DOE Advisory and Assistance Services Contract

Task Order 21: Operational Requirements for Standardized Dry Fuel Canister Systems

UPDATED FINAL REPORT

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Revision History

Revision	Date	Reason for Revision	Originator
Preliminary	**February 12, 2015**	**Preliminary Report for DOE Review**	**I. Thomas**
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EXECUTIVE SUMMARY

Per the requirements of the Task Order 21: *Operational Requirements for Standardized Dry Fuel Canister Systems*, Statement of Work (SOW), Energy*Solutions* and its team partners: NAC International, Booz Allen Hamilton and Exelon Nuclear Partners, hereafter referred to as "the Team", is providing for the U.S. Department of Energy (DOE) an Updated Final Report, which documents the results from the studies performed.

The purpose of Task Order 21 is to better understand and seek innovative solutions for addressing the operational impacts at nuclear power plant (NPP) utility sites of using a standardized transportation, aging and disposal (STAD) canister having a smaller capacity than conventional Dual Purpose Canisters (DPCs). This review was focused on identifying innovative processes that would facilitate moving the SOW designated number of spent nuclear fuel (SNF) assemblies from NPP spent fuel pools to on-site dry storage in a SOW designated time frame (i.e., the "required SNF throughput"). To ensure the processes identified were universally applicable, they had to apply to Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR) fuel types and to nine NPP cases with varying refueling schedules and numbers of reactors on the site. Three different capacities of STAD canisters were also required to be considered: small (4-PWR or 9-BWR), medium (12-PWR or 32-BWR) and large (21-PWR or 44-BWR).

OPERATIONAL APPROACHES

For the medium and large STAD canisters, the Team has determined that they will be loaded individually and will utilize a loading process, which is similar to the process that was used by Zion*Solutions* (an Energy*Solutions* company) to load sixty-one 37-PWR DPCs in less than 52 weeks at the shutdown Zion Nuclear Power Plant, in Illinois. This process represents the current state-of-the-art for dry storage across the country and the size of the Zion loading campaign has provided valuable lessons learned, operating experience and operations data, which has been fully utilized by the Team and is referred to as "baseline data".

Figure ES-1: STAD-in-Can Design Concept

For the small STAD canisters, the team knew that handling the small STADs individually would be a protracted process that would require improved loading practices and technological innovations to meet the throughput requirements. To streamline processing operations, two loading processes were identified and evaluated; each of which involves loading, welding, drying and transferring small STAD canisters in groups of four. The first process is referred to as the "STAD-in-Can". The end product that is loaded into a storage overpack for this design concept (see Figure ES-1) is an overpack can that that has a welded lid and contains four small STAD canisters. Prior to installing and welding the overpack lid, a single shield plug (with a lifting ring) is installed and welded in each small STAD canister. The second process is referred to as the "STAD-in-Carrier" and reflects a design concept (see Figure ES-2) where the end product loaded into a storage overpack is four small canisters; each with their inner (shield plug) and outer (top plate with lifting ring) lids installed and welded closed, and are jointly held within an open-sided carrier. The STAD-in-Carrier design concept is the subject of design engineering and analyses under DOE Advisory and Assistance Services (A&AS) Contract Task Order 18, *Generic Design for Small Standardized Transportation, Aging and Disposal Canister Systems*. This current report documents all of the costs and benefits of each option, and the STAD-in-Carrier design concept was the one finally recommended by the Team for processing the small STAD canisters. The STAD-in-Can design presents many challenges that don't exist with the current storage of DPCs, e.g. ensuring adequate heat transfer to preclude fuel cladding damage, drying the can, excess weight, and visual inspection of STAD canisters in storage. The details of each processing option are covered in the body of this report.

Figure ES-2: STAD-in-Carrier Design Concept

In conjunction with the loading processes, the Team has also performed in-depth investigations of two major dry storage process technologies: canister drying and welding/non-destructive examination (NDE), in order to identify improvements that will optimize canister welding and drying times. For welding, according to a welding vendor (Liburdi Automation), welding four small STAD canisters, in parallel, using independent remote controlled welding machines is feasible; however, a welding development program would need to be completed. Attributes that affect drying times include: fuel basket design (to minimize water retention), fuel assembly age and material condition (optimize available residual heat and minimize water retention), and neutron absorption material composition (utilize metal matrix neutron absorbing material). Use of automated vacuum drying systems has been demonstrated to achieve reduced vacuum drying times and more consistent dryness condition in each canister.

