Cask Fabrication Facility		$0
		C-UGS 01.01.06	Cask Maintenance Facility		$0
		C-UGS 01.01.07	Concrete Batch Plant		$1,850,000
		C-UGS 01.01.08	Visitor Center/ Auditorium		$0
		C-UGS 01.01.09	Administration Building		$3,140,000
		C-UGS 01.01.10	Security		$24,148,975
		C-UGS 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-UGS 01.01.12	Utilities		$18,682,150
		C-UGS 01.01.13	Roads		$18,212,737
		C-UGS 01.01.14	Parking		$735,000
		C-UGS 01.01.15	Site Work		$23,417,500
		C-UGS 01.01.16	Warehouse		$10,200,000
		C-UGS 01.01.17	Maintenance Facility		$0
		C-UGS 01.01.18	Waste management Facility		$0
		C-UGS 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-UGS 01.02		Expanded Interim Storage Facility	$0	
		C-UGS 01.02.01	Expanded Storage Pads and Dry Cask Storage Systems		$0
		C-UGS 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-UGS 01.02.03	Horizontal Dry Storage Modules		$0
		C-UGS 01.02.04	Vertical Dry Storage Casks		$0
		C-UGS 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-UGS 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-UGS 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-UGS 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-UGS 01.02.09	Administration Building (Expanded if needed)		$0
		C-UGS 01.02.10	Security (Expanded)		$0
		C-UGS 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-UGS 01.02.12	Utilities Expanded as needed)		$0
		C-UGS 01.02.13	Roads (Expanded)		$0
		C-UGS 01.02.14	Parking (Expanded as needed)		$0
		C-UGS 01.02.15	Site Work (Expanded)		$0
		C-UGS 01.02.16	Warehouse (Expanded if Needed)		$0
		C-UGS 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-UGS 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-UGS 01.02.19	Hot Cell / Laboratories		$0
		C-UGS 01.02.20	Pool Packaging Facility		$0
		C-UGS 01.02.21	Standardized Storage System		$0
		C-UGS 01.02.22	Standardized Disposal Canister		$0
		C-UGS 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-UGS 01.03		Transportation Equipment	$0	
		C-UGS 01.03.01	Transportation Casks		$0
		C-UGS 01.03.02	Rail Equipment		$0
		C-UGS 01.03.03	Rail Maintenance Facility		$0
		C-UGS 01.03.04	Transportation Systems Services		$0
	C-UGS 01.04		Pre-Construction Capitalized Costs	$56,269,000	
		C-UGS 01.04.01	Land or Land Leases		$1,920,000
		C-UGS 01.04.02	Site permits		$200,000
		C-UGS 01.04.03	Site Licensing		$6,240,000
		C-UGS 01.04.05	Plant Permits		$0
		C-UGS 01.04.06	Planning and Alternative Studies		$750,000
		C-UGS 01.04.07	Research and Development		$0
		C-UGS 01.04.08	Design		$23,955,000
		C-UGS 01.04.09	Other Pre-construction Costs		$13,204,000

		C-UGS 01.04.10	Pre-construction contingencies		$10,000,000
		C-UGS 01.04.xx	(Add Further Breakdown as needed)		$0
	C-UGS 01.05		Indirect Capitalized Costs	$63,180,000	
		C-UGS 01.05.01	Project Management		$2,700,000
		C-UGS 01.05.02	Construction Management		$3,600,000
		C-UGS 01.05.03	Field indirect services		$11,880,000
		C-UGS 01.05.o4	Design Services in support of Construction		$5,400,000
		C-UGS 01.05.05	QA/QC		$12,600,000
		C-UGS 01.05.06	Commissioning and Startup		$1,200,000
		C-UGS 01.05.07	Home office Engineering support to Construction		$7,200,000
		C-UGS 01.05.08	Document Control		$2,700,000
		C-UGS 01.05.09	Project Controls		$3,600,000
		C-UGS 01.05.10	Construction Testing		$2,700,000
		C-UGS 01.05.11	Inspections		$3,600,000
		C-UGS 01.05.12	Startup and Testing		$3,000,000
		C-UGS 01.05.13	Commissioning		$3,000,000
	C-UGS 01.06		Site Selection	$0	
		C-UGS 01.06.01	Site Selection		$0
		C-UGS 01.06.02	Public Information Process		$0
	C-UGS 01.07		Decontamination and Deconstruction	$0	
		C-UGS 01.07.01	Decommissioning		$0
		C-UGS 01.07.02	Decontamination		$0
		C-UGS 01.07.03	Deconstruction		$0
		C-UGS 01.07.04			$0
		C-UGS 01.07.05			$0
	C-UGS 01.08		Project Financial Costs	$91,435,160	
		C-UGS 01.08.01	Contractor Fees		$54,588,155
		C-UGS 01.08.02	Escalation Costs		$36,847,005
		C-UGS 01.08.03	Interest Payments		$0
		C-UGS 01.08.04	Indirect costs to support shipments to repository		$0
		C-UGS 01.08.05			$0
		C-UGS 01.08.xx	(Add Further Breakdown as needed)		$0
	C-UGS 01.09		Project Contingencies	$119,937,000	
		C-UGS 01.09.01	Management Reserve - Contractor Held		$38,689,355
		C-UGS 01.09.02	Contingency - DOE held		$81,247,645
	C-UGS 01.10				
		C-UGS 01.10.01	Other Direct Costs	$0	
		C-UGS 01.10.02	DOE Project Operations		$0
		C-UGS 01.10.03	DOE TM&E		$0
		C-UGS 01.10.04	Host site Operational Costs Miscellaneous		$0
		C-UGS 01.10.05	Miscellaneous ODC		$0
	C-UGS 01.11		Operational Costs	0	
		C-UGS 01.11.01	Operations Costs		$0
		C-UGS 01.11.02	Transportation Costs		$0
		C-UGS 01.11.03	Escalation (Operations/Transportation)		$0
Project Total					

TEC	(All Direct & indirect Costs, MR, Escalation)	$809,260,054
TPC	(TEC plus Contingency, ODCs)	$890,507,700
LCC	All Capitol, Operation, Transportation, Escalation	$890,507,700

APPENDIX C5-4

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 4 - S-UGS 21P/44B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 21P/44B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

40 Year Operating life

Annual Escalation: 1.90%
Discount Rate: 3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 24,243,717	$ -	$ -	$ 41,392,899	$ 265,636,616	$ 637,616,638
10	$ 362,619,301	$ 23,603,013	$ -	$ -	$ 79,985,128	$ 466,207,441	$ 1,103,824,079
11		$ 24,056,528	$ 12,836,230	$ -	$ 8,486,475	$ 45,379,232	$ 1,149,203,311
12	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 9,348,680	$ 46,241,438	$ 1,195,444,749
13	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 10,227,267	$ 47,120,025	$ 1,242,564,774
14	$ -	$ 11,144,331	$ -	$ -	$ 3,359,829	$ 14,504,160	$ 1,257,068,934
15	$ -	$ 11,144,331	$ -	$ -	$ 3,635,408	$ 14,779,739	$ 1,271,848,674
16	$ -	$ 11,144,331	$ -	$ -	$ 3,916,223	$ 15,060,554	$ 1,286,909,228
17	$ -	$ 11,144,331	$ -	$ -	$ 4,202,374	$ 15,346,705	$ 1,302,255,933
18	$ -	$ 11,144,331	$ -	$ -	$ 4,493,961	$ 15,638,292	$ 1,317,894,226
19	$ -	$ 11,144,331	$ -	$ -	$ 4,791,089	$ 15,935,420	$ 1,333,829,646
20	$ -	$ 11,144,331	$ -	$ -	$ 5,093,862	$ 16,238,193	$ 1,350,067,838
21	$ -	$ 11,144,331	$ -	$ -	$ 5,402,387	$ 16,546,719	$ 1,366,614,557
22	$ -	$ 11,144,331	$ -	$ -	$ 5,716,775	$ 16,861,106	$ 1,383,475,663
23	$ -	$ 11,144,331	$ -	$ -	$ 6,037,136	$ 17,181,467	$ 1,400,657,131
24	$ -	$ 11,144,331	$ -	$ -	$ 6,363,584	$ 17,507,915	$ 1,418,165,046
25	$ -	$ 11,144,331	$ -	$ -	$ 6,696,234	$ 17,840,566	$ 1,436,005,611
26	$ -	$ 11,144,331	$ -	$ -	$ 7,035,205	$ 18,179,536	$ 1,454,185,147
27	$ -	$ 11,144,331	$ -	$ -	$ 7,380,616	$ 18,524,947	$ 1,472,710,095
28	$ -	$ 11,144,331	$ -	$ -	$ 7,732,590	$ 18,876,921	$ 1,491,587,016
29	$ -	$ 11,144,331	$ -	$ -	$ 8,091,252	$ 19,235,583	$ 1,510,822,599
30	$ -	$ 11,144,331	$ -	$ -	$ 8,456,728	$ 19,601,059	$ 1,530,423,658
31	$ -	$ 11,144,331	$ -	$ -	$ 8,829,148	$ 19,973,479	$ 1,550,397,138
32	$ -	$ 11,144,331	$ -	$ -	$ 9,208,644	$ 20,352,975	$ 1,570,750,113
33	$ -	$ 11,144,331	$ -	$ -	$ 9,595,350	$ 20,739,682	$ 1,591,489,795
34	$ -	$ 11,144,331	$ -	$ -	$ 9,989,404	$ 21,133,736	$ 1,612,623,530
35	$ -	$ 11,144,331	$ -	$ -	$ 10,390,945	$ 21,535,277	$ 1,634,158,807
36	$ -	$ 11,144,331	$ -	$ -	$ 10,800,116	$ 21,944,447	$ 1,656,103,254
37	$ -	$ 11,144,331	$ -	$ -	$ 11,217,060	$ 22,361,391	$ 1,678,464,646
38	$ -	$ 11,144,331	$ -	$ -	$ 11,641,927	$ 22,786,258	$ 1,701,250,904
39	$ -	$ 11,144,331	$ -	$ -	$ 12,074,865	$ 23,219,197	$ 1,724,470,100
40	$ -	$ 11,144,331	$ -	$ -	$ 12,516,030	$ 23,660,362	$ 1,748,130,462
41	$ -	$ 11,144,331	$ -	$ -	$ 12,965,577	$ 24,109,908	$ 1,772,240,370
42	$ -	$ 11,144,331	$ -	$ -	$ 13,423,665	$ 24,567,997	$ 1,796,808,367
43	$ -	$ 11,144,331	$ -	$ -	$ 13,890,457	$ 25,034,789	$ 1,821,843,156
44	$ -	$ 11,144,331	$ -	$ -	$ 14,366,118	$ 25,510,450	$ 1,847,353,605
45	$ -	$ 11,144,331	$ -	$ -	$ 14,850,817	$ 25,995,148	$ 1,873,348,753
46	$ -	$ 11,144,331	$ -	$ -	$ 15,344,725	$ 26,489,056	$ 1,899,837,809
47	$ -	$ 11,144,331	$ -	$ -	$ 15,848,017	$ 26,992,348	$ 1,926,830,157
48	$ -	$ 11,144,331	$ -	$ -	$ 16,360,871	$ 27,505,203	$ 1,954,335,360
49	$ -	$ 11,144,331	$ -	$ -	$ 16,883,470	$ 28,027,801	$ 1,982,363,162
50	$ -	$ 11,144,331	$ -	$ -	$ 17,415,998	$ 28,560,330	$ 2,010,923,491
51	$ -	$ -	$ -	$ 22,900,000	$ 36,902,435	$ 59,802,435	$ 2,070,725,926
52	$ -	$ -	$ -	$ 24,000,000	$ 39,865,867	$ 63,865,867	$ 2,134,591,793
53	$ -	$ -	$ -	$ 21,112,970	$ 36,137,767	$ 57,250,737	$ 2,191,842,530
54	$ -	$ -	$ -	$ 21,112,970	$ 37,225,531	$ 58,338,501	$ 2,250,181,031
55	$ -	$ -	$ -	$ 21,112,970	$ 38,333,963	$ 59,446,933	$ 2,309,627,964
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,309,627,964
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,309,627,964
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,309,627,964
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,309,627,964
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,309,627,964

Total Design/Const	Total O&M		Total D&D	Total Escalation	Total Life Cycle
$ 890,507,700	$ 532,356,575	$ 38,508,689	$ 110,238,910	$ 738,016,091	$ 2,309,627,964

APPENDIX C5-4

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 4 - S-UGS 21P/44B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 21P/44B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

80 Year Operating Life

Annual Escalation 1.90%

Discount Rate 3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 24,243,717	$ -	$ -	$ 41,392,899	$265,636,616	$637,616,638
10	$ 362,619,301	$ 23,603,013	$ -	$ -	$ 79,985,128	$466,207,441	$1,103,824,079
11		$ 24,056,528	$ 12,836,230	$ -	$ 8,486,475	$45,379,232	$1,149,203,311
12	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 9,348,680	$46,241,438	$1,195,444,749
13	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 10,227,267	$47,120,025	$1,242,564,774
14	$ -	$ 11,144,331	$ -	$ -	$ 3,359,829	$14,504,160	$1,257,068,934
15	$ -	$ 11,144,331	$ -	$ -	$ 3,635,408	$14,779,739	$1,271,848,674
16	$ -	$ 11,144,331	$ -	$ -	$ 3,916,223	$15,060,554	$1,286,909,228
17	$ -	$ 11,144,331	$ -	$ -	$ 4,202,374	$15,346,705	$1,302,255,933
18	$ -	$ 11,144,331	$ -	$ -	$ 4,493,961	$15,638,292	$1,317,894,226
19	$ -	$ 11,144,331	$ -	$ -	$ 4,791,089	$15,935,420	$1,333,829,646
20	$ -	$ 11,144,331	$ -	$ -	$ 5,093,862	$16,238,193	$1,350,067,838
21	$ -	$ 11,144,331	$ -	$ -	$ 5,402,387	$16,546,719	$1,366,614,557
22	$ -	$ 11,144,331	$ -	$ -	$ 5,716,775	$16,861,106	$1,383,475,663
23	$ -	$ 11,144,331	$ -	$ -	$ 6,037,136	$17,181,467	$1,400,657,131
24	$ -	$ 11,144,331	$ -	$ -	$ 6,363,584	$17,507,915	$1,418,165,046
25	$ -	$ 11,144,331	$ -	$ -	$ 6,696,234	$17,840,566	$1,436,005,611
26	$ -	$ 11,144,331	$ -	$ -	$ 7,035,205	$18,179,536	$1,454,185,147
27	$ -	$ 11,144,331	$ -	$ -	$ 7,380,616	$18,524,947	$1,472,710,095
28	$ -	$ 11,144,331	$ -	$ -	$ 7,732,590	$18,876,921	$1,491,587,016
29	$ -	$ 11,144,331	$ -	$ -	$ 8,091,252	$19,235,583	$1,510,822,599
30	$ -	$ 11,144,331	$ -	$ -	$ 8,456,728	$19,601,059	$1,530,423,658
31	$ -	$ 11,144,331	$ -	$ -	$ 8,829,148	$19,973,479	$1,550,397,138
32	$ -	$ 11,144,331	$ -	$ -	$ 9,208,644	$20,352,975	$1,570,750,113
33	$ -	$ 11,144,331	$ -	$ -	$ 9,595,350	$20,739,682	$1,591,489,795
34	$ -	$ 11,144,331	$ -	$ -	$ 9,989,404	$21,133,736	$1,612,623,530
35	$ -	$ 11,144,331	$ -	$ -	$ 10,390,945	$21,535,277	$1,634,158,807
36	$ -	$ 11,144,331	$ -	$ -	$ 10,800,116	$21,944,447	$1,656,103,254
37	$ -	$ 11,144,331	$ -	$ -	$ 11,217,060	$22,361,391	$1,678,464,646
38	$ -	$ 11,144,331	$ -	$ -	$ 11,641,927	$22,786,258	$1,701,250,904
39	$ -	$ 11,144,331	$ -	$ -	$ 12,074,865	$23,219,197	$1,724,470,100
40	$ -	$ 11,144,331	$ -	$ -	$ 12,516,030	$23,660,362	$1,748,130,462
41	$ -	$ 11,144,331	$ -	$ -	$ 12,965,577	$24,109,908	$1,772,240,370
42	$ -	$ 11,144,331	$ -	$ -	$ 13,423,665	$24,567,997	$1,796,808,367
43	$ -	$ 11,144,331	$ -	$ -	$ 13,890,457	$25,034,789	$1,821,843,156
44	$ -	$ 11,144,331	$ -	$ -	$ 14,366,118	$25,510,450	$1,847,353,605
45	$ -	$ 11,144,331	$ -	$ -	$ 14,850,817	$25,995,148	$1,873,348,753
46	$ -	$ 11,144,331	$ -	$ -	$ 15,344,725	$26,489,056	$1,899,837,809
47	$ -	$ 11,144,331	$ -	$ -	$ 15,848,017	$26,992,348	$1,926,830,157
48	$ -	$ 11,144,331	$ -	$ -	$ 16,360,871	$27,505,203	$1,954,335,360
49	$ -	$ 11,144,331	$ -	$ -	$ 16,883,470	$28,027,801	$1,982,363,162
50	$ -	$ 11,144,331	$ -	$ -	$ 17,415,998	$28,560,330	$2,010,923,491
51	$ -	$ 11,144,331	$ -	$ -	$ 17,958,645	$29,102,976	$2,040,026,467
52	$ -	$ 11,144,331	$ -	$ -	$ 18,511,601	$29,655,933	$2,069,682,400
53	$ -	$ 11,144,331	$ -	$ -	$ 19,075,064	$30,219,395	$2,099,901,795
54	$ -	$ 11,144,331	$ -	$ -	$ 19,649,232	$30,793,564	$2,130,695,359
55	$ -	$ 11,144,331	$ -	$ -	$ 20,234,310	$31,378,641	$2,162,074,000
56	$ -	$ 11,144,331	$ -	$ -	$ 20,830,504	$31,974,836	$2,194,048,836
57	$ -	$ 11,144,331	$ -	$ -	$ 21,438,026	$32,582,358	$2,226,631,194
58	$ -	$ 11,144,331	$ -	$ -	$ 22,057,091	$33,201,422	$2,259,832,616

59	$ -	$ 11,144,331	$ -	$ -	$ 22,687,918	$33,832,249	$2,293,664,865
60	$ -	$ 11,144,331	$ -	$ -	$ 23,330,731	$34,475,062	$2,328,139,927
61	$ -	$ 11,144,331	$ -	$ -	$ 23,985,757	$35,130,088	$2,363,270,016
62	$ -	$ 11,144,331	$ -	$ -	$ 24,653,229	$35,797,560	$2,399,067,576
63	$ -	$ 11,144,331	$ -	$ -	$ 25,333,382	$36,477,714	$2,435,545,289
64	$ -	$ 11,144,331	$ -	$ -	$ 26,026,459	$37,170,790	$2,472,716,079
65	$0	$ 11,144,331	$ -	$ -	$ 26,732,704	$37,877,035	$2,510,593,114
66	$0	$ 11,144,331	$ -	$ -	$ 27,452,367	$38,596,699	$2,549,189,813
67	$0	$ 11,144,331	$ -	$ -	$ 28,185,705	$39,330,036	$2,588,519,849
68	$0	$ 11,144,331	$ -	$ -	$ 28,932,975	$40,077,307	$2,628,597,156
69	$0	$ 11,144,331	$ -	$ -	$ 29,694,444	$40,838,776	$2,669,435,932
70	$0	$ 11,144,331	$ -	$ -	$ 30,470,381	$41,614,712	$2,711,050,644
71	$0	$ 11,144,331	$ -	$ -	$ 31,261,061	$42,405,392	$2,753,456,036
72	$0	$ 11,144,331	$ -	$ -	$ 32,066,763	$43,211,094	$2,796,667,130
73	$0	$ 11,144,331	$ -	$ -	$ 32,887,774	$44,032,105	$2,840,699,236
74	$0	$ 11,144,331	$ -	$ -	$ 33,724,384	$44,868,715	$2,885,567,951
75	$0	$ 11,144,331	$ -	$ -	$ 34,576,889	$45,721,221	$2,931,289,171
76	$0	$ 11,144,331	$ -	$ -	$ 35,445,593	$46,589,924	$2,977,879,095
77	$0	$ 11,144,331	$ -	$ -	$ 36,330,801	$47,475,132	$3,025,354,228
78	$0	$ 11,144,331	$ -	$ -	$ 37,232,829	$48,377,160	$3,073,731,388
79	$0	$ 11,144,331	$ -	$ -	$ 38,151,995	$49,296,326	$3,123,027,714
80	$0	$ 11,144,331	$ -	$ -	$ 39,088,625	$50,232,956	$3,173,260,670
81	$0	$ 11,144,331	$ -	$ -	$ 40,043,051	$51,187,382	$3,224,448,052
82	$0	$ 11,144,331	$ -	$ -	$ 41,015,611	$52,159,943	$3,276,607,995
83	$0	$ 11,144,331	$ -	$ -	$ 42,006,650	$53,150,982	$3,329,758,977
84	$0	$ 11,144,331	$ -	$ -	$ 43,016,519	$54,160,850	$3,383,919,827
85	$0	$ 11,144,331	$ -	$ -	$ 44,045,575	$55,189,906	$3,439,109,733
86	$0	$ 11,144,331	$ -	$ -	$ 45,094,183	$56,238,515	$3,495,348,248
87	$0	$ 11,144,331	$ -	$ -	$ 46,162,715	$57,307,046	$3,552,655,294
88	$0	$ 11,144,331	$ -	$ -	$ 47,251,549	$58,395,880	$3,611,051,174
89	$0	$ 11,144,331	$ -	$ -	$ 48,361,071	$59,505,402	$3,670,556,576
90	$0	$ 11,144,331	$ -	$ -	$ 49,491,673	$60,636,005	$3,731,192,581
91			$ -	$ 22,900,000	$ 104,065,646	$126,965,646	$3,858,158,227
92			$ -	$ 24,000,000	$ 111,592,657	$135,592,657	$3,993,750,884
93			$ -	$ 21,112,970	$ 100,435,205	$121,548,175	$4,115,299,059
94			$ -	$ 21,112,970	$ 102,744,621	$123,857,591	$4,239,156,650
95			$ -	$ 21,112,970	$ 105,097,915	$126,210,885	$4,365,367,535
96				$ -	$ -	$0	$4,365,367,535
97				$ -	$ -	$0	$4,365,367,535
98					$ -	$0	$4,365,367,535
99					$ -	$0	$4,365,367,535
100					$ -	$0	$4,365,367,535

Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation	Total Life Cycle
$890,507,700	$978,129,829	$38,508,689	$110,238,910	$2,347,982,407	$4,365,367,535

APPENDIX C5-5

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 5 - S-UGS 12P/32B, PILOT, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 12P/32B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB
Annual Escalation Factor 1.90% Discount Rate 3.40%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$935,126,196*					*$935,126,196*
Operations & Maintenance (40 Year Life)		*$532,356,575*				*$532,356,575*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$131,093,906		*$131,093,906*
Escalation					$782,267,358	*$782,267,358*
Total Costs (40 year Life)						*$2,419,352,724*
Present Value						*$1,281,412,290*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$935,126,196*					*$935,126,196*
Operations & Maintenance (80 Year Life)		*$978,129,829*				*$978,129,829*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$131,093,906		*$131,093,906*
Escalation					$2,454,975,876	*$2,454,975,876*
Total Costs (80 Year Life)						*$4,537,834,496*
Present Value						$1,415,983,519

APPENDIX C5-5

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 5 - S-UGS 12P/32B, PILOT, LOW SEISMIC

CAPITAL COST SUMMARIES

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 12P/32B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate
CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-UGS 01			Interim Storage Facility and transportation Project		
	C-UGS 01.01		Pilot ISF Facility	$559,686,539	
		C-UGS 01.01.01	Storage Pads		$0
		C-UGS 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-UGS 01.01.03	Horizontal Dry Storage Modules		$0
		C-UGS 01.01.04	Vertical Dry Storage Module		$265,371,659
		C-UGS 01.01.05	Storage Cask Fabrication Facility		$0
		C-UGS 01.01.06	Cask Maintenance Facility		$0
		C-UGS 01.01.07	Concrete Batch Plant		$1,850,000
		C-UGS 01.01.08	Visitor Center/ Auditorium		$0
		C-UGS 01.01.09	Administration Building		$3,140,000
		C-UGS 01.01.10	Security		$24,148,975
		C-UGS 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-UGS 01.01.12	Utilities		$18,682,150
		C-UGS 01.01.13	Roads		$18,212,737
		C-UGS 01.01.14	Parking		$735,000
		C-UGS 01.01.15	Site Work		$23,417,500
		C-UGS 01.01.16	Warehouse		$10,200,000
		C-UGS 01.01.17	Maintenance Facility		$0
		C-UGS 01.01.18	Waste management Facility		$0
		C-UGS 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-UGS 01.02		Expanded Interim Storage Facility	$0	
		C-UGS 01.02.01	Expanded Storage Pads and Dry Cask Storage Systems		$0
		C-UGS 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-UGS 01.02.03	Horizontal Dry Storage Modules		$0
		C-UGS 01.02.04	Vertical Dry Storage Casks		$0
		C-UGS 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-UGS 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-UGS 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-UGS 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-UGS 01.02.09	Administration Building (Expanded if needed)		$0
		C-UGS 01.02.10	Security (Expanded)		$0
		C-UGS 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-UGS 01.02.12	Utilities Expanded as needed)		$0
		C-UGS 01.02.13	Roads (Expanded)		$0
		C-UGS 01.02.14	Parking (Expanded as needed)		$0
		C-UGS 01.02.15	Site Work (Expanded)		$0
		C-UGS 01.02.16	Warehouse (Expanded if Needed)		$0
		C-UGS 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-UGS 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-UGS 01.02.19	Hot Cell / Laboratories		$0
		C-UGS 01.02.20	Pool Packaging Facility		$0
		C-UGS 01.02.21	Standardized Storage System		$0
		C-UGS 01.02.22	Standardized Disposal Canister		$0
		C-UGS 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-UGS 01.03		Transportation Equipment	$0	
		C-UGS 01.03.01	Transportation Casks		$0
		C-UGS 01.03.02	Rail Equipment		$0
		C-UGS 01.03.03	Rail Maintenance Facility		$0
		C-UGS 01.03.04	Transportation Systems Services		$0
	C-UGS 01.04		Pre-Construction Capitalized Costs	$56,269,000	
		C-UGS 01.04.01	Land or Land Leases		$1,920,000
		C-UGS 01.04.02	Site permits		$200,000
		C-UGS 01.04.03	Site Licensing		$6,240,000
		C-UGS 01.04.05	Plant Permits		$0
		C-UGS 01.04.06	Planning and Alternative Studies		$750,000

		C-UGS 01.04.07	Research and Development		$0
		C-UGS 01.04.08	Design		$23,955,000
		C-UGS 01.04.09	Other Pre-construction Costs		$13,204,000
		C-UGS 01.04.10	Pre-construction contingencies		$10,000,000
		C-UGS 01.04.xx	(Add Further Breakdown as needed)		$0
	C-UGS 01.05		Indirect Capitalized Costs	$63,180,000	
		C-UGS 01.05.01	Project Management		$2,700,000
		C-UGS 01.05.02	Construction Management		$3,600,000
		C-UGS 01.05.03	Field indirect services		$11,880,000
		C-UGS 01.05.o4	Design Services in support of Construction		$5,400,000
		C-UGS 01.05.05	QA/QC		$12,600,000
		C-UGS 01.05.06	Commissioning and Startup		$1,200,000
		C-UGS 01.05.07	Home office Engineering support to Construction		$7,200,000
		C-UGS 01.05.08	Document Control		$2,700,000
		C-UGS 01.05.09	Project Controls		$3,600,000
		C-UGS 01.05.10	Construction Testing		$2,700,000
		C-UGS 01.05.11	Inspections		$3,600,000
		C-UGS 01.05.12	Startup and Testing		$3,000,000
		C-UGS 01.05.13	Commissioning		$3,000,000
	C-UGS 01.06		Site Selection	$0	
		C-UGS 01.06.01	Site Selection		$0
		C-UGS 01.06.02	Public Information Process		$0
	C-UGS 01.07		Decontamination and Deconstruction	$0	
		C-UGS 01.07.01	Decommissioning		$0
		C-UGS 01.07.02	Decontamination		$0
		C-UGS 01.07.03	Deconstruction		$0
		C-UGS 01.07.04			$0
		C-UGS 01.07.05			$0
	C-UGS 01.08		Project Financial Costs	$110,736,185	
		C-UGS 01.08.01	Contractor Fees		$66,111,155
		C-UGS 01.08.02	Escalation Costs		$44,625,030
		C-UGS 01.08.03	Interest Payments		$0
		C-UGS 01.08.04	Indirect costs to support shipments to repository		$0
		C-UGS 01.08.05			$0
		C-UGS 01.08.xx	(Add Further Breakdown as needed)		$0
	C-UGS 01.09		Project Contingencies	$145,254,472	
		C-UGS 01.09.01	Management Reserve - Contractor Held		$46,856,281
		C-UGS 01.09.02	Contingency - DOE held		$98,398,191
	C-UGS 01.10				
		C-UGS 01.10.01	Other Direct Costs	$0	
		C-UGS 01.10.02	DOE Project Operations		$0
		C-UGS 01.10.03	DOE TM&E		$0
		C-UGS 01.10.04	Host site Operational Costs Miscellaneous		$0
		C-UGS 01.10.05	Miscellaneous ODC		$0
	C-UGS 01.11		Operational Costs	0	
		C-UGS 01.11.01	Operations Costs		$0
		C-UGS 01.11.02	Transportation Costs		$0
		C-UGS 01.11.03	Escalation (Operations/Transportation)		$0
Project Total					

TEC	(All Direct & indirect Costs, MR, Escalation)	$836,728,005
TPC	(TEC plus Contingency, ODCs)	$935,126,196
LCC	All Capitol, Operation, Transportation, Escalation	$935,126,196

APPENDIX C5-5

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 5 - S-UGS 12P/32B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 12P/32B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

40 Year Operating life

Annual Escalation: 1.90%
Discount Rate: 3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 24,243,717	$ -	$ -	$ 41,392,899	$ 265,636,616	$ 637,616,638
10	$ 407,237,797	$ 23,603,013	$ -	$ -	$ 89,225,443	$ 520,066,253	$ 1,157,682,891
11		$ 24,056,528	$ 12,836,230	$ -	$ 8,486,475	$ 45,379,232	$ 1,203,062,123
12	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 9,348,680	$ 46,241,438	$ 1,249,303,561
13	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 10,227,267	$ 47,120,025	$ 1,296,423,586
14	$ -	$ 11,144,331	$ -	$ -	$ 3,359,829	$ 14,504,160	$ 1,310,927,746
15	$ -	$ 11,144,331	$ -	$ -	$ 3,635,408	$ 14,779,739	$ 1,325,707,486
16	$ -	$ 11,144,331	$ -	$ -	$ 3,916,223	$ 15,060,554	$ 1,340,768,040
17	$ -	$ 11,144,331	$ -	$ -	$ 4,202,374	$ 15,346,705	$ 1,356,114,745
18	$ -	$ 11,144,331	$ -	$ -	$ 4,493,961	$ 15,638,292	$ 1,371,753,038
19	$ -	$ 11,144,331	$ -	$ -	$ 4,791,089	$ 15,935,420	$ 1,387,688,458
20	$ -	$ 11,144,331	$ -	$ -	$ 5,093,862	$ 16,238,193	$ 1,403,926,651
21	$ -	$ 11,144,331	$ -	$ -	$ 5,402,387	$ 16,546,719	$ 1,420,473,369
22	$ -	$ 11,144,331	$ -	$ -	$ 5,716,775	$ 16,861,106	$ 1,437,334,475
23	$ -	$ 11,144,331	$ -	$ -	$ 6,037,136	$ 17,181,467	$ 1,454,515,943
24	$ -	$ 11,144,331	$ -	$ -	$ 6,363,584	$ 17,507,915	$ 1,472,023,858
25	$ -	$ 11,144,331	$ -	$ -	$ 6,696,234	$ 17,840,566	$ 1,489,864,423
26	$ -	$ 11,144,331	$ -	$ -	$ 7,035,205	$ 18,179,536	$ 1,508,043,960
27	$ -	$ 11,144,331	$ -	$ -	$ 7,380,616	$ 18,524,947	$ 1,526,568,907
28	$ -	$ 11,144,331	$ -	$ -	$ 7,732,590	$ 18,876,921	$ 1,545,445,829
29	$ -	$ 11,144,331	$ -	$ -	$ 8,091,252	$ 19,235,583	$ 1,564,681,411
30	$ -	$ 11,144,331	$ -	$ -	$ 8,456,728	$ 19,601,059	$ 1,584,282,471
31	$ -	$ 11,144,331	$ -	$ -	$ 8,829,148	$ 19,973,479	$ 1,604,255,950
32	$ -	$ 11,144,331	$ -	$ -	$ 9,208,644	$ 20,352,975	$ 1,624,608,925
33	$ -	$ 11,144,331	$ -	$ -	$ 9,595,350	$ 20,739,682	$ 1,645,348,607
34	$ -	$ 11,144,331	$ -	$ -	$ 9,989,404	$ 21,133,736	$ 1,666,482,343
35	$ -	$ 11,144,331	$ -	$ -	$ 10,390,945	$ 21,535,277	$ 1,688,017,619
36	$ -	$ 11,144,331	$ -	$ -	$ 10,800,116	$ 21,944,447	$ 1,709,962,066
37	$ -	$ 11,144,331	$ -	$ -	$ 11,217,060	$ 22,361,391	$ 1,732,323,458
38	$ -	$ 11,144,331	$ -	$ -	$ 11,641,927	$ 22,786,258	$ 1,755,109,716
39	$ -	$ 11,144,331	$ -	$ -	$ 12,074,865	$ 23,219,197	$ 1,778,328,912
40	$ -	$ 11,144,331	$ -	$ -	$ 12,516,030	$ 23,660,362	$ 1,801,989,274
41	$ -	$ 11,144,331	$ -	$ -	$ 12,965,577	$ 24,109,908	$ 1,826,099,182
42	$ -	$ 11,144,331	$ -	$ -	$ 13,423,665	$ 24,567,997	$ 1,850,667,179
43	$ -	$ 11,144,331	$ -	$ -	$ 13,890,457	$ 25,034,789	$ 1,875,701,968
44	$ -	$ 11,144,331	$ -	$ -	$ 14,366,118	$ 25,510,450	$ 1,901,212,417
45	$ -	$ 11,144,331	$ -	$ -	$ 14,850,817	$ 25,995,148	$ 1,927,207,566
46	$ -	$ 11,144,331	$ -	$ -	$ 15,344,725	$ 26,489,056	$ 1,953,696,622
47	$ -	$ 11,144,331	$ -	$ -	$ 15,848,017	$ 26,992,348	$ 1,980,688,970
48	$ -	$ 11,144,331	$ -	$ -	$ 16,360,871	$ 27,505,203	$ 2,008,194,172
49	$ -	$ 11,144,331	$ -	$ -	$ 16,883,470	$ 28,027,801	$ 2,036,221,974
50	$ -	$ 11,144,331	$ -	$ -	$ 17,415,998	$ 28,560,330	$ 2,064,782,303
51	$ -	$ -	$ -	$ 22,900,000	$ 36,902,435	$ 59,802,435	$ 2,124,584,738
52	$ -	$ -	$ -	$ 41,250,000	$ 68,519,458	$ 109,769,458	$ 2,234,354,197
53	$ -	$ -	$ -	$ 22,314,635	$ 38,194,584	$ 60,509,219	$ 2,294,863,416
54	$ -	$ -	$ -	$ 22,314,635	$ 39,344,259	$ 61,658,894	$ 2,356,522,310
55	$ -	$ -	$ -	$ 22,314,635	$ 40,515,778	$ 62,830,413	$ 2,419,352,724
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,419,352,724
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,419,352,724
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,419,352,724
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,419,352,724
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,419,352,724
	Total Design/Const	Total O&M		Total D&D	Total Escalation		Total Life Cycle
	$ 935,126,196	$ 532,356,575	$ 38,508,689	$ 131,093,906	$ 782,267,358		$ 2,419,352,724

APPENDIX C5-5

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 5 - S-UGS 12P/32B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 12P/32B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

80 Year Operating Life

Annual Escalation	Discount Rate
1.90%	3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 24,243,717	$ -	$ -	$ 41,392,899	$265,636,616	$637,616,638
10	$ 407,237,797	$ 23,603,013	$ -	$ -	$ 89,225,443	$520,066,253	$1,157,682,891
11		$ 24,056,528	$ 12,836,230	$ -	$ 8,486,475	$45,379,232	$1,203,062,123
12	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 9,348,680	$46,241,438	$1,249,303,561
13	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 10,227,267	$47,120,025	$1,296,423,586
14	$ -	$ 11,144,331	$ -	$ -	$ 3,359,829	$14,504,160	$1,310,927,746
15	$ -	$ 11,144,331	$ -	$ -	$ 3,635,408	$14,779,739	$1,325,707,486
16	$ -	$ 11,144,331	$ -	$ -	$ 3,916,223	$15,060,554	$1,340,768,040
17	$ -	$ 11,144,331	$ -	$ -	$ 4,202,374	$15,346,705	$1,356,114,745
18	$ -	$ 11,144,331	$ -	$ -	$ 4,493,961	$15,638,292	$1,371,753,038
19	$ -	$ 11,144,331	$ -	$ -	$ 4,791,089	$15,935,420	$1,387,688,458
20	$ -	$ 11,144,331	$ -	$ -	$ 5,093,862	$16,238,193	$1,403,926,651
21	$ -	$ 11,144,331	$ -	$ -	$ 5,402,387	$16,546,719	$1,420,473,369
22	$ -	$ 11,144,331	$ -	$ -	$ 5,716,775	$16,861,106	$1,437,334,475
23	$ -	$ 11,144,331	$ -	$ -	$ 6,037,136	$17,181,467	$1,454,515,943
24	$ -	$ 11,144,331	$ -	$ -	$ 6,363,584	$17,507,915	$1,472,023,858
25	$ -	$ 11,144,331	$ -	$ -	$ 6,696,234	$17,840,566	$1,489,864,423
26	$ -	$ 11,144,331	$ -	$ -	$ 7,035,205	$18,179,536	$1,508,043,960
27	$ -	$ 11,144,331	$ -	$ -	$ 7,380,616	$18,524,947	$1,526,568,907
28	$ -	$ 11,144,331	$ -	$ -	$ 7,732,590	$18,876,921	$1,545,445,829
29	$ -	$ 11,144,331	$ -	$ -	$ 8,091,252	$19,235,583	$1,564,681,411
30	$ -	$ 11,144,331	$ -	$ -	$ 8,456,728	$19,601,059	$1,584,282,471
31	$ -	$ 11,144,331	$ -	$ -	$ 8,829,148	$19,973,479	$1,604,255,950
32	$ -	$ 11,144,331	$ -	$ -	$ 9,208,644	$20,352,975	$1,624,608,925
33	$ -	$ 11,144,331	$ -	$ -	$ 9,595,350	$20,739,682	$1,645,348,607
34	$ -	$ 11,144,331	$ -	$ -	$ 9,989,404	$21,133,736	$1,666,482,343
35	$ -	$ 11,144,331	$ -	$ -	$ 10,390,945	$21,535,277	$1,688,017,619
36	$ -	$ 11,144,331	$ -	$ -	$ 10,800,116	$21,944,447	$1,709,962,066
37	$ -	$ 11,144,331	$ -	$ -	$ 11,217,060	$22,361,391	$1,732,323,458
38	$ -	$ 11,144,331	$ -	$ -	$ 11,641,927	$22,786,258	$1,755,109,716
39	$ -	$ 11,144,331	$ -	$ -	$ 12,074,865	$23,219,197	$1,778,328,912
40	$ -	$ 11,144,331	$ -	$ -	$ 12,516,030	$23,660,362	$1,801,989,274
41	$ -	$ 11,144,331	$ -	$ -	$ 12,965,577	$24,109,908	$1,826,099,182
42	$ -	$ 11,144,331	$ -	$ -	$ 13,423,665	$24,567,997	$1,850,667,179
43	$ -	$ 11,144,331	$ -	$ -	$ 13,890,457	$25,034,789	$1,875,701,968
44	$ -	$ 11,144,331	$ -	$ -	$ 14,366,118	$25,510,450	$1,901,212,417
45	$ -	$ 11,144,331	$ -	$ -	$ 14,850,817	$25,995,148	$1,927,207,566
46	$ -	$ 11,144,331	$ -	$ -	$ 15,344,725	$26,489,056	$1,953,696,622
47	$ -	$ 11,144,331	$ -	$ -	$ 15,848,017	$26,992,348	$1,980,688,970
48	$ -	$ 11,144,331	$ -	$ -	$ 16,360,871	$27,505,203	$2,008,194,172
49	$ -	$ 11,144,331	$ -	$ -	$ 16,883,470	$28,027,801	$2,036,221,974
50	$ -	$ 11,144,331	$ -	$ -	$ 17,415,998	$28,560,330	$2,064,782,303
51	$ -	$ 11,144,331	$ -	$ -	$ 17,958,645	$29,102,976	$2,093,885,279
52	$ -	$ 11,144,331	$ -	$ -	$ 18,511,601	$29,655,933	$2,123,541,212
53	$ -	$ 11,144,331	$ -	$ -	$ 19,075,064	$30,219,395	$2,153,760,607
54	$ -	$ 11,144,331	$ -	$ -	$ 19,649,232	$30,793,564	$2,184,554,171
55	$ -	$ 11,144,331	$ -	$ -	$ 20,234,310	$31,378,641	$2,215,932,812
56	$ -	$ 11,144,331	$ -	$ -	$ 20,830,504	$31,974,836	$2,247,907,648
57	$ -	$ 11,144,331	$ -	$ -	$ 21,438,026	$32,582,358	$2,280,490,006
58	$ -	$ 11,144,331	$ -	$ -	$ 22,057,091	$33,201,422	$2,313,691,428
59	$ -	$ 11,144,331	$ -	$ -	$ 22,687,918	$33,832,249	$2,347,523,677

60	$ -	$ 11,144,331	$ -	$ -	$ 23,330,731	$34,475,062	$2,381,998,739
61	$ -	$ 11,144,331	$ -	$ -	$ 23,985,757	$35,130,088	$2,417,128,828
62	$ -	$ 11,144,331	$ -	$ -	$ 24,653,229	$35,797,560	$2,452,926,388
63	$ -	$ 11,144,331	$ -	$ -	$ 25,333,382	$36,477,714	$2,489,404,101
64	$ -	$ 11,144,331	$ -	$ -	$ 26,026,459	$37,170,790	$2,526,574,891
65	$0	$ 11,144,331	$ -	$ -	$ 26,732,704	$37,877,035	$2,564,451,927
66	$0	$ 11,144,331	$ -	$ -	$ 27,452,367	$38,596,699	$2,603,048,625
67	$0	$ 11,144,331	$ -	$ -	$ 28,185,705	$39,330,036	$2,642,378,662
68	$0	$ 11,144,331	$ -	$ -	$ 28,932,975	$40,077,307	$2,682,455,968
69	$0	$ 11,144,331	$ -	$ -	$ 29,694,444	$40,838,776	$2,723,294,744
70	$0	$ 11,144,331	$ -	$ -	$ 30,470,381	$41,614,712	$2,764,909,456
71	$0	$ 11,144,331	$ -	$ -	$ 31,261,061	$42,405,392	$2,807,314,848
72	$0	$ 11,144,331	$ -	$ -	$ 32,066,763	$43,211,094	$2,850,525,943
73	$0	$ 11,144,331	$ -	$ -	$ 32,887,774	$44,032,105	$2,894,558,048
74	$0	$ 11,144,331	$ -	$ -	$ 33,724,384	$44,868,715	$2,939,426,763
75	$0	$ 11,144,331	$ -	$ -	$ 34,576,889	$45,721,221	$2,985,147,984
76	$0	$ 11,144,331	$ -	$ -	$ 35,445,593	$46,589,924	$3,031,737,907
77	$0	$ 11,144,331	$ -	$ -	$ 36,330,801	$47,475,132	$3,079,213,040
78	$0	$ 11,144,331	$ -	$ -	$ 37,232,829	$48,377,160	$3,127,590,200
79	$0	$ 11,144,331	$ -	$ -	$ 38,151,995	$49,296,326	$3,176,886,526
80	$0	$ 11,144,331	$ -	$ -	$ 39,088,625	$50,232,956	$3,227,119,482
81	$0	$ 11,144,331	$ -	$ -	$ 40,043,051	$51,187,382	$3,278,306,865
82	$0	$ 11,144,331	$ -	$ -	$ 41,015,611	$52,159,943	$3,330,466,807
83	$0	$ 11,144,331	$ -	$ -	$ 42,006,650	$53,150,982	$3,383,617,789
84	$0	$ 11,144,331	$ -	$ -	$ 43,016,519	$54,160,850	$3,437,778,639
85	$0	$ 11,144,331	$ -	$ -	$ 44,045,575	$55,189,906	$3,492,968,545
86	$0	$ 11,144,331	$ -	$ -	$ 45,094,183	$56,238,515	$3,549,207,060
87	$0	$ 11,144,331	$ -	$ -	$ 46,162,715	$57,307,046	$3,606,514,106
88	$0	$ 11,144,331	$ -	$ -	$ 47,251,549	$58,395,880	$3,664,909,987
89	$0	$ 11,144,331	$ -	$ -	$ 48,361,071	$59,505,402	$3,724,415,388
90	$0	$ 11,144,331	$ -	$ -	$ 49,491,673	$60,636,005	$3,785,051,393
91			$ -	$ 22,900,000	$ 104,065,646	$126,965,646	$3,912,017,039
92			$ -	$ 41,250,000	$ 191,799,879	$233,049,879	$4,145,066,918
93			$ -	$ 22,314,635	$ 106,151,574	$128,466,209	$4,273,533,127
94			$ -	$ 22,314,635	$ 108,592,432	$130,907,067	$4,404,440,195
95			$ -	$ 22,314,635	$ 111,079,666	$133,394,302	$4,537,834,496
96				$ -	$ -	$0	$4,537,834,496
97				$ -	$ -	$0	$4,537,834,496
98					$ -	$0	$4,537,834,496
99					$ -	$0	$4,537,834,496
100					$ -	$0	$4,537,834,496

Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation	Total Life Cycle
$935,126,196	$978,129,829	$38,508,689	$131,093,906	$2,454,975,876	$4,537,834,496

APPENDIX C5-6

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 6 - S-UGS 4P/9B, PILOT, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 4P/12B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 4P/12B
Separate CHB