PARAMETRIC STUDIES

Utilizing the above operational approaches, baseline Zion data, dual transfer casks (so one can be filled while the other is being unloaded) and process technology improvements, time and motion studies (referred to as the "Parametric Studies") have been performed. The approach followed was:

Step 1 - Determine the maximum number of assemblies that could be moved to dry storage in a 12-week window[1] for each STAD canister variant, beginning with currently understood dry storage operations ("Baseline") and then applying process technology and dual transfer cask improvements ("Optimized") to the various STAD configurations.

Step 2 - Determine whether each STAD variant can provide the throughput required for each of the nine plant cases defined in the SOW and, if so, identify the number of 12-week loading campaigns (assuming a maximum frequency of one campaign per calendar year) that are required over a 6-year period[1].

Step 3 - Assess the margins between the required performance (based on SOW throughput requirements) and the achievable performance and provide recommended loading frequencies for each of the nine plant cases.

Parametric Studies – Step 1 Results

Assuming a 24/7 operational schedule, the number of assemblies and STAD canisters that can be processed in a 12-week loading campaign are shown in Tables ES-1 and ES-2, respectively. For the "DPC (ref)" system, it should be noted that this refers to a DPC holding either 37 PWR or 87 BWR spent fuel assemblies, and the purpose of showing this information is to provide a comparison between the performance of the STAD canister variants and DPCs at or close to the largest capacities being used in industry today.

Table ES-1. Maximum Number of Assemblies per 12-Week Loading Campaign

System	Assemblies Per 12-Week Campaign			
	Baseline		Optimized	
	BWR	PWR	BWR	PWR
DPC (ref)	1131	555		
Large STAD	660	357	836	420
Medium STAD	608	252	768	300
Small STAD-in-Can	468	224	756	352
Small STAD-in-Carrier	504	240	864	400

[1] SOW requirement.

Table ES-2. Maximum Number of STAD Canister Variants per 12-Week Loading Campaign

System	DPC, Large/Medium STAD, or Can/Carrier Per 12-Week Campaign			
	Baseline		Optimized	
	BWR	PWR	BWR	PWR
DPC (ref)	13	15		
Large STAD	15	17	19	20
Medium STAD	19	21	24	25
Small STAD-in-Can	13	14	21	22
Small STAD-in-Carrier	14	15	24	25

Parametric Studies – Step 2 Results

The parametric time studies determined that each of the eight STAD system variants (4 PWR STAD systems and 4 BWR STAD systems) evaluated has the potential to meet the throughput requirements for each of the nine plant cases investigated, assuming that dual transfer casks and process technology improvements are used (i.e. the "Optimized" loading processes). As expected, the STAD canister variants require differing numbers of loading campaigns during a 6 year period and these are shown in Figure ES-3, below, together with how they compare with the "baseline" performance of 37-PWR and 87-BWR DPCs.

Table ES-3. Number of 12-Week Loading Campaigns Required Every 6 years Utilizing Optimized Loading Processes

Operational Case Number	Fuel Type	Number of Reactors On Site	Operating cycle length (months)	Number of 12-week loading campaigns required every 6 years using optimized loading processes				
				DPC (reference)	Large STAD	Medium STAD	Small STAD-in-Can	Small STAD-in-Carrier
				1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
1	BWR	1	18					
2	BWR	1	24					
3	BWR	2	24					
4	BWR	3	24					
5	PWR	1	18					
6	PWR	1	24					
7	PWR	2	18					
8	PWR	2	24					
9	PWR	3	18					

Parametric Studies - Step 3 Results

For the numbers of 12-week loading campaigns identified in Table ES-3, each one has a "margin" associated with it, which is a calculation of the margin between plant throughput needs (i.e., the SOW required quantities of fuel assemblies that need to be loaded to dry storage every 6 year period), and the peak STAD canister loading rate determined by the time and motion studies (see Tables ES-1 and ES-2). (Note: The margins for all cases and canister options are provided in Section 6 of this report). Two items to note pertaining to the medium STAD canister system are:

- In Table ES-3, for Case # 4 (Three Unit BWR, 24 month operating cycle), the medium STAD canister system has 9% margin when used for four loading campaigns during a 6 year period.
- In Table ES-3, for Case # 9 (Three Unit PWR, 18 month operating cycle) the medium STAD canister system has 4% margin when used for four loading campaigns during a 6 year period.

The margins for the two items, above, would be improved by moving to five or six 12-week loading campaigns every six years.

It should also be noted that for Case # 9 in Table ES-3, the DPC reference case has 0% margin when used for two loading campaigns during a 6 year period and could similarly be improved by moving to at least three 12-week loading campaigns over the 6 year period.