Annual Escalation Factor	1.90%	Discount Rate	3.40%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$1,725,589,068*					*$1,725,589,068*
Operations & Maintenance (40 Year Life)		*$532,356,575*				*$532,356,575*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$215,058,581		*$215,058,581*
Escalation					$1,094,034,579	*$1,094,034,579*
Total Costs (40 year Life)						*$3,605,547,492*
Present Value						*$2,002,548,222*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$1,725,589,068*					*$1,725,589,068*
Operations & Maintenance (80 Year Life)		*$978,129,829*				*$978,129,829*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$215,058,581		*$215,058,581*
Escalation					$3,027,332,635	*$3,027,332,635*
Total Costs (80 Year Life)						*$5,984,618,802*
Present Value						$2,120,237,520

APPENDIX C5-6

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 6 - S-UGS 4P/9B, PILOT, LOW SEISMIC

CAPITAL COST SUMMARY

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 4P/12B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 4P/12B
Separate
CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-UGS 01			Interim Storage Facility and transportation Project		
	C-UGS 01.01		Pilot ISF Facility	$1,197,265,174	
		C-UGS 01.01.01	Storage Pads		$0
		C-UGS 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-UGS 01.01.03	Horizontal Dry Storage Modules		$0
		C-UGS 01.01.04	Vertical Dry Storage Module		$902,950,294
		C-UGS 01.01.05	Storage Cask Fabrication Facility		$0
		C-UGS 01.01.06	Cask Maintenance Facility		$0
		C-UGS 01.01.07	Concrete Batch Plant		$1,850,000
		C-UGS 01.01.08	Visitor Center/ Auditorium		$0
		C-UGS 01.01.09	Administration Building		$3,140,000
		C-UGS 01.01.10	Security		$24,148,975
		C-UGS 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-UGS 01.01.12	Utilities		$18,682,150
		C-UGS 01.01.13	Roads		$18,212,737
		C-UGS 01.01.14	Parking		$735,000
		C-UGS 01.01.15	Site Work		$23,417,500
		C-UGS 01.01.16	Warehouse		$10,200,000
		C-UGS 01.01.17	Maintenance Facility		$0
		C-UGS 01.01.18	Waste management Facility		$0
		C-UGS 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-UGS 01.02		Expanded Interim Storage Facility	$0	
		C-UGS 01.02.01	Expanded Storage Pads and Dry Cask Storage Systems		$0
		C-UGS 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-UGS 01.02.03	Horizontal Dry Storage Modules		$0
		C-UGS 01.02.04	Vertical Dry Storage Casks		$0
		C-UGS 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-UGS 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-UGS 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-UGS 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-UGS 01.02.09	Administration Building (Expanded if needed)		$0
		C-UGS 01.02.10	Security (Expanded)		$0
		C-UGS 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-UGS 01.02.12	Utilities Expanded as needed)		$0
		C-UGS 01.02.13	Roads (Expanded)		$0
		C-UGS 01.02.14	Parking (Expanded as needed)		$0
		C-UGS 01.02.15	Site Work (Expanded)		$0
		C-UGS 01.02.16	Warehouse (Expanded if Needed)		$0
		C-UGS 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-UGS 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-UGS 01.02.19	Hot Cell / Laboratories		$0
		C-UGS 01.02.20	Pool Packaging Facility		$0
		C-UGS 01.02.21	Standardized Storage System		$0
		C-UGS 01.02.22	Standardized Disposal Canister		$0
		C-UGS 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-UGS 01.03		Transportation Equipment	$0	
		C-UGS 01.03.01	Transportation Casks		$0
		C-UGS 01.03.02	Rail Equipment		$0
		C-UGS 01.03.03	Rail Maintenance Facility		$0
		C-UGS 01.03.04	Transportation Systems Services		$0
	C-UGS 01.04		Pre-Construction Capitalized Costs	$56,269,000	
		C-UGS 01.04.01	Land or Land Leases		$1,920,000
		C-UGS 01.04.02	Site permits		$200,000
		C-UGS 01.04.03	Site Licensing		$6,240,000
		C-UGS 01.04.05	Plant Permits		$0
		C-UGS 01.04.06	Planning and Alternative Studies		$750,000

		C-UGS 01.04.07	Research and Development		$0
		C-UGS 01.04.08	Design		$23,955,000
		C-UGS 01.04.09	Other Pre-construction Costs		$13,204,000
		C-UGS 01.04.10	Pre-construction contingencies		$10,000,000
		C-UGS 01.04.xx	(Add Further Breakdown as needed)		$0
	C-UGS 01.05		Indirect Capitalized Costs	$63,180,000	
		C-UGS 01.05.01	Project Management		$2,700,000
		C-UGS 01.05.02	Construction Management		$3,600,000
		C-UGS 01.05.03	Field indirect services		$11,880,000
		C-UGS 01.05.o4	Design Services in support of Construction		$5,400,000
		C-UGS 01.05.05	QA/QC		$12,600,000
		C-UGS 01.05.06	Commissioning and Startup		$1,200,000
		C-UGS 01.05.07	Home office Engineering support to Construction		$7,200,000
		C-UGS 01.05.08	Document Control		$2,700,000
		C-UGS 01.05.09	Project Controls		$3,600,000
		C-UGS 01.05.10	Construction Testing		$2,700,000
		C-UGS 01.05.11	Inspections		$3,600,000
		C-UGS 01.05.12	Startup and Testing		$3,000,000
		C-UGS 01.05.13	Commissioning		$3,000,000
	C-UGS 01.06		Site Selection	$0	
		C-UGS 01.06.01	Site Selection		$0
		C-UGS 01.06.02	Public Information Process		$0
	C-UGS 01.07		Decontamination and Deconstruction	$0	
		C-UGS 01.07.01	Decommissioning		$0
		C-UGS 01.07.02	Decontamination		$0
		C-UGS 01.07.03	Deconstruction		$0
		C-UGS 01.07.04			$0
		C-UGS 01.07.05			$0
	C-UGS 01.08		Project Financial Costs	$176,870,697	
		C-UGS 01.08.01	Contractor Fees		$105,594,446
		C-UGS 01.08.02	Escalation Costs		$71,276,251
		C-UGS 01.08.03	Interest Payments		$0
		C-UGS 01.08.04	Indirect costs to support shipments to repository		$0
		C-UGS 01.08.05			$0
		C-UGS 01.08.xx	(Add Further Breakdown as needed)		$0
	C-UGS 01.09		Project Contingencies	$232,004,197	
		C-UGS 01.09.01	Management Reserve - Contractor Held		$74,840,064
		C-UGS 01.09.02	Contingency - DOE held		$157,164,133
	C-UGS 01.10				
		C-UGS 01.10.01	Other Direct Costs	$0	
		C-UGS 01.10.02	DOE Project Operations		$0
		C-UGS 01.10.03	DOE TM&E		$0
		C-UGS 01.10.04	Host site Operational Costs Miscellaneous		$0
		C-UGS 01.10.05	Miscellaneous ODC		$0
	C-UGS 01.11		Operational Costs	0	
		C-UGS 01.11.01	Operations Costs		$0
		C-UGS 01.11.02	Transportation Costs		$0
		C-UGS 01.11.03	Escalation (Operations/Transportation)		$0
Project Total					

TEC	(All Direct & indirect Costs, MR, Escalation)	$1,568,424,934
TPC	(TEC plus Contingency, ODCs)	$1,725,589,068
LCC	All Capitol, Operation, Transportation, Escalation	$1,725,589,068

APPENDIX C5-6

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 6 - S-UGS 4P/9B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 4P/12B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 4P/12B
Separate CHB

40 Year Operating life

Annual Escalation: 1.90%

Discount Rate: 3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 24,243,717	$ -	$ -	$ 41,392,899	$ 265,636,616	$ 637,616,638
10	$ 1,197,700,669	$ 23,603,013	$ -	$ -	$ 252,927,207	$ 1,474,230,889	$ 2,111,847,526
11		$ 24,056,528	$ 12,836,230	$ -	$ 8,486,475	$ 45,379,232	$ 2,157,226,759
12	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 9,348,680	$ 46,241,438	$ 2,203,468,196
13	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 10,227,267	$ 47,120,025	$ 2,250,588,221
14	$ -	$ 11,144,331	$ -	$ -	$ 3,359,829	$ 14,504,160	$ 2,265,092,382
15	$ -	$ 11,144,331	$ -	$ -	$ 3,635,408	$ 14,779,739	$ 2,279,872,121
16	$ -	$ 11,144,331	$ -	$ -	$ 3,916,223	$ 15,060,554	$ 2,294,932,676
17	$ -	$ 11,144,331	$ -	$ -	$ 4,202,374	$ 15,346,705	$ 2,310,279,381
18	$ -	$ 11,144,331	$ -	$ -	$ 4,493,961	$ 15,638,292	$ 2,325,917,673
19	$ -	$ 11,144,331	$ -	$ -	$ 4,791,089	$ 15,935,420	$ 2,341,853,093
20	$ -	$ 11,144,331	$ -	$ -	$ 5,093,862	$ 16,238,193	$ 2,358,091,286
21	$ -	$ 11,144,331	$ -	$ -	$ 5,402,387	$ 16,546,719	$ 2,374,638,004
22	$ -	$ 11,144,331	$ -	$ -	$ 5,716,775	$ 16,861,106	$ 2,391,499,111
23	$ -	$ 11,144,331	$ -	$ -	$ 6,037,136	$ 17,181,467	$ 2,408,680,578
24	$ -	$ 11,144,331	$ -	$ -	$ 6,363,584	$ 17,507,915	$ 2,426,188,493
25	$ -	$ 11,144,331	$ -	$ -	$ 6,696,234	$ 17,840,566	$ 2,444,029,059
26	$ -	$ 11,144,331	$ -	$ -	$ 7,035,205	$ 18,179,536	$ 2,462,208,595
27	$ -	$ 11,144,331	$ -	$ -	$ 7,380,616	$ 18,524,947	$ 2,480,733,542
28	$ -	$ 11,144,331	$ -	$ -	$ 7,732,590	$ 18,876,921	$ 2,499,610,464
29	$ -	$ 11,144,331	$ -	$ -	$ 8,091,252	$ 19,235,583	$ 2,518,846,047
30	$ -	$ 11,144,331	$ -	$ -	$ 8,456,728	$ 19,601,059	$ 2,538,447,106
31	$ -	$ 11,144,331	$ -	$ -	$ 8,829,148	$ 19,973,479	$ 2,558,420,585
32	$ -	$ 11,144,331	$ -	$ -	$ 9,208,644	$ 20,352,975	$ 2,578,773,560
33	$ -	$ 11,144,331	$ -	$ -	$ 9,595,350	$ 20,739,682	$ 2,599,513,242
34	$ -	$ 11,144,331	$ -	$ -	$ 9,989,404	$ 21,133,736	$ 2,620,646,978
35	$ -	$ 11,144,331	$ -	$ -	$ 10,390,945	$ 21,535,277	$ 2,642,182,254
36	$ -	$ 11,144,331	$ -	$ -	$ 10,800,116	$ 21,944,447	$ 2,664,126,701
37	$ -	$ 11,144,331	$ -	$ -	$ 11,217,060	$ 22,361,391	$ 2,686,488,093
38	$ -	$ 11,144,331	$ -	$ -	$ 11,641,927	$ 22,786,258	$ 2,709,274,351
39	$ -	$ 11,144,331	$ -	$ -	$ 12,074,865	$ 23,219,197	$ 2,732,493,548
40	$ -	$ 11,144,331	$ -	$ -	$ 12,516,030	$ 23,660,362	$ 2,756,153,909
41	$ -	$ 11,144,331	$ -	$ -	$ 12,965,577	$ 24,109,908	$ 2,780,263,818
42	$ -	$ 11,144,331	$ -	$ -	$ 13,423,665	$ 24,567,997	$ 2,804,831,814
43	$ -	$ 11,144,331	$ -	$ -	$ 13,890,457	$ 25,034,789	$ 2,829,866,603
44	$ -	$ 11,144,331	$ -	$ -	$ 14,366,118	$ 25,510,450	$ 2,855,377,053
45	$ -	$ 11,144,331	$ -	$ -	$ 14,850,817	$ 25,995,148	$ 2,881,372,201
46	$ -	$ 11,144,331	$ -	$ -	$ 15,344,725	$ 26,489,056	$ 2,907,861,257
47	$ -	$ 11,144,331	$ -	$ -	$ 15,848,017	$ 26,992,348	$ 2,934,853,605
48	$ -	$ 11,144,331	$ -	$ -	$ 16,360,871	$ 27,505,203	$ 2,962,358,807
49	$ -	$ 11,144,331	$ -	$ -	$ 16,883,470	$ 28,027,801	$ 2,990,386,609
50	$ -	$ 11,144,331	$ -	$ -	$ 17,415,998	$ 28,560,330	$ 3,018,946,939
51	$ -	$ -	$ -	$ 11,650,000	$ 18,773,509	$ 30,423,509	$ 3,049,370,448
52	$ -	$ -	$ -	$ 58,000,000	$ 96,342,511	$ 154,342,511	$ 3,203,712,959
53	$ -	$ -	$ -	$ 48,469,527	$ 82,962,297	$ 131,431,824	$ 3,335,144,783
54	$ -	$ -	$ -	$ 48,469,527	$ 85,459,502	$ 133,929,029	$ 3,469,073,812
55	$ -	$ -	$ -	$ 48,469,527	$ 88,004,153	$ 136,473,680	$ 3,605,547,492
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,605,547,492
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,605,547,492
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,605,547,492
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,605,547,492
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,605,547,492
	Total Design/Const	Total O&M		Total D&D	Total Escalation		Total Life Cycle
	$ 1,725,589,068	$ 532,356,575	$ 38,508,689	$ 215,058,581	$ 1,094,034,579		$ 3,605,547,492

APPENDIX C5-6

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 6 - S-UGS 4P/9B, PILOT, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Pilot Storage Facility (5,000 MTU)

Project: S-UGS Pilot (5,000 MTU) 4P/12B
PILOT Project - S-UGS 60/40 Vertical/Horizontal - Low Seismic 4P/12B
Separate CHB

80 Year Operating Life

Annual Escalation	Discount Rate
1.90%	3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 24,243,717	$ -	$ -	$ 41,392,899	$265,636,616	$637,616,638
10	$ 1,197,700,669	$ 23,603,013	$ -	$ -	$ 252,927,207	$1,474,230,889	$2,111,847,526
11		$ 24,056,528	$ 12,836,230	$ -	$ 8,486,475	$45,379,232	$2,157,226,759
12	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 9,348,680	$46,241,438	$2,203,468,196
13	$ -	$ 24,056,528	$ 12,836,230	$ -	$ 10,227,267	$47,120,025	$2,250,588,221
14	$ -	$ 11,144,331	$ -	$ -	$ 3,359,829	$14,504,160	$2,265,092,382
15	$ -	$ 11,144,331	$ -	$ -	$ 3,635,408	$14,779,739	$2,279,872,121
16	$ -	$ 11,144,331	$ -	$ -	$ 3,916,223	$15,060,554	$2,294,932,676
17	$ -	$ 11,144,331	$ -	$ -	$ 4,202,374	$15,346,705	$2,310,279,381
18	$ -	$ 11,144,331	$ -	$ -	$ 4,493,961	$15,638,292	$2,325,917,673
19	$ -	$ 11,144,331	$ -	$ -	$ 4,791,089	$15,935,420	$2,341,853,093
20	$ -	$ 11,144,331	$ -	$ -	$ 5,093,862	$16,238,193	$2,358,091,286
21	$ -	$ 11,144,331	$ -	$ -	$ 5,402,387	$16,546,719	$2,374,638,004
22	$ -	$ 11,144,331	$ -	$ -	$ 5,716,775	$16,861,106	$2,391,499,111
23	$ -	$ 11,144,331	$ -	$ -	$ 6,037,136	$17,181,467	$2,408,680,578
24	$ -	$ 11,144,331	$ -	$ -	$ 6,363,584	$17,507,915	$2,426,188,493
25	$ -	$ 11,144,331	$ -	$ -	$ 6,696,234	$17,840,566	$2,444,029,059
26	$ -	$ 11,144,331	$ -	$ -	$ 7,035,205	$18,179,536	$2,462,208,595
27	$ -	$ 11,144,331	$ -	$ -	$ 7,380,616	$18,524,947	$2,480,733,542
28	$ -	$ 11,144,331	$ -	$ -	$ 7,732,590	$18,876,921	$2,499,610,464
29	$ -	$ 11,144,331	$ -	$ -	$ 8,091,252	$19,235,583	$2,518,846,047
30	$ -	$ 11,144,331	$ -	$ -	$ 8,456,728	$19,601,059	$2,538,447,106
31	$ -	$ 11,144,331	$ -	$ -	$ 8,829,148	$19,973,479	$2,558,420,585
32	$ -	$ 11,144,331	$ -	$ -	$ 9,208,644	$20,352,975	$2,578,773,560
33	$ -	$ 11,144,331	$ -	$ -	$ 9,595,350	$20,739,682	$2,599,513,242
34	$ -	$ 11,144,331	$ -	$ -	$ 9,989,404	$21,133,736	$2,620,646,978
35	$ -	$ 11,144,331	$ -	$ -	$ 10,390,945	$21,535,277	$2,642,182,254
36	$ -	$ 11,144,331	$ -	$ -	$ 10,800,116	$21,944,447	$2,664,126,701
37	$ -	$ 11,144,331	$ -	$ -	$ 11,217,060	$22,361,391	$2,686,488,093
38	$ -	$ 11,144,331	$ -	$ -	$ 11,641,927	$22,786,258	$2,709,274,351
39	$ -	$ 11,144,331	$ -	$ -	$ 12,074,865	$23,219,197	$2,732,493,548
40	$ -	$ 11,144,331	$ -	$ -	$ 12,516,030	$23,660,362	$2,756,153,909
41	$ -	$ 11,144,331	$ -	$ -	$ 12,965,577	$24,109,908	$2,780,263,818
42	$ -	$ 11,144,331	$ -	$ -	$ 13,423,665	$24,567,997	$2,804,831,814
43	$ -	$ 11,144,331	$ -	$ -	$ 13,890,457	$25,034,789	$2,829,866,603
44	$ -	$ 11,144,331	$ -	$ -	$ 14,366,118	$25,510,450	$2,855,377,053
45	$ -	$ 11,144,331	$ -	$ -	$ 14,850,817	$25,995,148	$2,881,372,201
46	$ -	$ 11,144,331	$ -	$ -	$ 15,344,725	$26,489,056	$2,907,861,257
47	$ -	$ 11,144,331	$ -	$ -	$ 15,848,017	$26,992,348	$2,934,853,605
48	$ -	$ 11,144,331	$ -	$ -	$ 16,360,871	$27,505,203	$2,962,358,807
49	$ -	$ 11,144,331	$ -	$ -	$ 16,883,470	$28,027,801	$2,990,386,609
50	$ -	$ 11,144,331	$ -	$ -	$ 17,415,998	$28,560,330	$3,018,946,939
51	$ -	$ 11,144,331	$ -	$ -	$ 17,958,645	$29,102,976	$3,048,049,915
52	$ -	$ 11,144,331	$ -	$ -	$ 18,511,601	$29,655,933	$3,077,705,847
53	$ -	$ 11,144,331	$ -	$ -	$ 19,075,064	$30,219,395	$3,107,925,242
54	$ -	$ 11,144,331	$ -	$ -	$ 19,649,232	$30,793,564	$3,138,718,806
55	$ -	$ 11,144,331	$ -	$ -	$ 20,234,310	$31,378,641	$3,170,097,448
56	$ -	$ 11,144,331	$ -	$ -	$ 20,830,504	$31,974,836	$3,202,072,283
57	$ -	$ 11,144,331	$ -	$ -	$ 21,438,026	$32,582,358	$3,234,654,641
58	$ -	$ 11,144,331	$ -	$ -	$ 22,057,091	$33,201,422	$3,267,856,063
59	$ -	$ 11,144,331	$ -	$ -	$ 22,687,918	$33,832,249	$3,301,688,313

60	$ -	$ 11,144,331	$ -	$ -	$ 23,330,731	$34,475,062	$3,336,163,375
61	$ -	$ 11,144,331	$ -	$ -	$ 23,985,757	$35,130,088	$3,371,293,463
62	$ -	$ 11,144,331	$ -	$ -	$ 24,653,229	$35,797,560	$3,407,091,023
63	$ -	$ 11,144,331	$ -	$ -	$ 25,333,382	$36,477,714	$3,443,568,736
64	$ -	$ 11,144,331	$ -	$ -	$ 26,026,459	$37,170,790	$3,480,739,527
65	$0	$ 11,144,331	$ -	$ -	$ 26,732,704	$37,877,035	$3,518,616,562
66	$0	$ 11,144,331	$ -	$ -	$ 27,452,367	$38,596,699	$3,557,213,261
67	$0	$ 11,144,331	$ -	$ -	$ 28,185,705	$39,330,036	$3,596,543,297
68	$0	$ 11,144,331	$ -	$ -	$ 28,932,975	$40,077,307	$3,636,620,603
69	$0	$ 11,144,331	$ -	$ -	$ 29,694,444	$40,838,776	$3,677,459,379
70	$0	$ 11,144,331	$ -	$ -	$ 30,470,381	$41,614,712	$3,719,074,091
71	$0	$ 11,144,331	$ -	$ -	$ 31,261,061	$42,405,392	$3,761,479,483
72	$0	$ 11,144,331	$ -	$ -	$ 32,066,763	$43,211,094	$3,804,690,578
73	$0	$ 11,144,331	$ -	$ -	$ 32,887,774	$44,032,105	$3,848,722,683
74	$0	$ 11,144,331	$ -	$ -	$ 33,724,384	$44,868,715	$3,893,591,398
75	$0	$ 11,144,331	$ -	$ -	$ 34,576,889	$45,721,221	$3,939,312,619
76	$0	$ 11,144,331	$ -	$ -	$ 35,445,593	$46,589,924	$3,985,902,543
77	$0	$ 11,144,331	$ -	$ -	$ 36,330,801	$47,475,132	$4,033,377,675
78	$0	$ 11,144,331	$ -	$ -	$ 37,232,829	$48,377,160	$4,081,754,835
79	$0	$ 11,144,331	$ -	$ -	$ 38,151,995	$49,296,326	$4,131,051,161
80	$0	$ 11,144,331	$ -	$ -	$ 39,088,625	$50,232,956	$4,181,284,117
81	$0	$ 11,144,331	$ -	$ -	$ 40,043,051	$51,187,382	$4,232,471,500
82	$0	$ 11,144,331	$ -	$ -	$ 41,015,611	$52,159,943	$4,284,631,442
83	$0	$ 11,144,331	$ -	$ -	$ 42,006,650	$53,150,982	$4,337,782,424
84	$0	$ 11,144,331	$ -	$ -	$ 43,016,519	$54,160,850	$4,391,943,274
85	$0	$ 11,144,331	$ -	$ -	$ 44,045,575	$55,189,906	$4,447,133,180
86	$0	$ 11,144,331	$ -	$ -	$ 45,094,183	$56,238,515	$4,503,371,695
87	$0	$ 11,144,331	$ -	$ -	$ 46,162,715	$57,307,046	$4,560,678,741
88	$0	$ 11,144,331	$ -	$ -	$ 47,251,549	$58,395,880	$4,619,074,622
89	$0	$ 11,144,331	$ -	$ -	$ 48,361,071	$59,505,402	$4,678,580,024
90	$0	$ 11,144,331	$ -	$ -	$ 49,491,673	$60,636,005	$4,739,216,028
91			$ -	$ 11,650,000	$ 52,941,693	$64,591,693	$4,803,807,722
92			$ -	$ 58,000,000	$ 269,682,254	$327,682,254	$5,131,489,975
93			$ -	$ 48,469,527	$ 230,571,393	$279,040,920	$5,410,530,895
94			$ -	$ 48,469,527	$ 235,873,170	$284,342,698	$5,694,873,593
95			$ -	$ 48,469,527	$ 241,275,682	$289,745,209	$5,984,618,802
96				$ -	$ -	$0	$5,984,618,802
97				$ -	$ -	$0	$5,984,618,802
98					$ -	$0	$5,984,618,802
99					$ -	$0	$5,984,618,802
100					$ -	$0	$5,984,618,802
	Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation		Total Life Cycle
	$1,725,589,068	$978,129,829	$38,508,689	$215,058,581	$3,027,332,635		$5,984,618,802

APPENDIX C5-7

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 7 - S-BGV 21P/44B, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 21P-44B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

Annual Escalation Factor	1.90%
Discount Rate	3.40%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$795,493,114*					*$795,493,114*
Operations & Maintenance (40 Year Life)		*$532,376,272*				*$532,376,272*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$133,496,188		*$133,496,188*
Escalation					$756,442,153	*$756,442,153*
Total Costs (40 year Life)						*$2,256,316,416*
Present Value						*$1,162,639,967*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$795,493,114*					*$795,493,114*
Operations & Maintenance (80 Year Life)		*$973,159,561*				*$973,159,561*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$133,496,188		*$133,496,188*
Escalation					$2,424,323,782	*$2,424,323,782*
Total Costs (80 Year Life)						*$4,364,981,333*
Present Value						$1,295,024,252

APPENDIX C5-7

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 7 - S-BGV 21P/44B, LOW SEISMIC

CAPITAL COST SUMMARY

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 21P-44B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate
CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-BGV 01			Interim Storage Facility and transportation Project		
	C-BGV 01.01		Pilot ISF Facility	$478,148,287	
		C-BGV 01.01.01	Storage BGV LE s		$0
		C-BGV 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-BGV 01.01.03	Horizontal Dry Storage Modules		$0
		C-BGV 01.01.04	Vertical Dry Storage Module		$181,833,406
		C-BGV 01.01.05	Storage Cask Fabrication Facility		$2,000,000
		C-BGV 01.01.06	Cask Maintenance Facility		$0
		C-BGV 01.01.07	Concrete Batch Plant		$1,850,000
		C-BGV 01.01.08	Visitor Center/ Auditorium		$0
		C-BGV 01.01.09	Administration Building		$3,140,000
		C-BGV 01.01.10	Security		$24,148,975
		C-BGV 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-BGV 01.01.12	Utilities		$18,682,150
		C-BGV 01.01.13	Roads		$18,212,737
		C-BGV 01.01.14	Parking		$735,000
		C-BGV 01.01.15	Site Work		$23,417,500
		C-BGV 01.01.16	Warehouse		$10,200,000
		C-BGV 01.01.17	Maintenance Facility		$0
		C-BGV 01.01.18	Waste management Facility		$0
		C-BGV 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-BGV 01.02		Expanded Interim Storage Facility	$0	
		C-BGV 01.02.01	Expanded Storage BGV LE s and Dry Cask Storage Systems		$0
		C-BGV 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-BGV 01.02.03	Horizontal Dry Storage Modules		$0
		C-BGV 01.02.04	Vertical Dry Storage Casks		$0
		C-BGV 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-BGV 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-BGV 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-BGV 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-BGV 01.02.09	Administration Building (Expanded if needed)		$0
		C-BGV 01.02.10	Security (Expanded)		$0
		C-BGV 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-BGV 01.02.12	Utilities Expanded as needed)		$0
		C-BGV 01.02.13	Roads (Expanded)		$0
		C-BGV 01.02.14	Parking (Expanded as needed)		$0
		C-BGV 01.02.15	Site Work (Expanded)		$0
		C-BGV 01.02.16	Warehouse (Expanded if Needed)		$0
		C-BGV 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-BGV 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-BGV 01.02.19	Hot Cell / Laboratories		$0
		C-BGV 01.02.20	Pool Packaging Facility		$0
		C-BGV 01.02.21	Standardized Storage System		$0
		C-BGV 01.02.22	Standardized Disposal Canister		$0
		C-BGV 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-BGV 01.03		Transportation Equipment	$0	
		C-BGV 01.03.01	Transportation Casks		$0
		C-BGV 01.03.02	Rail Equipment		$0
		C-BGV 01.03.03	Rail Maintenance Facility		$0
		C-BGV 01.03.04	Transportation Systems Services		$0
	C-BGV 01.04		Pre-Construction Capitalized Costs	$66,025,000	
		C-BGV 01.04.01	Land or Land Leases		$7,680,000
		C-BGV 01.04.02	Site permits		$200,000
		C-BGV 01.04.03	Site Licensing		$6,240,000
		C-BGV 01.04.05	Plant Permits		$0
		C-BGV 01.04.06	Planning and Alternative Studies		$750,000

		C-BGV 01.04.07	Research and Development		$0
		C-BGV 01.04.08	Design		$23,955,000
		C-BGV 01.04.09	Other Pre-construction Costs		$17,200,000
		C-BGV 01.04.10	Pre-construction contingencies		$10,000,000
		C-BGV 01.04.xx	(Add Further Breakdown as needed)		$0
	C-BGV 01.05		Indirect Capitalized Costs	$63,180,000	
		C-BGV 01.05.01	Project Management		$2,700,000
		C-BGV 01.05.02	Construction Management		$3,600,000
		C-BGV 01.05.03	Field indirect services		$11,880,000
		C-BGV 01.05.o4	Design Services in support of Construction		$5,400,000
		C-BGV 01.05.05	QA/QC		$12,600,000
		C-BGV 01.05.06	Commissioning and Startup		$1,200,000
		C-BGV 01.05.07	Home office Engineering support to Construction		$7,200,000
		C-BGV 01.05.08	Document Control		$2,700,000
		C-BGV 01.05.09	Project Controls		$3,600,000
		C-BGV 01.05.10	Construction Testing		$2,700,000
		C-BGV 01.05.11	Inspections		$3,600,000
		C-BGV 01.05.12	Startup and Testing		$3,000,000
		C-BGV 01.05.13	Commissioning		$3,000,000
	C-BGV 01.06		Site Selection	$0	
		C-BGV 01.06.01	Site Selection		$0
		C-BGV 01.06.02	Public Information Process		$0
	C-BGV 01.07		Decontamination and Deconstruction	$0	
		C-BGV 01.07.01	Decommissioning		$0
		C-BGV 01.07.02	Decontamination		$0
		C-BGV 01.07.03	Deconstruction		$0
		C-BGV 01.07.04			$0
		C-BGV 01.07.05			$0
	C-BGV 01.08		Project Financial Costs	$81,385,340	
		C-BGV 01.08.01	Contractor Fees		$48,588,263
		C-BGV 01.08.02	Escalation Costs		$32,797,077
		C-BGV 01.08.03	Interest Payments		$0
		C-BGV 01.08.04	Indirect costs to support shipments to repository		$0
		C-BGV 01.08.05			$0
		C-BGV 01.08.xx	(Add Further Breakdown as needed)		$0
	C-BGV 01.09		Project Contingencies	$106,754,487	
		C-BGV 01.09.01	Management Reserve - Contractor Held		$34,436,931
		C-BGV 01.09.02	Contingency - DOE held		$72,317,556
	C-BGV 01.10				
		C-BGV 01.10.01	Other Direct Costs	$0	
		C-BGV 01.10.02	DOE Project Operations		$0
		C-BGV 01.10.03	DOE TM&E		$0
		C-BGV 01.10.04	Host site Operational Costs Miscellaneous		$0
		C-BGV 01.10.05	Miscellaneous ODC		$0
	C-BGV 01.11		Operational Costs	0	
		C-BGV 01.11.01	Operations Costs		$0
		C-BGV 01.11.02	Transportation Costs		$0
		C-BGV 01.11.03	Escalation (Operations/Transportation)		$0
Project Total					

TEC	(All Direct & indirect Costs, MR, Escalation)	$723,175,558
TPC	(TEC plus Contingency, ODCs)	$795,493,114
LCC	All Capitol, Operation, Transportation, Escalation	$795,493,114

APPENDIX C5-7

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 7 - S-BGV 21P/44B, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 21P-44B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

Annual Escalation: 1.90%
Discount Rate: 3.40%

40 Year Operating life

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$ 266,619,471	$ 638,599,492
10	$ 267,604,715	$ 24,539,498	$ -	$ -	$ 60,501,922	$ 352,646,135	$ 991,245,627
11		$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$ 46,555,646	$ 1,037,801,274
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$ 47,440,204	$ 1,085,241,477
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$ 48,341,568	$ 1,133,583,045
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$ 14,341,801	$ 1,147,924,846
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$ 14,614,296	$ 1,162,539,142
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$ 14,891,967	$ 1,177,431,109
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$ 15,174,915	$ 1,192,606,024
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$ 15,463,238	$ 1,208,069,262
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$ 15,757,040	$ 1,223,826,301
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$ 16,056,423	$ 1,239,882,725
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$ 16,361,495	$ 1,256,244,220
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$ 16,672,364	$ 1,272,916,584
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$ 16,989,139	$ 1,289,905,722
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$ 17,311,932	$ 1,307,217,655
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$ 17,640,859	$ 1,324,858,514
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$ 17,976,035	$ 1,342,834,549
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$ 18,317,580	$ 1,361,152,129
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$ 18,665,614	$ 1,379,817,743
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$ 19,020,261	$ 1,398,838,004
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$ 19,381,646	$ 1,418,219,649
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$ 19,749,897	$ 1,437,969,546
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$ 20,125,145	$ 1,458,094,691
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$ 20,507,523	$ 1,478,602,214
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$ 20,897,166	$ 1,499,499,380
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$ 21,294,212	$ 1,520,793,591
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$ 21,698,802	$ 1,542,492,393
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$ 22,111,079	$ 1,564,603,472
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$ 22,531,190	$ 1,587,134,662
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$ 22,959,282	$ 1,610,093,944
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$ 23,395,509	$ 1,633,489,452
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$ 23,840,023	$ 1,657,329,476
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$ 24,292,984	$ 1,681,622,459
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$ 24,754,550	$ 1,706,377,010
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$ 25,224,887	$ 1,731,601,896
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$ 25,704,160	$ 1,757,306,056
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$ 26,192,539	$ 1,783,498,595
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$ 26,690,197	$ 1,810,188,791
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$ 27,197,311	$ 1,837,386,102
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$ 27,714,060	$ 1,865,100,162
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$ 28,240,627	$ 1,893,340,788
51	$ -	$ -	$ -	$ 22,900,000	$ 36,902,435	$ 59,802,435	$ 1,953,143,223
52	$ -	$ -	$ -	$ 24,000,000	$ 39,865,867	$ 63,865,867	$ 2,017,009,090
53	$ -	$ -	$ -	$ 28,865,396	$ 49,407,116	$ 78,272,512	$ 2,095,281,602
54	$ -	$ -	$ -	$ 28,865,396	$ 50,894,294	$ 79,759,690	$ 2,175,041,292
55	$ -	$ -	$ -	$ 28,865,396	$ 52,409,728	$ 81,275,124	$ 2,256,316,416
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,256,316,416
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,256,316,416
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,256,316,416
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,256,316,416
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,256,316,416
	Total Design/Const	Total O&M		Total D&D	Total Escalation		Total Life Cycle
	$ 795,493,114	$ 532,376,272	$ 38,508,689	$ 133,496,188	$ 756,442,153		$ 2,256,316,416

APPENDIX C5-7

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 7 - S-BGV 21P/44B, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 21P-44B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

80 Year Operating Life

Annual Escalation	Discount Rate
1.90%	3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$266,619,471	$638,599,492
10	$ 267,604,715	$ 24,539,498	$ -	$ -	$ 60,501,922	$352,646,135	$991,245,627
11		$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$46,555,646	$1,037,801,274
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$47,440,204	$1,085,241,477
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$48,341,568	$1,133,583,045
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$14,341,801	$1,147,924,846
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$14,614,296	$1,162,539,142
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$14,891,967	$1,177,431,109
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$15,174,915	$1,192,606,024
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$15,463,238	$1,208,069,262
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$15,757,040	$1,223,826,301
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$16,056,423	$1,239,882,725
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$16,361,495	$1,256,244,220
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$16,672,364	$1,272,916,584
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$16,989,139	$1,289,905,722
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$17,311,932	$1,307,217,655
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$17,640,859	$1,324,858,514
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$17,976,035	$1,342,834,549
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$18,317,580	$1,361,152,129
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$18,665,614	$1,379,817,743
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$19,020,261	$1,398,838,004
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$19,381,646	$1,418,219,649
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$19,749,897	$1,437,969,546
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$20,125,145	$1,458,094,691
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$20,507,523	$1,478,602,214
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$20,897,166	$1,499,499,380
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$21,294,212	$1,520,793,591
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$21,698,802	$1,542,492,393
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$22,111,079	$1,564,603,472
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$22,531,190	$1,587,134,662
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$22,959,282	$1,610,093,944
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$23,395,509	$1,633,489,452
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$23,840,023	$1,657,329,476
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$24,292,984	$1,681,622,459
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$24,754,550	$1,706,377,010
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$25,224,887	$1,731,601,896
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$25,704,160	$1,757,306,056
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$26,192,539	$1,783,498,595
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$26,690,197	$1,810,188,791
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$27,197,311	$1,837,386,102
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$27,714,060	$1,865,100,162
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$28,240,627	$1,893,340,788
51	$ -	$ 11,019,582	$ -	$ -	$ 17,757,616	$28,777,199	$1,922,117,987
52	$ -	$ 11,019,582	$ -	$ -	$ 18,304,383	$29,323,965	$1,951,441,952
53	$ -	$ 11,019,582	$ -	$ -	$ 18,861,538	$29,881,121	$1,981,323,073
54	$ -	$ 11,019,582	$ -	$ -	$ 19,429,280	$30,448,862	$2,011,771,935
55	$ -	$ 11,019,582	$ -	$ -	$ 20,007,808	$31,027,390	$2,042,799,325
56	$ -	$ 11,019,582	$ -	$ -	$ 20,597,329	$31,616,911	$2,074,416,236
57	$ -	$ 11,019,582	$ -	$ -	$ 21,198,050	$32,217,632	$2,106,633,868
58	$ -	$ 11,019,582	$ -	$ -	$ 21,810,185	$32,829,767	$2,139,463,635
59	$ -	$ 11,019,582	$ -	$ -	$ 22,433,950	$33,453,533	$2,172,917,168
60	$ -	$ 11,019,582	$ -	$ -	$ 23,069,568	$34,089,150	$2,207,006,317
61	$ -	$ 11,019,582	$ -	$ -	$ 23,717,261	$34,736,844	$2,241,743,161
62	$ -	$ 11,019,582	$ -	$ -	$ 24,377,261	$35,396,844	$2,277,140,005

63	$ -	$ 11,019,582	$ -	$ -	$ 25,049,801	$36,069,384	$2,313,209,388
64	$ -	$ 11,019,582	$ -	$ -	$ 25,735,120	$36,754,702	$2,349,964,090
65	$0	$ 11,019,582	$ -	$ -	$ 26,433,459	$37,453,041	$2,387,417,131
66	$0	$ 11,019,582	$ -	$ -	$ 27,145,067	$38,164,649	$2,425,581,780
67	$0	$ 11,019,582	$ -	$ -	$ 27,870,195	$38,889,777	$2,464,471,558
68	$0	$ 11,019,582	$ -	$ -	$ 28,609,101	$39,628,683	$2,504,100,241
69	$0	$ 11,019,582	$ -	$ -	$ 29,362,046	$40,381,628	$2,544,481,869
70	$0	$ 11,019,582	$ -	$ -	$ 30,129,297	$41,148,879	$2,585,630,748
71	$0	$ 11,019,582	$ -	$ -	$ 30,911,126	$41,930,708	$2,627,561,456
72	$0	$ 11,019,582	$ -	$ -	$ 31,707,809	$42,727,391	$2,670,288,847
73	$0	$ 11,019,582	$ -	$ -	$ 32,519,629	$43,539,212	$2,713,828,059
74	$0	$ 11,019,582	$ -	$ -	$ 33,346,874	$44,366,457	$2,758,194,516
75	$0	$ 11,019,582	$ -	$ -	$ 34,189,837	$45,209,419	$2,803,403,935
76	$0	$ 11,019,582	$ -	$ -	$ 35,048,816	$46,068,398	$2,849,472,333
77	$0	$ 11,019,582	$ -	$ -	$ 35,924,116	$46,943,698	$2,896,416,031
78	$0	$ 11,019,582	$ -	$ -	$ 36,816,046	$47,835,628	$2,944,251,659
79	$0	$ 11,019,582	$ -	$ -	$ 37,724,923	$48,744,505	$2,992,996,165
80	$0	$ 11,019,582	$ -	$ -	$ 38,651,068	$49,670,651	$3,042,666,815
81	$0	$ 11,019,582	$ -	$ -	$ 39,594,811	$50,614,393	$3,093,281,208
82	$0	$ 11,019,582	$ -	$ -	$ 40,556,484	$51,576,067	$3,144,857,275
83	$0	$ 11,019,582	$ -	$ -	$ 41,536,430	$52,556,012	$3,197,413,287
84	$0	$ 11,019,582	$ -	$ -	$ 42,534,994	$53,554,576	$3,250,967,863
85	$0	$ 11,019,582	$ -	$ -	$ 43,552,531	$54,572,113	$3,305,539,976
86	$0	$ 11,019,582	$ -	$ -	$ 44,589,401	$55,608,983	$3,361,148,959
87	$0	$ 11,019,582	$ -	$ -	$ 45,645,972	$56,665,554	$3,417,814,513
88	$0	$ 11,019,582	$ -	$ -	$ 46,722,617	$57,742,199	$3,475,556,712
89	$0	$ 11,019,582	$ -	$ -	$ 47,819,719	$58,839,301	$3,534,396,013
90	$0	$ 11,019,582	$ -	$ -	$ 48,937,666	$59,957,248	$3,594,353,261
91			$ -	$ 22,900,000	$ 104,065,646	$126,965,646	$3,721,318,907
92			$ -	$ 24,000,000	$ 111,592,657	$135,592,657	$3,856,911,564
93			$ -	$ 28,865,396	$ 137,313,792	$166,179,188	$4,023,090,752
94			$ -	$ 28,865,396	$ 140,471,197	$169,336,593	$4,192,427,345
95			$ -	$ 28,865,396	$ 143,688,592	$172,553,988	$4,364,981,333
96				$ -	$ -	$0	$4,364,981,333
97				$ -	$ -	$0	$4,364,981,333
98					$ -	$0	$4,364,981,333
99					$ -	$0	$4,364,981,333
100					$ -	$0	$4,364,981,333
	Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation		Total Life Cycle
	$795,493,114	$973,159,561	$38,508,689	$133,496,188	$2,424,323,782		$4,364,981,333

APPENDIX C5-8

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 8 - S-BGV 12P/32B, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 12P/32B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

Annual Escalation Factor	1.90%
Discount Rate	3.40%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$823,585,033*					*$823,585,033*
Operations & Maintenance (40 Year Life)		*$532,376,272*				*$532,376,272*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$144,101,185		*$144,101,185*
Escalation					$780,244,783	*$780,244,783*
Total Costs (40 year Life)						*$2,318,815,961*
Present Value						*$1,191,824,415*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$823,585,033*					*$823,585,033*
Operations & Maintenance (80 Year Life)		*$973,159,561*				*$973,159,561*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$144,101,185		*$144,101,185*
Escalation					$2,480,235,297	*$2,480,235,297*
Total Costs (80 Year Life)						*$4,459,589,764*
Present Value						$1,322,034,621

APPENDIX C5-8

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 8 - S-BGV 12P/32B, LOW SEISMIC

CAPITAL COST SUMMARY

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 12P/32B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate
CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-BGV 01			Interim Storage Facility and transportation Project		
	C-BGV 01.01		Pilot ISF Facility	$499,596,265	
		C-BGV 01.01.01	Storage BGV LE s		$0
		C-BGV 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-BGV 01.01.03	Horizontal Dry Storage Modules		$0
		C-BGV 01.01.04	Vertical Dry Storage Module		$203,281,385
		C-BGV 01.01.05	Storage Cask Fabrication Facility		$2,000,000
		C-BGV 01.01.06	Cask Maintenance Facility		$0
		C-BGV 01.01.07	Concrete Batch Plant		$1,850,000
		C-BGV 01.01.08	Visitor Center/ Auditorium		$0
		C-BGV 01.01.09	Administration Building		$3,140,000
		C-BGV 01.01.10	Security		$24,148,975
		C-BGV 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-BGV 01.01.12	Utilities		$18,682,150
		C-BGV 01.01.13	Roads		$18,212,737
		C-BGV 01.01.14	Parking		$735,000
		C-BGV 01.01.15	Site Work		$23,417,500
		C-BGV 01.01.16	Warehouse		$10,200,000
		C-BGV 01.01.17	Maintenance Facility		$0
		C-BGV 01.01.18	Waste management Facility		$0
		C-BGV 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-BGV 01.02		Expanded Interim Storage Facility	$0	
		C-BGV 01.02.01	Expanded Storage BGV LE s and Dry Cask Storage Systems		$0
		C-BGV 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-BGV 01.02.03	Horizontal Dry Storage Modules		$0
		C-BGV 01.02.04	Vertical Dry Storage Casks		$0
		C-BGV 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-BGV 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-BGV 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-BGV 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-BGV 01.02.09	Administration Building (Expanded if needed)		$0
		C-BGV 01.02.10	Security (Expanded)		$0
		C-BGV 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-BGV 01.02.12	Utilities Expanded as needed)		$0
		C-BGV 01.02.13	Roads (Expanded)		$0
		C-BGV 01.02.14	Parking (Expanded as needed)		$0
		C-BGV 01.02.15	Site Work (Expanded)		$0
		C-BGV 01.02.16	Warehouse (Expanded if Needed)		$0
		C-BGV 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-BGV 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-BGV 01.02.19	Hot Cell / Laboratories		$0
		C-BGV 01.02.20	Pool Packaging Facility		$0
		C-BGV 01.02.21	Standardized Storage System		$0
		C-BGV 01.02.22	Standardized Disposal Canister		$0
		C-BGV 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-BGV 01.03		Transportation Equipment	$0	
		C-BGV 01.03.01	Transportation Casks		$0
		C-BGV 01.03.02	Rail Equipment		$0
		C-BGV 01.03.03	Rail Maintenance Facility		$0
		C-BGV 01.03.04	Transportation Systems Services		$0
	C-BGV 01.04		Pre-Construction Capitalized Costs	$66,025,000	
		C-BGV 01.04.01	Land or Land Leases		$7,680,000
		C-BGV 01.04.02	Site permits		$200,000
		C-BGV 01.04.03	Site Licensing		$6,240,000
		C-BGV 01.04.05	Plant Permits		$0
		C-BGV 01.04.06	Planning and Alternative Studies		$750,000
		C-BGV 01.04.07	Research and Development		$0
		C-BGV 01.04.08	Design		$23,955,000
		C-BGV 01.04.09	Other Pre-construction Costs		$17,200,000