OPTIMIZED LOADING PROCESS

Regarding the optimized loading process, many of the operations performed during fuel transfer are not amenable to improvement. Crane lifting and transfer speeds can't be changed, and transport of systems to dry storage is slow by design. For the activities that are amenable to process improvement, it is important to note the following items:

Dual Transfer Casks

In the baseline process, a loaded transfer cask is unavailable for further fuel loading operations until the STAD canister(s) it holds have been transferred to a storage overpack in the receipt area of the Fuel Handling Building. For the optimized loading process, by utilizing a second transfer cask and performing transfer operations outside of the Fuel Handling Building then, as soon as a loaded transfer cask is moved from the decontamination pit to the receipt area, the second transfer cask (loaded with a STAD canister or a carrier holding multiple small canisters) can be moved to the decontamination pit to be prepared for fuel loading and then moved into the spent fuel pool for fuel loading. Once the first transfer cask has been emptied, it will then be returned to the Fuel Handing building. Time is also saved using the dual transfer cask because storage overpacks do not need to be received at the Fuel Handling Building because all transfers are performed outside of the building, noting that a cask transfer facility; with an associated capital cost (estimated $2.76 M), would be required for performing these transfer operations. When averaged over multiple transfer loads, the use of dual transfer casks provides an estimated 18 hours reduction in the baseline loading time for each transfer cask load.

It should be noted that the above discussion addresses a PWR Light Water Reactor (LWR) design with a Fuel Handling Building. However, a similar configuration could be established for BWRs; most of which do not have a separate Fuel Handling Building.

<u>Process Technology Improvements</u>

1. Vacuum Drying

The vacuum drying times used in the study were scaled (see Section 5.1) from the Zion data and an additional 17% reduction was applied to the scaled drying time, based on the use of automated vacuum drying system technology, which, per operational observations at other plants, has been demonstrated to achieve faster drying times compared with identical equipment that is not automated. Some of the DPCs loaded at Zion had metal matrix neutron absorbing panels, which have been noted to have significantly shorter vacuum drying times than more porous design alternatives such as Boral™. The Zion vacuum drying times used as the baseline data for this study are for the DPCs that had metal matrix neutron absorbers, which is acceptable because the STAD canisters will contain borated stainless steel; a neutron absorber that will have a similar drying time. It has also been assumed that the four small STAD canisters loaded in a can or carrier are dried in parallel, which is a reasonable assumption based on the Team's experience.

To be able to achieve optimum drying times for future STAD canister systems and validate the assumptions made in this study, noting that fuel assembly age and condition can also be significant factors in canister vacuum drying durations, two recommendations of this study are:

I. The STAD canisters need to incorporate materials (e.g., low porosity) and design features (e.g., minimal horizontal surfaces that can hold water) that minimize the amount of residual water after canister blowdown.

II. A standardized and automated drying system should be developed, which is optimized for use with the STAD canister design and loading configuration.

2. Parallel Welding of Small STAD Canisters

It has been assumed that the four small STAD canisters loaded in a carrier (or can) will be welded in parallel using independent remote controlled welding machines. This has been assessed as feasible by an expert welding company but, as explained previously, in order to validate this assumption, it is necessary to complete a welding development program, which is a further recommendation of this study.

COST ESTIMATES

All STAD canister types would cost more than DPCs on a per assembly and total cost basis. For the STADs themselves, the Large STAD shows the lowest cost. Overall percentage cost increases for STADs over DPCs range from the 25% (BWR) to 35% (PWR) range for the Large STAD, to the 55% to 85% range for the Small STADs-in-Carrier, to higher percentage increases for the Medium STAD and the Small STADs-in-Can. Having said this, these extra costs would likely be offset by avoiding the need to repackage a portion of the SNF before it can be consigned to a geologic repository. Mobilization and demobilization costs are not included in the operational cost estimates.

PRACTICALITY OF STUDY RESULTS VERSUS PLANT OPERATING EXPERIENCE

The Team has also drawn on its plant operating experience and looked at the configurations of operating sites with regards to the practicality of performing the frequencies of loading campaigns identified in Table ES-3.

The consensus for single unit PWR or BWR sites (Cases 1, 2, 5, and 6) is that the proposed loading frequencies could be accommodated, noting that 18 month operating cycles do lead to more refueling outages over time and thus, less time to perform other large projects and often shorter windows to do so.

Dual unit BWR sites running on 24-month operating cycles (Case 3) require one refueling outage per year alternating between each of the units, and the Refuel Floor time available for spent fuel load out is limited, so a large dry storage loading campaign every other year is desirable. This equates to three loading campaigns over a six year period and is consistent with what is shown in Table ES-3 for the STAD canister system variants.