	C-BGV 01.04.10	Pre-construction contingencies		$10,000,000
	C-BGV 01.04.xx	(Add Further Breakdown as needed)		$0
C-BGV 01.05		Indirect Capitalized Costs	$63,180,000	
	C-BGV 01.05.01	Project Management		$2,700,000
	C-BGV 01.05.02	Construction Management		$3,600,000
	C-BGV 01.05.03	Field indirect services		$11,880,000
	C-BGV 01.05.o4	Design Services in support of Construction		$5,400,000
	C-BGV 01.05.05	QA/QC		$12,600,000
	C-BGV 01.05.06	Commissioning and Startup		$1,200,000
	C-BGV 01.05.07	Home office Engineering support to Construction		$7,200,000
	C-BGV 01.05.08	Document Control		$2,700,000
	C-BGV 01.05.09	Project Controls		$3,600,000
	C-BGV 01.05.10	Construction Testing		$2,700,000
	C-BGV 01.05.11	Inspections		$3,600,000
	C-BGV 01.05.12	Startup and Testing		$3,000,000
	C-BGV 01.05.13	Commissioning		$3,000,000
C-BGV 01.06		Site Selection	$0	
	C-BGV 01.06.01	Site Selection		$0
	C-BGV 01.06.02	Public Information Process		$0
C-BGV 01.07		Decontamination and Deconstruction	$0	
	C-BGV 01.07.01	Decommissioning		$0
	C-BGV 01.07.02	Decontamination		$0
	C-BGV 01.07.03	Deconstruction		$0
	C-BGV 01.07.04			$0
	C-BGV 01.07.05			$0
C-BGV 01.08		Project Financial Costs	$84,259,369	
	C-BGV 01.08.01	Contractor Fees		$50,304,101
	C-BGV 01.08.02	Escalation Costs		$33,955,268
	C-BGV 01.08.03	Interest Payments		$0
	C-BGV 01.08.04	Indirect costs to support shipments to repository		$0
	C-BGV 01.08.05			$0
	C-BGV 01.08.xx	(Add Further Breakdown as needed)		$0
C-BGV 01.09		Project Contingencies	$110,524,398	
	C-BGV 01.09.01	Management Reserve - Contractor Held		$35,653,032
	C-BGV 01.09.02	Contingency - DOE held		$74,871,367
C-BGV 01.10				
	C-BGV 01.10.01	Other Direct Costs	$0	
	C-BGV 01.10.02	DOE Project Operations		$0
	C-BGV 01.10.03	DOE TM&E		$0
	C-BGV 01.10.04	Host site Operational Costs Miscellaneous		$0
	C-BGV 01.10.05	Miscellaneous ODC		$0
C-BGV 01.11		Operational Costs	0	
	C-BGV 01.11.01	Operations Costs		$0
	C-BGV 01.11.02	Transportation Costs		$0
	C-BGV 01.11.03	Escalation (Operations/Transportation)		$0

Project Total

TEC	(All Direct & indirect Costs, MR, Escalation)	$748,713,666
TPC	(TEC plus Contingency, ODCs)	$823,585,033
LCC	All Capitol, Operation, Transportation, Escalation	$823,585,033

APPENDIX C5-8

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 8 - S-BGV 12P/32B, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 12P/32B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

40 Year Operating life

Annual Escalation: 1.90%

Discount Rate: 3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$ 266,619,471	$ 638,599,492
10	$ 295,696,634	$ 24,539,498	$ -	$ -	$ 66,319,648	$ 386,555,779	$ 1,025,155,272
11		$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$ 46,555,646	$ 1,071,710,918
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$ 47,440,204	$ 1,119,151,122
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$ 48,341,568	$ 1,167,492,689
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$ 14,341,801	$ 1,181,834,491
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$ 14,614,296	$ 1,196,448,787
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$ 14,891,967	$ 1,211,340,754
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$ 15,174,915	$ 1,226,515,668
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$ 15,463,238	$ 1,241,978,906
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$ 15,757,040	$ 1,257,735,946
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$ 16,056,423	$ 1,273,792,369
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$ 16,361,495	$ 1,290,153,865
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$ 16,672,364	$ 1,306,826,228
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$ 16,989,139	$ 1,323,815,367
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$ 17,311,932	$ 1,341,127,299
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$ 17,640,859	$ 1,358,768,158
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$ 17,976,035	$ 1,376,744,194
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$ 18,317,580	$ 1,395,061,774
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$ 18,665,614	$ 1,413,727,388
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$ 19,020,261	$ 1,432,747,648
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$ 19,381,646	$ 1,452,129,294
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$ 19,749,897	$ 1,471,879,191
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$ 20,125,145	$ 1,492,004,336
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$ 20,507,523	$ 1,512,511,859
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$ 20,897,166	$ 1,533,409,024
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$ 21,294,212	$ 1,554,703,236
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$ 21,698,802	$ 1,576,402,038
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$ 22,111,079	$ 1,598,513,117
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$ 22,531,190	$ 1,621,044,306
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$ 22,959,282	$ 1,644,003,589
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$ 23,395,509	$ 1,667,399,097
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$ 23,840,023	$ 1,691,239,120
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$ 24,292,984	$ 1,715,532,104
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$ 24,754,550	$ 1,740,286,654
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$ 25,224,887	$ 1,765,511,541
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$ 25,704,160	$ 1,791,215,701
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$ 26,192,539	$ 1,817,408,239
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$ 26,690,197	$ 1,844,098,436
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$ 27,197,311	$ 1,871,295,747
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$ 27,714,060	$ 1,899,009,806
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$ 28,240,627	$ 1,927,250,433
51	$ -	$ -	$ -	$ 22,900,000	$ 36,902,435	$ 59,802,435	$ 1,987,052,868
52	$ -	$ -	$ -	$ 31,000,000	$ 51,493,411	$ 82,493,411	$ 2,069,546,279
53	$ -	$ -	$ -	$ 30,067,062	$ 51,463,933	$ 81,530,994	$ 2,151,077,273
54	$ -	$ -	$ -	$ 30,067,062	$ 53,013,022	$ 83,080,083	$ 2,234,157,356
55	$ -	$ -	$ -	$ 30,067,062	$ 54,591,543	$ 84,658,605	$ 2,318,815,961
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,318,815,961
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,318,815,961
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,318,815,961
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,318,815,961
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,318,815,961

Total Design/Const	Total O&M		Total D&D	Total Escalation	Total Life Cycle
$ 823,585,033	$ 532,376,272	$ 38,508,689	$ 144,101,185	$ 780,244,783	$ 2,318,815,961

APPENDIX C5-8

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 8 - S-BGV 12P/32B, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 12P/32B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

80 Year Operating Life

Annual Escalation	Discount Rate
1.90%	3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$266,619,471	$638,599,492
10	$ 295,696,634	$ 24,539,498	$ -	$ -	$ 66,319,648	$386,555,779	$1,025,155,272
11		$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$46,555,646	$1,071,710,918
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$47,440,204	$1,119,151,122
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$48,341,568	$1,167,492,689
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$14,341,801	$1,181,834,491
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$14,614,296	$1,196,448,787
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$14,891,967	$1,211,340,754
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$15,174,915	$1,226,515,668
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$15,463,238	$1,241,978,906
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$15,757,040	$1,257,735,946
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$16,056,423	$1,273,792,369
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$16,361,495	$1,290,153,865
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$16,672,364	$1,306,826,228
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$16,989,139	$1,323,815,367
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$17,311,932	$1,341,127,299
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$17,640,859	$1,358,768,158
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$17,976,035	$1,376,744,194
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$18,317,580	$1,395,061,774
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$18,665,614	$1,413,727,388
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$19,020,261	$1,432,747,648
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$19,381,646	$1,452,129,294
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$19,749,897	$1,471,879,191
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$20,125,145	$1,492,004,336
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$20,507,523	$1,512,511,859
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$20,897,166	$1,533,409,024
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$21,294,212	$1,554,703,236
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$21,698,802	$1,576,402,038
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$22,111,079	$1,598,513,117
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$22,531,190	$1,621,044,306
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$22,959,282	$1,644,003,589
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$23,395,509	$1,667,399,097
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$23,840,023	$1,691,239,120
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$24,292,984	$1,715,532,104
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$24,754,550	$1,740,286,654
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$25,224,887	$1,765,511,541
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$25,704,160	$1,791,215,701
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$26,192,539	$1,817,408,239
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$26,690,197	$1,844,098,436
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$27,197,311	$1,871,295,747
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$27,714,060	$1,899,009,806
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$28,240,627	$1,927,250,433
51	$ -	$ 11,019,582	$ -	$ -	$ 17,757,616	$28,777,199	$1,956,027,631
52	$ -	$ 11,019,582	$ -	$ -	$ 18,304,383	$29,323,965	$1,985,351,597
53	$ -	$ 11,019,582	$ -	$ -	$ 18,861,538	$29,881,121	$2,015,232,717
54	$ -	$ 11,019,582	$ -	$ -	$ 19,429,280	$30,448,862	$2,045,681,579
55	$ -	$ 11,019,582	$ -	$ -	$ 20,007,808	$31,027,390	$2,076,708,970
56	$ -	$ 11,019,582	$ -	$ -	$ 20,597,329	$31,616,911	$2,108,325,880
57	$ -	$ 11,019,582	$ -	$ -	$ 21,198,050	$32,217,632	$2,140,543,512
58	$ -	$ 11,019,582	$ -	$ -	$ 21,810,185	$32,829,767	$2,173,373,280
59	$ -	$ 11,019,582	$ -	$ -	$ 22,433,950	$33,453,533	$2,206,826,812

60	$ -	$ 11,019,582	$ -	$ -	$ 23,069,568	$34,089,150	$2,240,915,962
61	$ -	$ 11,019,582	$ -	$ -	$ 23,717,261	$34,736,844	$2,275,652,806
62	$ -	$ 11,019,582	$ -	$ -	$ 24,377,261	$35,396,844	$2,311,049,649
63	$ -	$ 11,019,582	$ -	$ -	$ 25,049,801	$36,069,384	$2,347,119,033
64	$ -	$ 11,019,582	$ -	$ -	$ 25,735,120	$36,754,702	$2,383,873,735
65	$0	$ 11,019,582	$ -	$ -	$ 26,433,459	$37,453,041	$2,421,326,776
66	$0	$ 11,019,582	$ -	$ -	$ 27,145,067	$38,164,649	$2,459,491,425
67	$0	$ 11,019,582	$ -	$ -	$ 27,870,195	$38,889,777	$2,498,381,203
68	$0	$ 11,019,582	$ -	$ -	$ 28,609,101	$39,628,683	$2,538,009,886
69	$0	$ 11,019,582	$ -	$ -	$ 29,362,046	$40,381,628	$2,578,391,514
70	$0	$ 11,019,582	$ -	$ -	$ 30,129,297	$41,148,879	$2,619,540,393
71	$0	$ 11,019,582	$ -	$ -	$ 30,911,126	$41,930,708	$2,661,471,101
72	$0	$ 11,019,582	$ -	$ -	$ 31,707,809	$42,727,391	$2,704,198,492
73	$0	$ 11,019,582	$ -	$ -	$ 32,519,629	$43,539,212	$2,747,737,704
74	$0	$ 11,019,582	$ -	$ -	$ 33,346,874	$44,366,457	$2,792,104,160
75	$0	$ 11,019,582	$ -	$ -	$ 34,189,837	$45,209,419	$2,837,313,580
76	$0	$ 11,019,582	$ -	$ -	$ 35,048,816	$46,068,398	$2,883,381,978
77	$0	$ 11,019,582	$ -	$ -	$ 35,924,116	$46,943,698	$2,930,325,676
78	$0	$ 11,019,582	$ -	$ -	$ 36,816,046	$47,835,628	$2,978,161,304
79	$0	$ 11,019,582	$ -	$ -	$ 37,724,923	$48,744,505	$3,026,905,809
80	$0	$ 11,019,582	$ -	$ -	$ 38,651,068	$49,670,651	$3,076,576,460
81	$0	$ 11,019,582	$ -	$ -	$ 39,594,811	$50,614,393	$3,127,190,853
82	$0	$ 11,019,582	$ -	$ -	$ 40,556,484	$51,576,067	$3,178,766,920
83	$0	$ 11,019,582	$ -	$ -	$ 41,536,430	$52,556,012	$3,231,322,931
84	$0	$ 11,019,582	$ -	$ -	$ 42,534,994	$53,554,576	$3,284,877,507
85	$0	$ 11,019,582	$ -	$ -	$ 43,552,531	$54,572,113	$3,339,449,620
86	$0	$ 11,019,582	$ -	$ -	$ 44,589,401	$55,608,983	$3,395,058,603
87	$0	$ 11,019,582	$ -	$ -	$ 45,645,972	$56,665,554	$3,451,724,157
88	$0	$ 11,019,582	$ -	$ -	$ 46,722,617	$57,742,199	$3,509,466,357
89	$0	$ 11,019,582	$ -	$ -	$ 47,819,719	$58,839,301	$3,568,305,658
90	$0	$ 11,019,582	$ -	$ -	$ 48,937,666	$59,957,248	$3,628,262,905
91			$ -	$ 22,900,000	$ 104,065,646	$126,965,646	$3,755,228,552
92			$ -	$ 31,000,000	$ 144,140,515	$175,140,515	$3,930,369,067
93			$ -	$ 30,067,062	$ 143,030,161	$173,097,222	$4,103,466,289
94			$ -	$ 30,067,062	$ 146,319,008	$176,386,070	$4,279,852,359
95			$ -	$ 30,067,062	$ 149,670,343	$179,737,405	$4,459,589,764
96				$ -	$ -	$0	$4,459,589,764
97				$ -	$ -	$0	$4,459,589,764
98					$ -	$0	$4,459,589,764
99					$ -	$0	$4,459,589,764
100					$ -	$0	$4,459,589,764

Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation	Total Life Cycle
$823,585,033	$973,159,561	$38,508,689	$144,101,185	$2,480,235,297	$4,459,589,764

APPENDIX C5-9

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 9 - S-BGV 4P/9B, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 4P/9B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB

Annual Escalation Factor	1.90%
Discount Rate	3.40%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$879,273,229*					*$879,273,229*
Operations & Maintenance (40 Year Life)		*$532,376,272*				*$532,376,272*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$210,701,146		*$210,701,146*
Escalation					$906,409,450	*$906,409,450*
Total Costs (40 year Life)						*$2,567,268,786*
Present Value						*$1,270,566,439*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$879,273,229*					*$879,273,229*
Operations & Maintenance (80 Year Life)		*$973,159,561*				*$973,159,561*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$210,701,146		*$210,701,146*
Escalation					$2,809,938,685	*$2,809,938,685*
Total Costs (80 Year Life)						*$4,911,581,310*
Present Value						$1,387,221,230

APPENDIX C5-9

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 9 - S-BGV 4P/9B, LOW SEISMIC

CAPITAL COST SUMMARIES

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 4P/9B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate
CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-BGV 01			Interim Storage Facility and transportation Project		
	C-BGV 01.01		Pilot ISF Facility	$542,113,804	
		C-BGV 01.01.01	Storage BGV LE s		$0
		C-BGV 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-BGV 01.01.03	Horizontal Dry Storage Modules		$0
		C-BGV 01.01.04	Vertical Dry Storage Module		$245,798,923
		C-BGV 01.01.05	Storage Cask Fabrication Facility		$2,000,000
		C-BGV 01.01.06	Cask Maintenance Facility		$0
		C-BGV 01.01.07	Concrete Batch Plant		$1,850,000
		C-BGV 01.01.08	Visitor Center/ Auditorium		$0
		C-BGV 01.01.09	Administration Building		$3,140,000
		C-BGV 01.01.10	Security		$24,148,975
		C-BGV 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-BGV 01.01.12	Utilities		$18,682,150
		C-BGV 01.01.13	Roads		$18,212,737
		C-BGV 01.01.14	Parking		$735,000
		C-BGV 01.01.15	Site Work		$23,417,500
		C-BGV 01.01.16	Warehouse		$10,200,000
		C-BGV 01.01.17	Maintenance Facility		$0
		C-BGV 01.01.18	Waste management Facility		$0
		C-BGV 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-BGV 01.02		Expanded Interim Storage Facility	$0	
		C-BGV 01.02.01	Expanded Storage BGV LE s and Dry Cask Storage Systems		$0
		C-BGV 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-BGV 01.02.03	Horizontal Dry Storage Modules		$0
		C-BGV 01.02.04	Vertical Dry Storage Casks		$0
		C-BGV 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-BGV 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-BGV 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-BGV 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-BGV 01.02.09	Administration Building (Expanded if needed)		$0
		C-BGV 01.02.10	Security (Expanded)		$0
		C-BGV 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-BGV 01.02.12	Utilities Expanded as needed)		$0
		C-BGV 01.02.13	Roads (Expanded)		$0
		C-BGV 01.02.14	Parking (Expanded as needed)		$0
		C-BGV 01.02.15	Site Work (Expanded)		$0
		C-BGV 01.02.16	Warehouse (Expanded if Needed)		$0
		C-BGV 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-BGV 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-BGV 01.02.19	Hot Cell / Laboratories		$0
		C-BGV 01.02.20	Pool Packaging Facility		$0
		C-BGV 01.02.21	Standardized Storage System		$0
		C-BGV 01.02.22	Standardized Disposal Canister		$0
		C-BGV 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-BGV 01.03		Transportation Equipment	$0	
		C-BGV 01.03.01	Transportation Casks		$0
		C-BGV 01.03.02	Rail Equipment		$0
		C-BGV 01.03.03	Rail Maintenance Facility		$0
		C-BGV 01.03.04	Transportation Systems Services		$0
	C-BGV 01.04		Pre-Construction Capitalized Costs	$66,025,000	
		C-BGV 01.04.01	Land or Land Leases		$7,680,000
		C-BGV 01.04.02	Site permits		$200,000
		C-BGV 01.04.03	Site Licensing		$6,240,000
		C-BGV 01.04.05	Plant Permits		$0
		C-BGV 01.04.06	Planning and Alternative Studies		$750,000

	C-BGV 01.04.07	Research and Development		$0
	C-BGV 01.04.08	Design		$23,955,000
	C-BGV 01.04.09	Other Pre-construction Costs		$17,200,000
	C-BGV 01.04.10	Pre-construction contingencies		$10,000,000
	C-BGV 01.04.xx	(Add Further Breakdown as needed)		$0
C-BGV 01.05		Indirect Capitalized Costs	$63,180,000	
	C-BGV 01.05.01	Project Management		$2,700,000
	C-BGV 01.05.02	Construction Management		$3,600,000
	C-BGV 01.05.03	Field indirect services		$11,880,000
	C-BGV 01.05.o4	Design Services in support of Construction		$5,400,000
	C-BGV 01.05.05	QA/QC		$12,600,000
	C-BGV 01.05.06	Commissioning and Startup		$1,200,000
	C-BGV 01.05.07	Home office Engineering support to Construction		$7,200,000
	C-BGV 01.05.08	Document Control		$2,700,000
	C-BGV 01.05.09	Project Controls		$3,600,000
	C-BGV 01.05.10	Construction Testing		$2,700,000
	C-BGV 01.05.11	Inspections		$3,600,000
	C-BGV 01.05.12	Startup and Testing		$3,000,000
	C-BGV 01.05.13	Commissioning		$3,000,000
C-BGV 01.06		Site Selection	$0	
	C-BGV 01.06.01	Site Selection		$0
	C-BGV 01.06.02	Public Information Process		$0
C-BGV 01.07		Decontamination and Deconstruction	$0	
	C-BGV 01.07.01	Decommissioning		$0
	C-BGV 01.07.02	Decontamination		$0
	C-BGV 01.07.03	Deconstruction		$0
	C-BGV 01.07.04			$0
	C-BGV 01.07.05			$0
C-BGV 01.08		Project Financial Costs	$89,956,720	
	C-BGV 01.08.01	Contractor Fees		$53,705,504
	C-BGV 01.08.02	Escalation Costs		$36,251,215
	C-BGV 01.08.03	Interest Payments		$0
	C-BGV 01.08.04	Indirect costs to support shipments to repository		$0
	C-BGV 01.08.05			$0
	C-BGV 01.08.xx	(Add Further Breakdown as needed)		$0
C-BGV 01.09		Project Contingencies	$117,997,706	
	C-BGV 01.09.01	Management Reserve - Contractor Held		$38,063,776
	C-BGV 01.09.02	Contingency - DOE held		$79,933,930
C-BGV 01.10				
	C-BGV 01.10.01	Other Direct Costs	$0	
	C-BGV 01.10.02	DOE Project Operations		$0
	C-BGV 01.10.03	DOE TM&E		$0
	C-BGV 01.10.04	Host site Operational Costs Miscellaneous		$0
	C-BGV 01.10.05	Miscellaneous ODC		$0
C-BGV 01.11		Operational Costs	0	
	C-BGV 01.11.01	Operations Costs		$0
	C-BGV 01.11.02	Transportation Costs		$0
	C-BGV 01.11.03	Escalation (Operations/Transportation)		$0

Project Total

TEC	(All Direct & indirect Costs, MR, Escalation)	$799,339,299
TPC	(TEC plus Contingency, ODCs)	$879,273,229
LCC	All Capitol, Operation, Transportation, Escalation	$879,273,229

APPENDIX C5-9

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 9 - S-BGV 4P/9B, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 4P/9B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB

40 Year Operating life

Annual Escalation: 1.90%

Discount Rate: 3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$ 266,619,471	$ 638,599,492
10	$ 351,384,830	$ 24,539,498	$ -	$ -	$ 77,852,455	$ 453,776,784	$ 1,092,376,276
11		$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$ 46,555,646	$ 1,138,931,922
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$ 47,440,204	$ 1,186,372,126
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$ 48,341,568	$ 1,234,713,694
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$ 14,341,801	$ 1,249,055,495
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$ 14,614,296	$ 1,263,669,791
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$ 14,891,967	$ 1,278,561,758
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$ 15,174,915	$ 1,293,736,673
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$ 15,463,238	$ 1,309,199,911
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$ 15,757,040	$ 1,324,956,950
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$ 16,056,423	$ 1,341,013,373
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$ 16,361,495	$ 1,357,374,869
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$ 16,672,364	$ 1,374,047,233
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$ 16,989,139	$ 1,391,036,371
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$ 17,311,932	$ 1,408,348,304
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$ 17,640,859	$ 1,425,989,163
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$ 17,976,035	$ 1,443,965,198
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$ 18,317,580	$ 1,462,282,778
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$ 18,665,614	$ 1,480,948,392
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$ 19,020,261	$ 1,499,968,653
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$ 19,381,646	$ 1,519,350,298
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$ 19,749,897	$ 1,539,100,195
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$ 20,125,145	$ 1,559,225,340
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$ 20,507,523	$ 1,579,732,863
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$ 20,897,166	$ 1,600,630,028
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$ 21,294,212	$ 1,621,924,240
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$ 21,698,802	$ 1,643,623,042
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$ 22,111,079	$ 1,665,734,121
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$ 22,531,190	$ 1,688,265,311
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$ 22,959,282	$ 1,711,224,593
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$ 23,395,509	$ 1,734,620,101
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$ 23,840,023	$ 1,758,460,124
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$ 24,292,984	$ 1,782,753,108
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$ 24,754,550	$ 1,807,507,658
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$ 25,224,887	$ 1,832,732,545
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$ 25,704,160	$ 1,858,436,705
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$ 26,192,539	$ 1,884,629,243
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$ 26,690,197	$ 1,911,319,440
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$ 27,197,311	$ 1,938,516,751
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$ 27,714,060	$ 1,966,230,810
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$ 28,240,627	$ 1,994,471,437
51	$ -	$ -	$ -	$ 22,900,000	$ 36,902,435	$ 59,802,435	$ 2,054,273,872
52	$ -	$ -	$ -	$ 58,500,000	$ 97,173,050	$ 155,673,050	$ 2,209,946,922
53	$ -	$ -	$ -	$ 43,100,382	$ 73,772,262	$ 116,872,644	$ 2,326,819,566
54	$ -	$ -	$ -	$ 43,100,382	$ 75,992,843	$ 119,093,225	$ 2,445,912,791
55	$ -	$ -	$ -	$ 43,100,382	$ 78,255,614	$ 121,355,996	$ 2,567,268,786
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,567,268,786
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,567,268,786
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,567,268,786
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,567,268,786
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,567,268,786
	Total Design/Const	Total O&M		Total D&D	Total Escalation		Total Life Cycle
	$ 879,273,229	$ 532,376,272	$ 38,508,689	$ 210,701,146	$ 906,409,450		$ 2,567,268,786

APPENDIX C5-9

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 9 - S-BGV 4P/9B, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-BGV (5,000 MTU) 4P/9B
PILOT Project - S-BGV 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB

80 Year Operating Life

Annual Escalation 1.90%

Discount Rate 3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	$ -	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$266,619,471	$638,599,492
10	$ 351,384,830	$ 24,539,498	$ -	$ -	$ 77,852,455	$453,776,784	$1,092,376,276
11		$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$46,555,646	$1,138,931,922
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$47,440,204	$1,186,372,126
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$48,341,568	$1,234,713,694
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$14,341,801	$1,249,055,495
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$14,614,296	$1,263,669,791
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$14,891,967	$1,278,561,758
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$15,174,915	$1,293,736,673
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$15,463,238	$1,309,199,911
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$15,757,040	$1,324,956,950
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$16,056,423	$1,341,013,373
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$16,361,495	$1,357,374,869
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$16,672,364	$1,374,047,233
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$16,989,139	$1,391,036,371
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$17,311,932	$1,408,348,304
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$17,640,859	$1,425,989,163
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$17,976,035	$1,443,965,198
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$18,317,580	$1,462,282,778
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$18,665,614	$1,480,948,392
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$19,020,261	$1,499,968,653
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$19,381,646	$1,519,350,298
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$19,749,897	$1,539,100,195
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$20,125,145	$1,559,225,340
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$20,507,523	$1,579,732,863
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$20,897,166	$1,600,630,028
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$21,294,212	$1,621,924,240
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$21,698,802	$1,643,623,042
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$22,111,079	$1,665,734,121
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$22,531,190	$1,688,265,311
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$22,959,282	$1,711,224,593
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$23,395,509	$1,734,620,101
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$23,840,023	$1,758,460,124
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$24,292,984	$1,782,753,108
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$24,754,550	$1,807,507,658
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$25,224,887	$1,832,732,545
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$25,704,160	$1,858,436,705
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$26,192,539	$1,884,629,243
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$26,690,197	$1,911,319,440
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$27,197,311	$1,938,516,751
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$27,714,060	$1,966,230,810
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$28,240,627	$1,994,471,437
51	$ -	$ 11,019,582	$ -	$ -	$ 17,757,616	$28,777,199	$2,023,248,636
52	$ -	$ 11,019,582	$ -	$ -	$ 18,304,383	$29,323,965	$2,052,572,601
53	$ -	$ 11,019,582	$ -	$ -	$ 18,861,538	$29,881,121	$2,082,453,722
54	$ -	$ 11,019,582	$ -	$ -	$ 19,429,280	$30,448,862	$2,112,902,584
55	$ -	$ 11,019,582	$ -	$ -	$ 20,007,808	$31,027,390	$2,143,929,974
56	$ -	$ 11,019,582	$ -	$ -	$ 20,597,329	$31,616,911	$2,175,546,885
57	$ -	$ 11,019,582	$ -	$ -	$ 21,198,050	$32,217,632	$2,207,764,517
58	$ -	$ 11,019,582	$ -	$ -	$ 21,810,185	$32,829,767	$2,240,594,284
59	$ -	$ 11,019,582	$ -	$ -	$ 22,433,950	$33,453,533	$2,274,047,816

60	$ -	$ 11,019,582	$ -	$ -	$ 23,069,568	$34,089,150	$2,308,136,966
61	$ -	$ 11,019,582	$ -	$ -	$ 23,717,261	$34,736,844	$2,342,873,810
62	$ -	$ 11,019,582	$ -	$ -	$ 24,377,261	$35,396,844	$2,378,270,653
63	$ -	$ 11,019,582	$ -	$ -	$ 25,049,801	$36,069,384	$2,414,340,037
64	$ -	$ 11,019,582	$ -	$ -	$ 25,735,120	$36,754,702	$2,451,094,739
65	$0	$ 11,019,582	$ -	$ -	$ 26,433,459	$37,453,041	$2,488,547,780
66	$0	$ 11,019,582	$ -	$ -	$ 27,145,067	$38,164,649	$2,526,712,429
67	$0	$ 11,019,582	$ -	$ -	$ 27,870,195	$38,889,777	$2,565,602,207
68	$0	$ 11,019,582	$ -	$ -	$ 28,609,101	$39,628,683	$2,605,230,890
69	$0	$ 11,019,582	$ -	$ -	$ 29,362,046	$40,381,628	$2,645,612,518
70	$0	$ 11,019,582	$ -	$ -	$ 30,129,297	$41,148,879	$2,686,761,397
71	$0	$ 11,019,582	$ -	$ -	$ 30,911,126	$41,930,708	$2,728,692,105
72	$0	$ 11,019,582	$ -	$ -	$ 31,707,809	$42,727,391	$2,771,419,496
73	$0	$ 11,019,582	$ -	$ -	$ 32,519,629	$43,539,212	$2,814,958,708
74	$0	$ 11,019,582	$ -	$ -	$ 33,346,874	$44,366,457	$2,859,325,165
75	$0	$ 11,019,582	$ -	$ -	$ 34,189,837	$45,209,419	$2,904,534,584
76	$0	$ 11,019,582	$ -	$ -	$ 35,048,816	$46,068,398	$2,950,602,982
77	$0	$ 11,019,582	$ -	$ -	$ 35,924,116	$46,943,698	$2,997,546,680
78	$0	$ 11,019,582	$ -	$ -	$ 36,816,046	$47,835,628	$3,045,382,308
79	$0	$ 11,019,582	$ -	$ -	$ 37,724,923	$48,744,505	$3,094,126,813
80	$0	$ 11,019,582	$ -	$ -	$ 38,651,068	$49,670,651	$3,143,797,464
81	$0	$ 11,019,582	$ -	$ -	$ 39,594,811	$50,614,393	$3,194,411,857
82	$0	$ 11,019,582	$ -	$ -	$ 40,556,484	$51,576,067	$3,245,987,924
83	$0	$ 11,019,582	$ -	$ -	$ 41,536,430	$52,556,012	$3,298,543,936
84	$0	$ 11,019,582	$ -	$ -	$ 42,534,994	$53,554,576	$3,352,098,512
85	$0	$ 11,019,582	$ -	$ -	$ 43,552,531	$54,572,113	$3,406,670,624
86	$0	$ 11,019,582	$ -	$ -	$ 44,589,401	$55,608,983	$3,462,279,608
87	$0	$ 11,019,582	$ -	$ -	$ 45,645,972	$56,665,554	$3,518,945,161
88	$0	$ 11,019,582	$ -	$ -	$ 46,722,617	$57,742,199	$3,576,687,361
89	$0	$ 11,019,582	$ -	$ -	$ 47,819,719	$58,839,301	$3,635,526,662
90	$0	$ 11,019,582	$ -	$ -	$ 48,937,666	$59,957,248	$3,695,483,910
91			$ -	$ 22,900,000	$ 104,065,646	$126,965,646	$3,822,449,556
92			$ -	$ 58,500,000	$ 272,007,101	$330,507,101	$4,152,956,657
93			$ -	$ 43,100,382	$ 205,030,164	$248,130,546	$4,401,087,202
94			$ -	$ 43,100,382	$ 209,744,644	$252,845,026	$4,653,932,228
95			$ -	$ 43,100,382	$ 214,548,700	$257,649,081	$4,911,581,310
96				$ -	$ -	$0	$4,911,581,310
97				$ -	$ -	$0	$4,911,581,310
98					$ -	$0	$4,911,581,310
99					$ -	$0	$4,911,581,310
100					$ -	$0	$4,911,581,310

Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation	Total Life Cycle
$879,273,229	$973,159,561	$38,508,689	$210,701,146	$2,809,938,685	$4,911,581,310

APPENDIX C5-10

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 10 - S-AGV 21P/44B, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 21P.44B
Expanded Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

Annual Escalation Factor	1.90%
Discount Rate	3.40%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$840,356,820*					*$840,356,820*
Operations & Maintenance (40 Year Life)		*$532,376,272*				*$532,376,272*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$138,496,183		*$138,496,183*
Escalation					$774,550,670	*$774,550,670*
Total Costs (40 year Life)						*$2,324,288,635*
Present Value						*$1,203,675,656*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$840,356,820*					*$840,356,820*
Operations & Maintenance (80 Year Life)		*$973,159,561*				*$973,159,561*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$138,496,183		*$138,496,183*
Escalation					$2,457,950,429	*$2,457,950,429*
Total Costs (80 Year Life)						*$4,448,471,682*
Present Value						$1,335,054,549

APPENDIX C5-10

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 10 - S-AGV 21P/44B, LOW SEISMIC

CAPITAL COST SUMMARY

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 21P.44B
Expanded Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-AGV EX 01			Interim Storage Facility and transportation Project		
	C-AGV EX 01.01		Pilot ISF Facility	$512,401,405	
		C-AGV EX 01.01.01	Storage AGVs		$0
		C-AGV EX 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-AGV EX 01.01.03	Horizontal Dry Storage Modules		$0
		C-AGV EX 01.01.04	Vertical Dry Storage Module		$218,086,524
		C-AGV EX 01.01.05	Storage Cask Fabrication Facility		$0
		C-AGV EX 01.01.06	Cask Maintenance Facility		$0
		C-AGV EX 01.01.07	Concrete Batch Plant		$1,850,000
		C-AGV EX 01.01.08	Visitor Center/ Auditorium		$0
		C-AGV EX 01.01.09	Administration Building		$3,140,000
		C-AGV EX 01.01.10	Security		$24,148,975
		C-AGV EX 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-AGV EX 01.01.12	Utilities		$18,682,150
		C-AGV EX 01.01.13	Roads		$18,212,737
		C-AGV EX 01.01.14	Parking		$735,000
		C-AGV EX 01.01.15	Site Work		$23,417,500
		C-AGV EX 01.01.16	Warehouse		$10,200,000
		C-AGV EX 01.01.17	Maintenance Facility		$0
		C-AGV EX 01.01.18	Waste management Facility		$0
		C-AGV EX 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-AGV EX 01.02		Expanded Interim Storage Facility	$0	
		C-AGV EX 01.02.01	Expanded Storage AGVs and Dry Cask Storage Systems		$0
		C-AGV EX 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-AGV EX 01.02.03	Horizontal Dry Storage Modules		$0
		C-AGV EX 01.02.04	Vertical Dry Storage Casks		$0
		C-AGV EX 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-AGV EX 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-AGV EX 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-AGV EX 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-AGV EX 01.02.09	Administration Building (Expanded if needed)		$0
		C-AGV EX 01.02.10	Security (Expanded)		$0
		C-AGV EX 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-AGV EX 01.02.12	Utilities Expanded as needed)		$0
		C-AGV EX 01.02.13	Roads (Expanded)		$0
		C-AGV EX 01.02.14	Parking (Expanded as needed)		$0
		C-AGV EX 01.02.15	Site Work (Expanded)		$0
		C-AGV EX 01.02.16	Warehouse (Expanded if Needed)		$0
		C-AGV EX 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-AGV EX 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-AGV EX 01.02.19	Hot Cell / Laboratories		$0
		C-AGV EX 01.02.20	Pool Packaging Facility		$0
		C-AGV EX 01.02.21	Standardized Storage System		$0
		C-AGV EX 01.02.22	Standardized Disposal Canister		$0
		C-AGV EX 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-AGV EX 01.03		Transportation Equipment	$0	
		C-AGV EX 01.03.01	Transportation Casks		$0
		C-AGV EX 01.03.02	Rail Equipment		$0
		C-AGV EX 01.03.03	Rail Maintenance Facility		$0
		C-AGV EX 01.03.04	Transportation Systems Services		$0
	C-AGV EX 01.04		Pre-Construction Capitalized Costs	$66,025,000	
		C-AGV EX 01.04.01	Land or Land Leases		$7,680,000
		C-AGV EX 01.04.02	Site permits		$200,000
		C-AGV EX 01.04.03	Site Licensing		$6,240,000
		C-AGV EX 01.04.05	Plant Permits		$0
		C-AGV EX 01.04.06	Planning and Alternative Studies		$750,000

		C-AGV EX 01.04.07	Research and Development		$0
		C-AGV EX 01.04.08	Design		$23,955,000
		C-AGV EX 01.04.09	Other Pre-construction Costs		$17,200,000
		C-AGV EX 01.04.10	Pre-construction contingencies		$10,000,000
		C-AGV EX 01.04.xx	(Add Further Breakdown as needed)		$0
	C-AGV EX 01.05		Indirect Capitalized Costs	$63,180,000	
		C-AGV EX 01.05.01	Project Management		$2,700,000
		C-AGV EX 01.05.02	Construction Management		$3,600,000
		C-AGV EX 01.05.03	Field indirect services		$11,880,000
		C-AGV EX 01.05.o4	Design Services in support of Construction		$5,400,000
		C-AGV EX 01.05.05	QA/QC		$12,600,000
		C-AGV EX 01.05.06	Commissioning and Startup		$1,200,000
		C-AGV EX 01.05.07	Home office Engineering support to Construction		$7,200,000
		C-AGV EX 01.05.08	Document Control		$2,700,000
		C-AGV EX 01.05.09	Project Controls		$3,600,000
		C-AGV EX 01.05.10	Construction Testing		$2,700,000
		C-AGV EX 01.05.11	Inspections		$3,600,000
		C-AGV EX 01.05.12	Startup and Testing		$3,000,000
		C-AGV EX 01.05.13	Commissioning		$3,000,000
	C-AGV EX 01.06		Site Selection	$0	
		C-AGV EX 01.06.01	Site Selection		$0
		C-AGV EX 01.06.02	Public Information Process		$0
	C-AGV EX 01.07		Decontamination and Deconstruction	$0	
		C-AGV EX 01.07.01	Decommissioning		$0
		C-AGV EX 01.07.02	Decontamination		$0
		C-AGV EX 01.07.03	Deconstruction		$0
		C-AGV EX 01.07.04			$0
		C-AGV EX 01.07.05			$0
	C-AGV EX 01.08		Project Financial Costs	$85,975,258	
		C-AGV EX 01.08.01	Contractor Fees		$51,328,512
		C-AGV EX 01.08.02	Escalation Costs		$34,646,746
		C-AGV EX 01.08.03	Interest Payments		$0
		C-AGV EX 01.08.04	Indirect costs to support shipments to repository		$0
		C-AGV EX 01.08.05			$0
		C-AGV EX 01.08.xx	(Add Further Breakdown as needed)		$0
	C-AGV EX 01.09		Project Contingencies	$112,775,158	
		C-AGV EX 01.09.01	Management Reserve - Contractor Held		$36,379,083
		C-AGV EX 01.09.02	Contingency - DOE held		$76,396,075
	C-AGV EX 01.10				
		C-AGV EX 01.10.01	Other Direct Costs	$0	
		C-AGV EX 01.10.02	DOE Project Operations		$0
		C-AGV EX 01.10.03	DOE TM&E		$0
		C-AGV EX 01.10.04	Host site Operational Costs Miscellaneous		$0
		C-AGV EX 01.10.05	Miscellaneous ODC		$0
	C-AGV EX 01.11		Operational Costs	0	
		C-AGV EX 01.11.01	Operations Costs		$0
		C-AGV EX 01.11.02	Transportation Costs		$0
		C-AGV EX 01.11.03	Escalation (Operations/Transportation)		$0
Project Total					

TEC	(All Direct & indirect Costs, MR, Escalation)	$763,960,746
TPC	(TEC plus Contingency, ODCs)	$840,356,820
LCC	All Capitol, Operation, Transportation, Escalation	$840,356,820

APPENDIX C5-10

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 10 - S-AGV 21P/44B, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 21P.44B
Expanded Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

	Annual Escalation	Discount Rate
40 Year Operating life	1.90%	3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	Cask Handling	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$ 266,619,471	$ 638,599,492
10	$ 312,468,421	$ 24,539,498	$ -	$ -	$ 69,793,020	$ 406,800,939	$ 1,045,400,431
11	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$ 46,555,646	$ 1,091,956,078
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$ 47,440,204	$ 1,139,396,281
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$ 48,341,568	$ 1,187,737,849
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$ 14,341,801	$ 1,202,079,650
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$ 14,614,296	$ 1,216,693,946
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$ 14,891,967	$ 1,231,585,913
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$ 15,174,915	$ 1,246,760,828
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$ 15,463,238	$ 1,262,224,066
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$ 15,757,040	$ 1,277,981,105
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$ 16,056,423	$ 1,294,037,529
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$ 16,361,495	$ 1,310,399,024
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$ 16,672,364	$ 1,327,071,388
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$ 16,989,139	$ 1,344,060,526
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$ 17,311,932	$ 1,361,372,459
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$ 17,640,859	$ 1,379,013,318
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$ 17,976,035	$ 1,396,989,353
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$ 18,317,580	$ 1,415,306,933
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$ 18,665,614	$ 1,433,972,547
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$ 19,020,261	$ 1,452,992,808
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$ 19,381,646	$ 1,472,374,454
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$ 19,749,897	$ 1,492,124,350
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$ 20,125,145	$ 1,512,249,495
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$ 20,507,523	$ 1,532,757,018
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$ 20,897,166	$ 1,553,654,184
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$ 21,294,212	$ 1,574,948,396
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$ 21,698,802	$ 1,596,647,197
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$ 22,111,079	$ 1,618,758,276
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$ 22,531,190	$ 1,641,289,466
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$ 22,959,282	$ 1,664,248,748
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$ 23,395,509	$ 1,687,644,257
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$ 23,840,023	$ 1,711,484,280
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$ 24,292,984	$ 1,735,777,263
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$ 24,754,550	$ 1,760,531,814
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$ 25,224,887	$ 1,785,756,700
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$ 25,704,160	$ 1,811,460,860
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$ 26,192,539	$ 1,837,653,399
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$ 26,690,197	$ 1,864,343,596
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$ 27,197,311	$ 1,891,540,906
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$ 27,714,060	$ 1,919,254,966
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$ 28,240,627	$ 1,947,495,592
51	$ -	$ -	$ -	$ 22,900,000	$ 36,902,435	$ 59,802,435	$ 2,007,298,027
52	$ -	$ -	$ -	$ 24,000,000	$ 39,865,867	$ 63,865,867	$ 2,071,163,894
53	$ -	$ -	$ -	$ 30,532,061	$ 52,259,844	$ 82,791,905	$ 2,153,955,799
54	$ -	$ -	$ -	$ 30,532,061	$ 53,832,890	$ 84,364,951	$ 2,238,320,750
55	$ -	$ -	$ -	$ 30,532,061	$ 55,435,824	$ 85,967,885	$ 2,324,288,635
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,324,288,635
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,324,288,635
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,324,288,635
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,324,288,635
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,324,288,635

Total Design/Const	Total O&M		Total D&D	Total Escalation		Total Life Cycle
$ 840,356,820	$ 532,376,272	$ 38,508,689	$ 138,496,183	$ 774,550,670		$ 2,324,288,635

APPENDIX C5-10

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 10 - S-AGV 21P/44B, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 21P.44B
Expanded Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 21P/44B
Separate CHB

80 Year Operating Life

Annual Escalation	Discount Rate
1.90%	3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	Cask Handling	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$266,619,471	$638,599,492
10	$ 312,468,421	$ 24,539,498	$ -	$ -	$ 69,793,020	$406,800,939	$1,045,400,431
11		$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$46,555,646	$1,091,956,078
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$47,440,204	$1,139,396,281
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$48,341,568	$1,187,737,849
14	$ -	$ 11,019,582		$ -	$ 3,322,219	$14,341,801	$1,202,079,650
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$14,614,296	$1,216,693,946
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$14,891,967	$1,231,585,913
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$15,174,915	$1,246,760,828
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$15,463,238	$1,262,224,066
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$15,757,040	$1,277,981,105
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$16,056,423	$1,294,037,529
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$16,361,495	$1,310,399,024
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$16,672,364	$1,327,071,388
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$16,989,139	$1,344,060,526
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$17,311,932	$1,361,372,459
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$17,640,859	$1,379,013,318
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$17,976,035	$1,396,989,353
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$18,317,580	$1,415,306,933
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$18,665,614	$1,433,972,547
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$19,020,261	$1,452,992,808
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$19,381,646	$1,472,374,454
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$19,749,897	$1,492,124,350
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$20,125,145	$1,512,249,495
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$20,507,523	$1,532,757,018
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$20,897,166	$1,553,654,184
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$21,294,212	$1,574,948,396
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$21,698,802	$1,596,647,197
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$22,111,079	$1,618,758,276
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$22,531,190	$1,641,289,466
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$22,959,282	$1,664,248,748
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$23,395,509	$1,687,644,257
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$23,840,023	$1,711,484,280
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$24,292,984	$1,735,777,263
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$24,754,550	$1,760,531,814
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$25,224,887	$1,785,756,700
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$25,704,160	$1,811,460,860
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$26,192,539	$1,837,653,399
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$26,690,197	$1,864,343,596
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$27,197,311	$1,891,540,906
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$27,714,060	$1,919,254,966
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$28,240,627	$1,947,495,592
51	$ -	$ 11,019,582	$ -	$ -	$ 17,757,616	$28,777,199	$1,976,272,791
52	$ -	$ 11,019,582	$ -	$ -	$ 18,304,383	$29,323,965	$2,005,596,756
53	$ -	$ 11,019,582	$ -	$ -	$ 18,861,538	$29,881,121	$2,035,477,877
54	$ -	$ 11,019,582	$ -	$ -	$ 19,429,280	$30,448,862	$2,065,926,739
55	$ -	$ 11,019,582	$ -	$ -	$ 20,007,808	$31,027,390	$2,096,954,129
56	$ -	$ 11,019,582	$ -	$ -	$ 20,597,329	$31,616,911	$2,128,571,040
57	$ -	$ 11,019,582	$ -	$ -	$ 21,198,050	$32,217,632	$2,160,788,672
58	$ -	$ 11,019,582	$ -	$ -	$ 21,810,185	$32,829,767	$2,193,618,439