For dual unit PWR sites running on 18 month refueling cycles (Case 7), refueling outages alternate between the two units for two years and during the third year the site needs to implement an outage for both of the units. It is not desirable to perform a loading campaign during a year when both units will be executing a refueling outage. Thus, the ideal plan is to load fuel to dry storage for two consecutive years and then skip a year to enable the site to execute the refueling outages for both units. This would equate to loading campaigns being performed during four of the 6 years, or the equivalent of an 18-month interval between campaigns. Table ES-3 shows that each of STAD variants will be able to support this frequency.

Regarding why it is not desirable to perform a loading campaign during a year when both units will be executing a refueling outage, a refuel can take from 3 to 4 months[2] and thus, two refuels in a calendar year will not leave sufficient time to perform a 12-week loading campaign, even without counting the time required for mobilization and demobilization. Conducting shorter loading campaigns between refuel outages is also not desirable because the mobilization/demobilization costs for a loading campaign are high (several $100 K) and utilities want to minimize them. It should also be noted that during single refuel outage years, utilities could (and do) choose to extend a loading campaign.

For dual unit PWR sites running on 24 month refueling cycles (Case 8), an outage will be executed every year; alternating between the two units. There is no year where an outage is executed for both units. Thus, it is possible for these sites to perform three loading campaigns during each six year cycle. Table ES-3 shows that each of the STAD variants will be able to support this frequency.

For the three unit PWR site that runs on an 18 month refueling cycle (Case 9), the Team's knowledge of operations at the Palo Verde site is that it typically loads to dry storage twice a year between outages; of which there are two a year. Table ES-3 shows that each of the STAD variants will be able to support this frequency. It is also important to note that the configuration of the three PWR reactors at Palo Verde is such that each reactor has its own spent fuel pool and overhead crane, which explains why Palo Verde is able to perform loading campaigns at the above frequency.

For the three unit BWR site that runs on a 24 month refueling cycle (Case 4), the Team's knowledge of operations at Browns Ferry is that it currently loads to dry storage every year. Table ES-3 shows that each of the STAD variants will be able to support this frequency. Regarding Browns Ferry, it is important to note that although there are three BWR reactors, two of them function as a dual-unit installation with a shared spent fuel pool, and the other reactor functions as a single-unit installation and has a dedicated spent fuel pool. This provides

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[2] A refuel typically comprises of the following items: (i) Four weeks to stage new fuel in the pool, (ii) two weeks to mobilize equipment, (iii) four to eight weeks for the refuel outage, and (iv) two weeks to demobilize equipment.

Browns Ferry with the ability to load annually based on the refueling outage schedules for what are effectively two separate power plants.

The unique configurations for Browns Ferry and Palo Verde emphasize the important part that the configuration of multi-unit reactor sites will ultimately play in determining if loading campaigns utilizing smaller capacity (compared with DPCs) STAD canisters will be able to support the required throughput rates.

In conclusion, each STAD canister system option appears capable of working at most, if not all, sites, depending on the loading campaign frequency. However, the medium STAD canister systems had the lowest overall performance and would not be recommended for the plant scenarios with higher throughput requirements.

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ACRONYMS

A&AS	Advisory and Assistance Service
ALARA	As Low As Reasonably Achievable
ASME	American Society of Mechanical Engineers
B&PV	Boiler & Pressure Vessel
BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
CMT	Cold Metal Transfer
CoC	Certificate of Compliance
CREVS	Control Emergency Ventilation Equipment System
DCS	Dry Cask Storage
DOE	U.S. Department of Energy
DPC	Dual Purpose Canister
EBW	Electron Beam Welding
EGW	Electrogas Welding
EONC	Enhanced On-Site Container
ESW	Electroslag Welding
FCAW	Flux Cored Arc Welding
FHB	Fuel Handling Building
FHD	forced helium drying
FSW	Friction Stir Welding
FME	Foreign Material Exclusion
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
GWd/MTU	Gigawatt-days/Metric Ton of Uranium
HBU	High Burnup
HEPA	high efficiency particulate air
HW	hotwire
I.D.	inside diameter
ISF	Interim Storage Facility
ISFSI	Independent Spent Fuel Storage Installation
kW	Kilowatt
LPI	liquid penetrant inspection
LWR	Light Water Reactor
MEG	monoethylene glycol
MEMS	micro-electromechanical systems
MMC	Metal Matrix Composite
MTU	Metric Tons Uranium