59	$ -	$ 11,019,582	$ -	$ -	$ 22,433,950	$33,453,533	$2,227,071,972
60	$ -	$ 11,019,582	$ -	$ -	$ 23,069,568	$34,089,150	$2,261,161,121
61	$ -	$ 11,019,582	$ -	$ -	$ 23,717,261	$34,736,844	$2,295,897,965
62	$ -	$ 11,019,582	$ -	$ -	$ 24,377,261	$35,396,844	$2,331,294,809
63	$ -	$ 11,019,582	$ -	$ -	$ 25,049,801	$36,069,384	$2,367,364,192
64	$ -	$ 11,019,582	$ -	$ -	$ 25,735,120	$36,754,702	$2,404,118,894
65	$0	$ 11,019,582	$ -	$ -	$ 26,433,459	$37,453,041	$2,441,571,935
66	$0	$ 11,019,582	$ -	$ -	$ 27,145,067	$38,164,649	$2,479,736,585
67	$0	$ 11,019,582	$ -	$ -	$ 27,870,195	$38,889,777	$2,518,626,362
68	$0	$ 11,019,582	$ -	$ -	$ 28,609,101	$39,628,683	$2,558,255,045
69	$0	$ 11,019,582	$ -	$ -	$ 29,362,046	$40,381,628	$2,598,636,673
70	$0	$ 11,019,582	$ -	$ -	$ 30,129,297	$41,148,879	$2,639,785,552
71	$0	$ 11,019,582	$ -	$ -	$ 30,911,126	$41,930,708	$2,681,716,260
72	$0	$ 11,019,582	$ -	$ -	$ 31,707,809	$42,727,391	$2,724,443,651
73	$0	$ 11,019,582	$ -	$ -	$ 32,519,629	$43,539,212	$2,767,982,863
74	$0	$ 11,019,582	$ -	$ -	$ 33,346,874	$44,366,457	$2,812,349,320
75	$0	$ 11,019,582	$ -	$ -	$ 34,189,837	$45,209,419	$2,857,558,739
76	$0	$ 11,019,582	$ -	$ -	$ 35,048,816	$46,068,398	$2,903,627,137
77	$0	$ 11,019,582	$ -	$ -	$ 35,924,116	$46,943,698	$2,950,570,835
78	$0	$ 11,019,582	$ -	$ -	$ 36,816,046	$47,835,628	$2,998,406,464
79	$0	$ 11,019,582	$ -	$ -	$ 37,724,923	$48,744,505	$3,047,150,969
80	$0	$ 11,019,582	$ -	$ -	$ 38,651,068	$49,670,651	$3,096,821,619
81	$0	$ 11,019,582	$ -	$ -	$ 39,594,811	$50,614,393	$3,147,436,012
82	$0	$ 11,019,582	$ -	$ -	$ 40,556,484	$51,576,067	$3,199,012,079
83	$0	$ 11,019,582	$ -	$ -	$ 41,536,430	$52,556,012	$3,251,568,091
84	$0	$ 11,019,582	$ -	$ -	$ 42,534,994	$53,554,576	$3,305,122,667
85	$0	$ 11,019,582	$ -	$ -	$ 43,552,531	$54,572,113	$3,359,694,780
86	$0	$ 11,019,582	$ -	$ -	$ 44,589,401	$55,608,983	$3,415,303,763
87	$0	$ 11,019,582	$ -	$ -	$ 45,645,972	$56,665,554	$3,471,969,317
88	$0	$ 11,019,582	$ -	$ -	$ 46,722,617	$57,742,199	$3,529,711,516
89	$0	$ 11,019,582	$ -	$ -	$ 47,819,719	$58,839,301	$3,588,550,817
90	$0	$ 11,019,582	$ -	$ -	$ 48,937,666	$59,957,248	$3,648,508,065
91			$ -	$ 22,900,000	$ 104,065,646	$126,965,646	$3,775,473,711
92			$ -	$ 24,000,000	$ 111,592,657	$135,592,657	$3,911,066,368
93			$ -	$ 30,532,061	$ 145,242,181	$175,774,243	$4,086,840,610
94			$ -	$ 30,532,061	$ 148,581,892	$179,113,953	$4,265,954,563
95			$ -	$ 30,532,061	$ 151,985,057	$182,517,118	$4,448,471,682
96				$ -	$ -	$0	$4,448,471,682
97				$ -	$ -	$0	$4,448,471,682
98					$ -	$0	$4,448,471,682
99					$ -	$0	$4,448,471,682
100					$ -	$0	$4,448,471,682

	Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation		Total Life Cycle
	$840,356,820	$973,159,561	$38,508,689	$138,496,183	$2,457,950,429		$4,448,471,682

APPENDIX C5-11

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 11 - S-AGV 12P/32B, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 12P/32B
Expanded Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

Annual Escalation Factor	1.90%
Discount Rate	3.40%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$843,921,011*					*$843,921,011*
Operations & Maintenance (40 Year Life)		*$532,376,272*				*$532,376,272*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$149,101,180		*$149,101,180*
Escalation					$793,273,704	*$793,273,704*
Total Costs (40 year Life)						*$2,357,180,856*
Present Value						*$1,211,667,039*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$843,921,011*					*$843,921,011*
Operations & Maintenance (80 Year Life)		*$973,159,561*				*$973,159,561*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$149,101,180		*$149,101,180*
Escalation					$2,508,782,348	*$2,508,782,348*
Total Costs (80 Year Life)						*$4,513,472,788*
Present Value						$1,340,871,853

APPENDIX C5-11

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 11 - S-AGV 12P/32B, LOW SEISMIC

CAPITAL COST SUMMARY

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 12P/32B
Expanded Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-AGV EX 01			Interim Storage Facility and transportation Project		
	C-AGV EX 01.01		Pilot ISF Facility	$515,122,639	
		C-AGV EX 01.01.01	Storage AGVs		$0
		C-AGV EX 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-AGV EX 01.01.03	Horizontal Dry Storage Modules		$0
		C-AGV EX 01.01.04	Vertical Dry Storage Module		$220,807,758
		C-AGV EX 01.01.05	Storage Cask Fabrication Facility		$0
		C-AGV EX 01.01.06	Cask Maintenance Facility		$0
		C-AGV EX 01.01.07	Concrete Batch Plant		$1,850,000
		C-AGV EX 01.01.08	Visitor Center/ Auditorium		$0
		C-AGV EX 01.01.09	Administration Building		$3,140,000
		C-AGV EX 01.01.10	Security		$24,148,975
		C-AGV EX 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-AGV EX 01.01.12	Utilities		$18,682,150
		C-AGV EX 01.01.13	Roads		$18,212,737
		C-AGV EX 01.01.14	Parking		$735,000
		C-AGV EX 01.01.15	Site Work		$23,417,500
		C-AGV EX 01.01.16	Warehouse		$10,200,000
		C-AGV EX 01.01.17	Maintenance Facility		$0
		C-AGV EX 01.01.18	Waste management Facility		$0
		C-AGV EX 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-AGV EX 01.02		Expanded Interim Storage Facility	$0	
		C-AGV EX 01.02.01	Expanded Storage AGVs and Dry Cask Storage Systems		$0
		C-AGV EX 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-AGV EX 01.02.03	Horizontal Dry Storage Modules		$0
		C-AGV EX 01.02.04	Vertical Dry Storage Casks		$0
		C-AGV EX 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-AGV EX 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-AGV EX 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-AGV EX 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-AGV EX 01.02.09	Administration Building (Expanded if needed)		$0
		C-AGV EX 01.02.10	Security (Expanded)		$0
		C-AGV EX 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-AGV EX 01.02.12	Utilities Expanded as needed)		$0
		C-AGV EX 01.02.13	Roads (Expanded)		$0
		C-AGV EX 01.02.14	Parking (Expanded as needed)		$0
		C-AGV EX 01.02.15	Site Work (Expanded)		$0
		C-AGV EX 01.02.16	Warehouse (Expanded if Needed)		$0
		C-AGV EX 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-AGV EX 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-AGV EX 01.02.19	Hot Cell / Laboratories		$0
		C-AGV EX 01.02.20	Pool Packaging Facility		$0
		C-AGV EX 01.02.21	Standardized Storage System		$0
		C-AGV EX 01.02.22	Standardized Disposal Canister		$0
		C-AGV EX 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-AGV EX 01.03		Transportation Equipment	$0	
		C-AGV EX 01.03.01	Transportation Casks		$0
		C-AGV EX 01.03.02	Rail Equipment		$0
		C-AGV EX 01.03.03	Rail Maintenance Facility		$0
		C-AGV EX 01.03.04	Transportation Systems Services		$0
	C-AGV EX 01.04		Pre-Construction Capitalized Costs	$66,025,000	
		C-AGV EX 01.04.01	Land or Land Leases		$7,680,000
		C-AGV EX 01.04.02	Site permits		$200,000
		C-AGV EX 01.04.03	Site Licensing		$6,240,000
		C-AGV EX 01.04.05	Plant Permits		$0
		C-AGV EX 01.04.06	Planning and Alternative Studies		$750,000

		C-AGV EX 01.04.07	Research and Development		$0
		C-AGV EX 01.04.08	Design		$23,955,000
		C-AGV EX 01.04.09	Other Pre-construction Costs		$17,200,000
		C-AGV EX 01.04.10	Pre-construction contingencies		$10,000,000
		C-AGV EX 01.04.xx	(Add Further Breakdown as needed)		$0
	C-AGV EX 01.05		Indirect Capitalized Costs	$63,180,000	
		C-AGV EX 01.05.01	Project Management		$2,700,000
		C-AGV EX 01.05.02	Construction Management		$3,600,000
		C-AGV EX 01.05.03	Field indirect services		$11,880,000
		C-AGV EX 01.05.o4	Design Services in support of Construction		$5,400,000
		C-AGV EX 01.05.05	QA/QC		$12,600,000
		C-AGV EX 01.05.06	Commissioning and Startup		$1,200,000
		C-AGV EX 01.05.07	Home office Engineering support to Construction		$7,200,000
		C-AGV EX 01.05.08	Document Control		$2,700,000
		C-AGV EX 01.05.09	Project Controls		$3,600,000
		C-AGV EX 01.05.10	Construction Testing		$2,700,000
		C-AGV EX 01.05.11	Inspections		$3,600,000
		C-AGV EX 01.05.12	Startup and Testing		$3,000,000
		C-AGV EX 01.05.13	Commissioning		$3,000,000
	C-AGV EX 01.06		Site Selection	$0	
		C-AGV EX 01.06.01	Site Selection		$0
		C-AGV EX 01.06.02	Public Information Process		$0
	C-AGV EX 01.07		Decontamination and Deconstruction	$0	
		C-AGV EX 01.07.01	Decommissioning		$0
		C-AGV EX 01.07.02	Decontamination		$0
		C-AGV EX 01.07.03	Deconstruction		$0
		C-AGV EX 01.07.04			$0
		C-AGV EX 01.07.05			$0
	C-AGV EX 01.08		Project Financial Costs	$86,339,904	
		C-AGV EX 01.08.01	Contractor Fees		$51,546,211
		C-AGV EX 01.08.02	Escalation Costs		$34,793,692
		C-AGV EX 01.08.03	Interest Payments		$0
		C-AGV EX 01.08.04	Indirect costs to support shipments to repository		$0
		C-AGV EX 01.08.05			$0
		C-AGV EX 01.08.xx	(Add Further Breakdown as needed)		$0
	C-AGV EX 01.09		Project Contingencies	$113,253,469	
		C-AGV EX 01.09.01	Management Reserve - Contractor Held		$36,533,377
		C-AGV EX 01.09.02	Contingency - DOE held		$76,720,092
	C-AGV EX 01.10				
		C-AGV EX 01.10.01	Other Direct Costs	$0	
		C-AGV EX 01.10.02	DOE Project Operations		$0
		C-AGV EX 01.10.03	DOE TM&E		$0
		C-AGV EX 01.10.04	Host site Operational Costs Miscellaneous		$0
		C-AGV EX 01.10.05	Miscellaneous ODC		$0
	C-AGV EX 01.11		Operational Costs	0	
		C-AGV EX 01.11.01	Operations Costs		$0
		C-AGV EX 01.11.02	Transportation Costs		$0
		C-AGV EX 01.11.03	Escalation (Operations/Transportation)		$0
Project Total					

TEC	(All Direct & indirect Costs, MR, Escalation)	$767,200,919
TPC	(TEC plus Contingency, ODCs)	$843,921,011
LCC	All Capitol, Operation, Transportation, Escalation	$843,921,011

APPENDIX C5-11

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 11 - S-AGV 12P/32B, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 12P/32B
Expanded Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

40 Year Operating life

Annual Escalation 1.90%

Discount Rate 3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	Cask Handling	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$ 266,619,471	$ 638,599,492
10	$ 316,032,612	$ 24,539,498	$ -	$ -	$ 70,531,149	$ 411,103,260	$ 1,049,702,752
11	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$ 46,555,646	$ 1,096,258,398
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$ 47,440,204	$ 1,143,698,602
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$ 48,341,568	$ 1,192,040,170
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$ 14,341,801	$ 1,206,381,971
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$ 14,614,296	$ 1,220,996,267
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$ 14,891,967	$ 1,235,888,234
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$ 15,174,915	$ 1,251,063,149
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$ 15,463,238	$ 1,266,526,387
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$ 15,757,040	$ 1,282,283,426
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$ 16,056,423	$ 1,298,339,850
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$ 16,361,495	$ 1,314,701,345
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$ 16,672,364	$ 1,331,373,709
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$ 16,989,139	$ 1,348,362,847
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$ 17,311,932	$ 1,365,674,780
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$ 17,640,859	$ 1,383,315,639
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$ 17,976,035	$ 1,401,291,674
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$ 18,317,580	$ 1,419,609,254
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$ 18,665,614	$ 1,438,274,868
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$ 19,020,261	$ 1,457,295,129
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$ 19,381,646	$ 1,476,676,774
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$ 19,749,897	$ 1,496,426,671
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$ 20,125,145	$ 1,516,551,816
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$ 20,507,523	$ 1,537,059,339
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$ 20,897,166	$ 1,557,956,505
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$ 21,294,212	$ 1,579,250,716
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$ 21,698,802	$ 1,600,949,518
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$ 22,111,079	$ 1,623,060,597
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$ 22,531,190	$ 1,645,591,787
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$ 22,959,282	$ 1,668,551,069
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$ 23,395,509	$ 1,691,946,577
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$ 23,840,023	$ 1,715,786,601
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$ 24,292,984	$ 1,740,079,584
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$ 24,754,550	$ 1,764,834,134
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$ 25,224,887	$ 1,790,059,021
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$ 25,704,160	$ 1,815,763,181
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$ 26,192,539	$ 1,841,955,719
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$ 26,690,197	$ 1,868,645,916
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$ 27,197,311	$ 1,895,843,227
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$ 27,714,060	$ 1,923,557,286
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$ 28,240,627	$ 1,951,797,913
51	$ -	$ -	$ -	$ 22,900,000	$ 36,902,435	$ 59,802,435	$ 2,011,600,348
52	$ -	$ -	$ -	$ 31,000,000	$ 51,493,411	$ 82,493,411	$ 2,094,093,759
53	$ -	$ -	$ -	$ 31,733,727	$ 54,316,660	$ 86,050,387	$ 2,180,144,146
54	$ -	$ -	$ -	$ 31,733,727	$ 55,951,618	$ 87,685,344	$ 2,267,829,490
55	$ -	$ -	$ -	$ 31,733,727	$ 57,617,639	$ 89,351,366	$ 2,357,180,856
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,357,180,856
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,357,180,856
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,357,180,856
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,357,180,856
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,357,180,856
	Total Design/Const	Total O&M		Total D&D	Total Escalation		Total Life Cycle
	$ 843,921,011	$ 532,376,272	$ 38,508,689	$ 149,101,180	$ 793,273,704		$ 2,357,180,856

APPENDIX C5-11

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 11 - S-AGV 12P/32B, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 12P/32B
Expanded Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 12P/32B
Separate CHB

80 Year Operating Life

	Annual Escalation	Discount Rate
	1.90%	3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	Cask Handling	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$266,619,471	$638,599,492
10	$ 316,032,612	$ 24,539,498	$ -	$ -	$ 70,531,149	$411,103,260	$1,049,702,752
11	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$46,555,646	$1,096,258,398
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$47,440,204	$1,143,698,602
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$48,341,568	$1,192,040,170
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$14,341,801	$1,206,381,971
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$14,614,296	$1,220,996,267
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$14,891,967	$1,235,888,234
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$15,174,915	$1,251,063,149
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$15,463,238	$1,266,526,387
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$15,757,040	$1,282,283,426
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$16,056,423	$1,298,339,850
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$16,361,495	$1,314,701,345
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$16,672,364	$1,331,373,709
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$16,989,139	$1,348,362,847
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$17,311,932	$1,365,674,780
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$17,640,859	$1,383,315,639
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$17,976,035	$1,401,291,674
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$18,317,580	$1,419,609,254
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$18,665,614	$1,438,274,868
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$19,020,261	$1,457,295,129
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$19,381,646	$1,476,676,774
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$19,749,897	$1,496,426,671
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$20,125,145	$1,516,551,816
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$20,507,523	$1,537,059,339
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$20,897,166	$1,557,956,505
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$21,294,212	$1,579,250,716
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$21,698,802	$1,600,949,518
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$22,111,079	$1,623,060,597
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$22,531,190	$1,645,591,787
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$22,959,282	$1,668,551,069
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$23,395,509	$1,691,946,577
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$23,840,023	$1,715,786,601
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$24,292,984	$1,740,079,584
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$24,754,550	$1,764,834,134
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$25,224,887	$1,790,059,021
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$25,704,160	$1,815,763,181
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$26,192,539	$1,841,955,719
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$26,690,197	$1,868,645,916
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$27,197,311	$1,895,843,227
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$27,714,060	$1,923,557,286
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$28,240,627	$1,951,797,913
51	$ -	$ 11,019,582	$ -	$ -	$ 17,757,616	$28,777,199	$1,980,575,112
52	$ -	$ 11,019,582	$ -	$ -	$ 18,304,383	$29,323,965	$2,009,899,077
53	$ -	$ 11,019,582	$ -	$ -	$ 18,861,538	$29,881,121	$2,039,780,198
54	$ -	$ 11,019,582	$ -	$ -	$ 19,429,280	$30,448,862	$2,070,229,060
55	$ -	$ 11,019,582	$ -	$ -	$ 20,007,808	$31,027,390	$2,101,256,450
56	$ -	$ 11,019,582	$ -	$ -	$ 20,597,329	$31,616,911	$2,132,873,361
57	$ -	$ 11,019,582	$ -	$ -	$ 21,198,050	$32,217,632	$2,165,090,993
58	$ -	$ 11,019,582	$ -	$ -	$ 21,810,185	$32,829,767	$2,197,920,760
59	$ -	$ 11,019,582	$ -	$ -	$ 22,433,950	$33,453,533	$2,231,374,292
60	$ -	$ 11,019,582	$ -	$ -	$ 23,069,568	$34,089,150	$2,265,463,442
61	$ -	$ 11,019,582	$ -	$ -	$ 23,717,261	$34,736,844	$2,300,200,286

62	$ -	$ 11,019,582	$ -	$ -	$ 24,377,261	$35,396,844	$2,335,597,129
63	$ -	$ 11,019,582	$ -	$ -	$ 25,049,801	$36,069,384	$2,371,666,513
64	$ -	$ 11,019,582	$ -	$ -	$ 25,735,120	$36,754,702	$2,408,421,215
65	$0	$ 11,019,582	$ -	$ -	$ 26,433,459	$37,453,041	$2,445,874,256
66	$0	$ 11,019,582	$ -	$ -	$ 27,145,067	$38,164,649	$2,484,038,905
67	$0	$ 11,019,582	$ -	$ -	$ 27,870,195	$38,889,777	$2,522,928,683
68	$0	$ 11,019,582	$ -	$ -	$ 28,609,101	$39,628,683	$2,562,557,366
69	$0	$ 11,019,582	$ -	$ -	$ 29,362,046	$40,381,628	$2,602,938,994
70	$0	$ 11,019,582	$ -	$ -	$ 30,129,297	$41,148,879	$2,644,087,873
71	$0	$ 11,019,582	$ -	$ -	$ 30,911,126	$41,930,708	$2,686,018,581
72	$0	$ 11,019,582	$ -	$ -	$ 31,707,809	$42,727,391	$2,728,745,972
73	$0	$ 11,019,582	$ -	$ -	$ 32,519,629	$43,539,212	$2,772,285,184
74	$0	$ 11,019,582	$ -	$ -	$ 33,346,874	$44,366,457	$2,816,651,641
75	$0	$ 11,019,582	$ -	$ -	$ 34,189,837	$45,209,419	$2,861,861,060
76	$0	$ 11,019,582	$ -	$ -	$ 35,048,816	$46,068,398	$2,907,929,458
77	$0	$ 11,019,582	$ -	$ -	$ 35,924,116	$46,943,698	$2,954,873,156
78	$0	$ 11,019,582	$ -	$ -	$ 36,816,046	$47,835,628	$3,002,708,784
79	$0	$ 11,019,582	$ -	$ -	$ 37,724,923	$48,744,505	$3,051,453,289
80	$0	$ 11,019,582	$ -	$ -	$ 38,651,068	$49,670,651	$3,101,123,940
81	$0	$ 11,019,582	$ -	$ -	$ 39,594,811	$50,614,393	$3,151,738,333
82	$0	$ 11,019,582	$ -	$ -	$ 40,556,484	$51,576,067	$3,203,314,400
83	$0	$ 11,019,582	$ -	$ -	$ 41,536,430	$52,556,012	$3,255,870,412
84	$0	$ 11,019,582	$ -	$ -	$ 42,534,994	$53,554,576	$3,309,424,988
85	$0	$ 11,019,582	$ -	$ -	$ 43,552,531	$54,572,113	$3,363,997,101
86	$0	$ 11,019,582	$ -	$ -	$ 44,589,401	$55,608,983	$3,419,606,084
87	$0	$ 11,019,582	$ -	$ -	$ 45,645,972	$56,665,554	$3,476,271,637
88	$0	$ 11,019,582	$ -	$ -	$ 46,722,617	$57,742,199	$3,534,013,837
89	$0	$ 11,019,582	$ -	$ -	$ 47,819,719	$58,839,301	$3,592,853,138
90	$0	$ 11,019,582	$ -	$ -	$ 48,937,666	$59,957,248	$3,652,810,386
91			$ -	$ 22,900,000	$ 104,065,646	$126,965,646	$3,779,776,032
92			$ -	$ 31,000,000	$ 144,140,515	$175,140,515	$3,954,916,547
93			$ -	$ 31,733,727	$ 150,958,550	$182,692,277	$4,137,608,823
94			$ -	$ 31,733,727	$ 154,429,703	$186,163,430	$4,323,772,253
95			$ -	$ 31,733,727	$ 157,966,808	$189,700,535	$4,513,472,788
96				$ -	$ -	$0	$4,513,472,788
97				$ -	$ -	$0	$4,513,472,788
98					$ -	$0	$4,513,472,788
99					$ -	$0	$4,513,472,788
100					$ -	$0	$4,513,472,788

Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation	Total Life Cycle
$843,921,011	$973,159,561	$38,508,689	$149,101,180	$2,508,782,348	$4,513,472,788

APPENDIX C5-12

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 12 - S-AGV 4P/9B, LOW SEISMIC

LIFE CYCLE COST SUMMARIES

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 4P/9B
Pilot Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB

Annual Escalation Factor	1.90%
Discount Rate	3.40%

Life Cycle Costs (40 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$906,861,243*					*$906,861,243*
Operations & Maintenance (40 Year Life)		*$532,376,272*				*$532,376,272*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$190,951,165		*$190,951,165*
Escalation					$877,294,012	*$877,294,012*
Total Costs (40 year Life)						*$2,545,991,382*
Present Value						*$1,285,431,623*

Life Cycle Costs (80 Year Life)	Capital	Operations	Transport	Decommissioning	Escalation	Total Costs
Design & Construction	*$906,861,243*					*$906,861,243*
Operations & Maintenance (80 Year Life)		*$973,159,561*				*$973,159,561*
Cask Handling		$38,508,689				*$38,508,689*
Transportation Equipment	$0					*$0*
Transport Operations		$0	$0			*$0*
Repackaging	$0	$0				*$0*
Transport to Repository	$0		$0			*$0*
D&D				$190,951,165		*$190,951,165*
Escalation					$2,719,526,635	*$2,719,526,635*
Total Costs (80 Year Life)						*$4,829,007,293*
Present Value						$1,406,057,712

APPENDIX C5-12

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 12 - S-AGV 4P/9B, LOW SEISMIC

CAPITAL COST SUMMARY

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 4P/9B
Pilot Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB

Level 3 Cost Summary - First of A kind module

Level 1	Level 2	Level 3	Description		Level 3 Total
C-AGV EX 01			Interim Storage Facility and transportation Project		
	C-AGV EX 01.01		Pilot ISF Facility	$563,177,054	
		C-AGV EX 01.01.01	Storage AGVs		$0
		C-AGV EX 01.01.02	Cask Handling (Transfer) Facility		$135,175,719
		C-AGV EX 01.01.03	Horizontal Dry Storage Modules		$0
		C-AGV EX 01.01.04	Vertical Dry Storage Module		$268,862,174
		C-AGV EX 01.01.05	Storage Cask Fabrication Facility		$0
		C-AGV EX 01.01.06	Cask Maintenance Facility		$0
		C-AGV EX 01.01.07	Concrete Batch Plant		$1,850,000
		C-AGV EX 01.01.08	Visitor Center/ Auditorium		$0
		C-AGV EX 01.01.09	Administration Building		$3,140,000
		C-AGV EX 01.01.10	Security		$24,148,975
		C-AGV EX 01.01.11	Rail Spur/ Receiving Yard		$58,752,800
		C-AGV EX 01.01.12	Utilities		$18,682,150
		C-AGV EX 01.01.13	Roads		$18,212,737
		C-AGV EX 01.01.14	Parking		$735,000
		C-AGV EX 01.01.15	Site Work		$23,417,500
		C-AGV EX 01.01.16	Warehouse		$10,200,000
		C-AGV EX 01.01.17	Maintenance Facility		$0
		C-AGV EX 01.01.18	Waste management Facility		$0
		C-AGV EX 01.01.01.xx	(Add Further Breakdown as needed)		$0
	C-AGV EX 01.02		Expanded Interim Storage Facility	$0	
		C-AGV EX 01.02.01	Expanded Storage AGVs and Dry Cask Storage Systems		$0
		C-AGV EX 01.02.02	Expanded Cask Handling Facility (if required)		$0
		C-AGV EX 01.02.03	Horizontal Dry Storage Modules		$0
		C-AGV EX 01.02.04	Vertical Dry Storage Casks		$0
		C-AGV EX 01.02.05	Storage Cask Fabrication Facility (Expanded)		$0
		C-AGV EX 01.02.06	Cask Maintenance Facility (Expanded)		$0
		C-AGV EX 01.02.07	Concrete Batch Plant (Expanded if needed)		$0
		C-AGV EX 01.02.08	Visitor Center/ Auditorium (expanded if needed)		$0
		C-AGV EX 01.02.09	Administration Building (Expanded if needed)		$0
		C-AGV EX 01.02.10	Security (Expanded)		$0
		C-AGV EX 01.02.11	Rail Spur/ Receiving Yard (Expanded)		$0
		C-AGV EX 01.02.12	Utilities Expanded as needed)		$0
		C-AGV EX 01.02.13	Roads (Expanded)		$0
		C-AGV EX 01.02.14	Parking (Expanded as needed)		$0
		C-AGV EX 01.02.15	Site Work (Expanded)		$0
		C-AGV EX 01.02.16	Warehouse (Expanded if Needed)		$0
		C-AGV EX 01.02.17	Maintenance Facility (Expanded if needed)		$0
		C-AGV EX 01.02.18	Waste management Facility (Expanded if needed)		$0
		C-AGV EX 01.02.19	Hot Cell / Laboratories		$0
		C-AGV EX 01.02.20	Pool Packaging Facility		$0
		C-AGV EX 01.02.21	Standardized Storage System		$0
		C-AGV EX 01.02.22	Standardized Disposal Canister		$0
		C-AGV EX 01.02.23	Canister Repackaging Facility (For Repository		$0
	C-AGV EX 01.03		Transportation Equipment	$0	
		C-AGV EX 01.03.01	Transportation Casks		$0
		C-AGV EX 01.03.02	Rail Equipment		$0
		C-AGV EX 01.03.03	Rail Maintenance Facility		$0
		C-AGV EX 01.03.04	Transportation Systems Services		$0
	C-AGV EX 01.04		Pre-Construction Capitalized Costs	$66,025,000	
		C-AGV EX 01.04.01	Land or Land Leases		$7,680,000
		C-AGV EX 01.04.02	Site permits		$200,000
		C-AGV EX 01.04.03	Site Licensing		$6,240,000
		C-AGV EX 01.04.05	Plant Permits		$0
		C-AGV EX 01.04.06	Planning and Alternative Studies		$750,000
		C-AGV EX 01.04.07	Research and Development		$0
		C-AGV EX 01.04.08	Design		$23,955,000
		C-AGV EX 01.04.09	Other Pre-construction Costs		$17,200,000

	C-AGV EX 01.04.10	Pre-construction contingencies		$10,000,000
	C-AGV EX 01.04.xx	(Add Further Breakdown as needed)		$0
C-AGV EX 01.05		Indirect Capitalized Costs	$63,180,000	
	C-AGV EX 01.05.01	Project Management		$2,700,000
	C-AGV EX 01.05.02	Construction Management		$3,600,000
	C-AGV EX 01.05.03	Field indirect services		$11,880,000
	C-AGV EX 01.05.o4	Design Services in support of Construction		$5,400,000
	C-AGV EX 01.05.05	QA/QC		$12,600,000
	C-AGV EX 01.05.06	Commissioning and Startup		$1,200,000
	C-AGV EX 01.05.07	Home office Engineering support to Construction		$7,200,000
	C-AGV EX 01.05.08	Document Control		$2,700,000
	C-AGV EX 01.05.09	Project Controls		$3,600,000
	C-AGV EX 01.05.10	Construction Testing		$2,700,000
	C-AGV EX 01.05.11	Inspections		$3,600,000
	C-AGV EX 01.05.12	Startup and Testing		$3,000,000
	C-AGV EX 01.05.13	Commissioning		$3,000,000
C-AGV EX 01.06		Site Selection	$0	
	C-AGV EX 01.06.01	Site Selection		$0
	C-AGV EX 01.06.02	Public Information Process		$0
C-AGV EX 01.07		Decontamination and Deconstruction	$0	
	C-AGV EX 01.07.01	Decommissioning		$0
	C-AGV EX 01.07.02	Decontamination		$0
	C-AGV EX 01.07.03	Deconstruction		$0
	C-AGV EX 01.07.04			$0
	C-AGV EX 01.07.05			$0
C-AGV EX 01.08		Project Financial Costs	$92,779,195	
	C-AGV EX 01.08.01	Contractor Fees		$55,390,564
	C-AGV EX 01.08.02	Escalation Costs		$37,388,631
	C-AGV EX 01.08.03	Interest Payments		$0
	C-AGV EX 01.08.04	Indirect costs to support shipments to repository		$0
	C-AGV EX 01.08.05			$0
	C-AGV EX 01.08.xx	(Add Further Breakdown as needed)		$0
C-AGV EX 01.09		Project Contingencies	$121,699,994	
	C-AGV EX 01.09.01	Management Reserve - Contractor Held		$39,258,062
	C-AGV EX 01.09.02	Contingency - DOE held		$82,441,931
C-AGV EX 01.10				
	C-AGV EX 01.10.01	Other Direct Costs	$0	
	C-AGV EX 01.10.02	DOE Project Operations		$0
	C-AGV EX 01.10.03	DOE TM&E		$0
	C-AGV EX 01.10.04	Host site Operational Costs Miscellaneous		$0
	C-AGV EX 01.10.05	Miscellaneous ODC		$0
C-AGV EX 01.11		Operational Costs	0	
	C-AGV EX 01.11.01	Operations Costs		$0
	C-AGV EX 01.11.02	Transportation Costs		$0
	C-AGV EX 01.11.03	Escalation (Operations/Transportation)		$0

Project Total

TEC	(All Direct & indirect Costs, MR, Escalation)	$824,419,312
TPC	(TEC plus Contingency, ODCs)	$906,861,243
LCC	All Capitol, Operation, Transportation, Escalation	$906,861,243

APPENDIX C5-12

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 12 - S-AGV 4P/9B, LOW SEISMIC

LIFE CYCLE COST – 40 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 4P/9B
Pilot Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB

	Annual Escalation	Discount Rate
40 Year Operating life	1.90%	3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	Cask Handling	$ -	$ 190,000	$ 10,190,000	$ 10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$ 10,383,610	$ 20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$ 21,161,797	$ 41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$ 21,563,871	$ 63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$ 21,973,585	$ 85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$ 22,391,083	$ 107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$ 31,815,802	$ 139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$ 232,500,273	$ 371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$ 266,619,471	$ 638,599,492
10	$ 378,972,844	$ 24,539,498	$ -	$ -	$ 83,565,825	$ 487,078,167	$ 1,125,677,659
11		$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$ 46,555,646	$ 1,172,233,306
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$ 47,440,204	$ 1,219,673,509
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$ 48,341,568	$ 1,268,015,077
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$ 14,341,801	$ 1,282,356,878
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$ 14,614,296	$ 1,296,971,174
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$ 14,891,967	$ 1,311,863,141
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$ 15,174,915	$ 1,327,038,056
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$ 15,463,238	$ 1,342,501,294
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$ 15,757,040	$ 1,358,258,334
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$ 16,056,423	$ 1,374,314,757
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$ 16,361,495	$ 1,390,676,252
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$ 16,672,364	$ 1,407,348,616
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$ 16,989,139	$ 1,424,337,755
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$ 17,311,932	$ 1,441,649,687
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$ 17,640,859	$ 1,459,290,546
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$ 17,976,035	$ 1,477,266,581
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$ 18,317,580	$ 1,495,584,161
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$ 18,665,614	$ 1,514,249,775
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$ 19,020,261	$ 1,533,270,036
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$ 19,381,646	$ 1,552,651,682
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$ 19,749,897	$ 1,572,401,578
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$ 20,125,145	$ 1,592,526,723
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$ 20,507,523	$ 1,613,034,246
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$ 20,897,166	$ 1,633,931,412
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$ 21,294,212	$ 1,655,225,624
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$ 21,698,802	$ 1,676,924,425
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$ 22,111,079	$ 1,699,035,504
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$ 22,531,190	$ 1,721,566,694
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$ 22,959,282	$ 1,744,525,976
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$ 23,395,509	$ 1,767,921,485
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$ 23,840,023	$ 1,791,761,508
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$ 24,292,984	$ 1,816,054,491
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$ 24,754,550	$ 1,840,809,042
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$ 25,224,887	$ 1,866,033,928
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$ 25,704,160	$ 1,891,738,088
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$ 26,192,539	$ 1,917,930,627
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$ 26,690,197	$ 1,944,620,824
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$ 27,197,311	$ 1,971,818,134
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$ 27,714,060	$ 1,999,532,194
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$ 28,240,627	$ 2,027,772,820
51	$ -	$ -	$ -	$ 22,900,000	$ 36,902,435	$ 59,802,435	$ 2,087,575,255
52	$ -	$ -	$ -	$ 58,500,000	$ 97,173,050	$ 155,673,050	$ 2,243,248,305
53	$ -	$ -	$ -	$ 36,517,055	$ 62,503,989	$ 99,021,044	$ 2,342,269,349
54	$ -	$ -	$ -	$ 36,517,055	$ 64,385,388	$ 100,902,443	$ 2,443,171,792
55	$ -	$ -	$ -	$ 36,517,055	$ 66,302,535	$ 102,819,590	$ 2,545,991,382
56	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,545,991,382
57	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,545,991,382
58	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,545,991,382
59	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,545,991,382
60	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,545,991,382

Total Design/Const	Total O&M		Total D&D	Total Escalation	Total Life Cycle
$ 906,861,243	$ 532,376,272	$ 38,508,689	$ 190,951,165	$ 877,294,012	$ 2,545,991,382

APPENDIX C5-12

STUDY 3 - ALTERNATIVE STORAGE SYSTEMS FOR SPENT NUCLEAR FUEL USING STAD CANISTERS

COST DETAILS

ALTERNATIVE 12 - S-AGV 4P/9B, LOW SEISMIC

LIFE CYCLE COST – 80 YEAR OPERATING LIFE

Interim Storage Facility

Interim Storage Facility (5,000 MTU)

Project: S-AGV (5,000 MTU) 4P/9B
Pilot Project - S-AGV 60/40 Vertical/Horizontal - Low Seismic 4P/9B
Separate CHB

80 Year Operating Life

Annual Escalation	Discount Rate
1.90%	3.40%

YEAR	Design/Const	O&M	Cask Handling	D&D	Escalation	Annual Expense	Cumulative
1	$ 10,000,000	$ -	Cask Handling	$ -	$ 190,000	$10,190,000	$10,190,000
2	$ 10,000,000	$ -	$ -	$ -	$ 383,610	$10,383,610	$20,573,610
3	$ 20,000,000	$ -	$ -	$ -	$ 1,161,797	$21,161,797	$41,735,407
4	$ 20,000,000	$ -	$ -	$ -	$ 1,563,871	$21,563,871	$63,299,279
5	$ 20,000,000	$ -	$ -	$ -	$ 1,973,585	$21,973,585	$85,272,863
6	$ 20,000,000	$ -	$ -	$ -	$ 2,391,083	$22,391,083	$107,663,946
7	$ 27,888,399	$ -	$ -	$ -	$ 3,927,403	$31,815,802	$139,479,748
8	$ 200,000,000	$ -	$ -	$ -	$ 32,500,273	$232,500,273	$371,980,021
9	$ 200,000,000	$ 25,073,418	$ -	$ -	$ 41,546,053	$266,619,471	$638,599,492
10	$ 378,972,844	$ 24,539,498	$ -	$ -	$ 83,565,825	$487,078,167	$1,125,677,659
11		$ 25,012,938	$ 12,836,230	$ -	$ 8,706,478	$46,555,646	$1,172,233,306
12	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 9,591,036	$47,440,204	$1,219,673,509
13	$ -	$ 25,012,938	$ 12,836,230	$ -	$ 10,492,400	$48,341,568	$1,268,015,077
14	$ -	$ 11,019,582	$ -	$ -	$ 3,322,219	$14,341,801	$1,282,356,878
15	$ -	$ 11,019,582	$ -	$ -	$ 3,594,713	$14,614,296	$1,296,971,174
16	$ -	$ 11,019,582	$ -	$ -	$ 3,872,385	$14,891,967	$1,311,863,141
17	$ -	$ 11,019,582	$ -	$ -	$ 4,155,332	$15,174,915	$1,327,038,056
18	$ -	$ 11,019,582	$ -	$ -	$ 4,443,656	$15,463,238	$1,342,501,294
19	$ -	$ 11,019,582	$ -	$ -	$ 4,737,457	$15,757,040	$1,358,258,334
20	$ -	$ 11,019,582	$ -	$ -	$ 5,036,841	$16,056,423	$1,374,314,757
21	$ -	$ 11,019,582	$ -	$ -	$ 5,341,913	$16,361,495	$1,390,676,252
22	$ -	$ 11,019,582	$ -	$ -	$ 5,652,782	$16,672,364	$1,407,348,616
23	$ -	$ 11,019,582	$ -	$ -	$ 5,969,556	$16,989,139	$1,424,337,755
24	$ -	$ 11,019,582	$ -	$ -	$ 6,292,350	$17,311,932	$1,441,649,687
25	$ -	$ 11,019,582	$ -	$ -	$ 6,621,277	$17,640,859	$1,459,290,546
26	$ -	$ 11,019,582	$ -	$ -	$ 6,956,453	$17,976,035	$1,477,266,581
27	$ -	$ 11,019,582	$ -	$ -	$ 7,297,998	$18,317,580	$1,495,584,161
28	$ -	$ 11,019,582	$ -	$ -	$ 7,646,032	$18,665,614	$1,514,249,775
29	$ -	$ 11,019,582	$ -	$ -	$ 8,000,678	$19,020,261	$1,533,270,036
30	$ -	$ 11,019,582	$ -	$ -	$ 8,362,063	$19,381,646	$1,552,651,682
31	$ -	$ 11,019,582	$ -	$ -	$ 8,730,315	$19,749,897	$1,572,401,578
32	$ -	$ 11,019,582	$ -	$ -	$ 9,105,563	$20,125,145	$1,592,526,723
33	$ -	$ 11,019,582	$ -	$ -	$ 9,487,941	$20,507,523	$1,613,034,246
34	$ -	$ 11,019,582	$ -	$ -	$ 9,877,583	$20,897,166	$1,633,931,412
35	$ -	$ 11,019,582	$ -	$ -	$ 10,274,630	$21,294,212	$1,655,225,624
36	$ -	$ 11,019,582	$ -	$ -	$ 10,679,220	$21,698,802	$1,676,924,425
37	$ -	$ 11,019,582	$ -	$ -	$ 11,091,497	$22,111,079	$1,699,035,504
38	$ -	$ 11,019,582	$ -	$ -	$ 11,511,607	$22,531,190	$1,721,566,694
39	$ -	$ 11,019,582	$ -	$ -	$ 11,939,700	$22,959,282	$1,744,525,976
40	$ -	$ 11,019,582	$ -	$ -	$ 12,375,926	$23,395,509	$1,767,921,485
41	$ -	$ 11,019,582	$ -	$ -	$ 12,820,441	$23,840,023	$1,791,761,508
42	$ -	$ 11,019,582	$ -	$ -	$ 13,273,401	$24,292,984	$1,816,054,491
43	$ -	$ 11,019,582	$ -	$ -	$ 13,734,968	$24,754,550	$1,840,809,042
44	$ -	$ 11,019,582	$ -	$ -	$ 14,205,305	$25,224,887	$1,866,033,928
45	$ -	$ 11,019,582	$ -	$ -	$ 14,684,577	$25,704,160	$1,891,738,088
46	$ -	$ 11,019,582	$ -	$ -	$ 15,172,956	$26,192,539	$1,917,930,627
47	$ -	$ 11,019,582	$ -	$ -	$ 15,670,615	$26,690,197	$1,944,620,824
48	$ -	$ 11,019,582	$ -	$ -	$ 16,177,728	$27,197,311	$1,971,818,134
49	$ -	$ 11,019,582	$ -	$ -	$ 16,694,477	$27,714,060	$1,999,532,194
50	$ -	$ 11,019,582	$ -	$ -	$ 17,221,044	$28,240,627	$2,027,772,820
51	$ -	$ 11,019,582	$ -	$ -	$ 17,757,616	$28,777,199	$2,056,550,019
52	$ -	$ 11,019,582	$ -	$ -	$ 18,304,383	$29,323,965	$2,085,873,984
53	$ -	$ 11,019,582	$ -	$ -	$ 18,861,538	$29,881,121	$2,115,755,105
54	$ -	$ 11,019,582	$ -	$ -	$ 19,429,280	$30,448,862	$2,146,203,967
55	$ -	$ 11,019,582	$ -	$ -	$ 20,007,808	$31,027,390	$2,177,231,357
56	$ -	$ 11,019,582	$ -	$ -	$ 20,597,329	$31,616,911	$2,208,848,268
57	$ -	$ 11,019,582	$ -	$ -	$ 21,198,050	$32,217,632	$2,241,065,900
58	$ -	$ 11,019,582	$ -	$ -	$ 21,810,185	$32,829,767	$2,273,895,667
59	$ -	$ 11,019,582	$ -	$ -	$ 22,433,950	$33,453,533	$2,307,349,200
60	$ -	$ 11,019,582	$ -	$ -	$ 23,069,568	$34,089,150	$2,341,438,349

61	$ -	$ 11,019,582	$ -	$ -	$ 23,717,261	$34,736,844	$2,376,175,193
62	$ -	$ 11,019,582	$ -	$ -	$ 24,377,261	$35,396,844	$2,411,572,037
63	$ -	$ 11,019,582	$ -	$ -	$ 25,049,801	$36,069,384	$2,447,641,420
64	$ -	$ 11,019,582	$ -	$ -	$ 25,735,120	$36,754,702	$2,484,396,122
65	$0	$ 11,019,582	$ -	$ -	$ 26,433,459	$37,453,041	$2,521,849,164
66	$0	$ 11,019,582	$ -	$ -	$ 27,145,067	$38,164,649	$2,560,013,813
67	$0	$ 11,019,582	$ -	$ -	$ 27,870,195	$38,889,777	$2,598,903,590
68	$0	$ 11,019,582	$ -	$ -	$ 28,609,101	$39,628,683	$2,638,532,273
69	$0	$ 11,019,582	$ -	$ -	$ 29,362,046	$40,381,628	$2,678,913,901
70	$0	$ 11,019,582	$ -	$ -	$ 30,129,297	$41,148,879	$2,720,062,780
71	$0	$ 11,019,582	$ -	$ -	$ 30,911,126	$41,930,708	$2,761,993,488
72	$0	$ 11,019,582	$ -	$ -	$ 31,707,809	$42,727,391	$2,804,720,879
73	$0	$ 11,019,582	$ -	$ -	$ 32,519,629	$43,539,212	$2,848,260,091
74	$0	$ 11,019,582	$ -	$ -	$ 33,346,874	$44,366,457	$2,892,626,548
75	$0	$ 11,019,582	$ -	$ -	$ 34,189,837	$45,209,419	$2,937,835,967
76	$0	$ 11,019,582	$ -	$ -	$ 35,048,816	$46,068,398	$2,983,904,366
77	$0	$ 11,019,582	$ -	$ -	$ 35,924,116	$46,943,698	$3,030,848,063
78	$0	$ 11,019,582	$ -	$ -	$ 36,816,046	$47,835,628	$3,078,683,692
79	$0	$ 11,019,582	$ -	$ -	$ 37,724,923	$48,744,505	$3,127,428,197
80	$0	$ 11,019,582	$ -	$ -	$ 38,651,068	$49,670,651	$3,177,098,847
81	$0	$ 11,019,582	$ -	$ -	$ 39,594,811	$50,614,393	$3,227,713,241
82	$0	$ 11,019,582	$ -	$ -	$ 40,556,484	$51,576,067	$3,279,289,307
83	$0	$ 11,019,582	$ -	$ -	$ 41,536,430	$52,556,012	$3,331,845,319
84	$0	$ 11,019,582	$ -	$ -	$ 42,534,994	$53,554,576	$3,385,399,895
85	$0	$ 11,019,582	$ -	$ -	$ 43,552,531	$54,572,113	$3,439,972,008
86	$0	$ 11,019,582	$ -	$ -	$ 44,589,401	$55,608,983	$3,495,580,991
87	$0	$ 11,019,582	$ -	$ -	$ 45,645,972	$56,665,554	$3,552,246,545
88	$0	$ 11,019,582	$ -	$ -	$ 46,722,617	$57,742,199	$3,609,988,744
89	$0	$ 11,019,582	$ -	$ -	$ 47,819,719	$58,839,301	$3,668,828,045
90	$0	$ 11,019,582	$ -	$ -	$ 48,937,666	$59,957,248	$3,728,785,293
91			$ -	$ 22,900,000	$ 104,065,646	$126,965,646	$3,855,750,939
92			$ -	$ 58,500,000	$ 272,007,101	$330,507,101	$4,186,258,040
93			$ -	$ 36,517,055	$ 173,713,027	$210,230,082	$4,396,488,122
94			$ -	$ 36,517,055	$ 177,707,398	$214,224,453	$4,610,712,575
95			$ -	$ 36,517,055	$ 181,777,663	$218,294,718	$4,829,007,293
96				$ -	$ -	$0	$4,829,007,293
97				$ -	$ -	$0	$4,829,007,293
98					$ -	$0	$4,829,007,293
99					$ -	$0	$4,829,007,293
100					$ -	$0	$4,829,007,293
	Total Design/Const	Total O&M	Total Cask Handling	Total D&D	Total Escalation		Total Life Cycle
	$906,861,243	$973,159,561	$38,508,689	$190,951,165	$2,719,526,635		$4,829,007,293