NDE	Non-Destructive Examination
NEPS	nitrogen enhanced purging systems
NPP	nuclear power plant
NRC	U.S. Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
OSC	On-Site Container
PAW	Plasma Arc Welding
PQR	Procedure Qualification Recording
PT	Liquid Penetrant Testing
PWR	Pressurized Water Reactor
RT	Radiography Testing
RUAM	Ready-to-use Additive Manufacturing
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding
SNF	Spent Nuclear Fuel
SOW	Statement of Work
SRP	Standard Review Plan
STAD	Standardized Transportation, Aging and Disposal
TAD	Transportation, Aging and Disposal
TEG	triethylene glycol
TSC	Transportable Storage Canister
UGS	Underground Gas Storage
UT	Ultrasonic Testing
VDS	Vacuum Drying System
WPS	Welding Procedure Specification
WTP	Waste Treatment Plant

1 INTRODUCTION

On October 2, 2014, under the U.S. Department of Energy (DOE) Advisory and Assistance Services (A&AS), an integrated team headed by Energy*Solutions* was the sole awardee for Task Order 21. This task assists the DOE Office of Nuclear Energy with a study that explains and optimizes the movement of spent fuel at nuclear power plants (NPPs) from pools to dry storage. This optimization is a pre-requisite to any future use of standardized canisters that have a smaller capacity than the conventional Dual Purpose Canisters (DPCs) currently in use at the NPPs. Efficiency improvements are necessary to move the required number of Spent Nuclear Fuel (SNF) assemblies from the spent fuel pool to onsite dry storage in the designated time frame (i.e., the “required SNF throughput”) when smaller canisters are involved. In particular, the DOE wished to gain a better understanding of the detailed tasks, durations, costs, equipment, and human resource requirements to move a specific number of assemblies to dry storage over a fixed time period in three different smaller capacity standardized canister designs. Identification of innovative approaches for reducing impacts while meeting the required SNF throughput was also sought.

The standardized canisters to be considered for each SNF assembly type (Pressurized Water Reactor [PWR] or Boiling Water Reactor [BWR]) are:

- 4-, 12-, and 21-PWR assembly capacity canisters; and
- 9-, 32-, and 44-BWR assembly capacity canisters.

For each (small, medium, and large) canister size (i.e., 4-PWR/9-BWR, 12-PWR/32-BWR, and 21-PWR/44-BWR), the exterior dimensions for the PWR canisters, and for the BWR canisters, are required to be the same.

Given the constraints of the study provided in the Statement of Work (SOW) (reproduced in full in Appendix I), the output from this study provides DOE with information, including use of manpower and concepts for new equipment and processes that would be required to meet the SNF throughput while satisfying these constraints using the smaller canisters. DOE can use this information to make decisions on canister standardization activities moving forward, including areas of potential research and development

The background to Task Order 21 is that the DOE is evaluating the option of using a standardized canister system suitable for storage, transport, and disposal of commercial SNF as part of an integrated waste management system. To accommodate a wide range of geologies for potential disposal, some of these canisters are much smaller than the DPCs currently in use. This evaluation includes developing and evaluating standardized canister system design concepts and operations and assessing the associated benefits and impacts from an overall waste management system perspective.

The Energy*Solutions* team assembled for this task consists of the following members:

- **Energy*Solutions*** - Full nuclear fuel cycle company with interests in Federal and commercial nuclear waste treatment, clean-up and disposition, nuclear reactor and legacy facility decommissioning, SNF treatment, storage and disposition, and SNF recycling.
- **NAC International** - Specialties include nuclear materials transport, and spent fuel storage and transport technologies. NAC has provided transportable SNF storage canisters and casks for a significant proportion of the commercial nuclear reactor utilities in the U.S.
- **Exelon Nuclear Partners** - A business unit of Exelon Generation. Operates 22 nuclear units and two retired units, with 11 Independent Spent Fuel Storage Installations (ISFSIs) at both BWR and PWR sites. Maintains over 10,000 Metric Tons Uranium (MTU) of SNF in pool storage and has moved over 3,500 MTU of SNF into approximately 320 dry cask systems.
- **Booz Allen Hamilton** - A technology and strategy consulting company with extensive experience in performing economic analysis and risk management assessments, and developing strategic plans and business models for nuclear industry vendors and utilities.

2 PURPOSE AND SCOPE

The purpose of this report is to document the work completed by Energy*Solutions* and its team partners: NAC International, Booz Allen Hamilton and Exelon Nuclear Partners, here after referred to as "the Team", in addressing the requirements provided by the DOE in the Task Order 21 SOW. These requirements are detailed in Appendix I, and the sections of this report that cover them are shown in Appendix B.

To meet the requirements of Task Order 21, the Team followed a five-phase approach to develop standardized canister design concepts and perform operational studies of innovative approaches. The five phases were:

- **Phase 1** - Subsequent to the award of Task Order 21 on October 2, 2014, the Team reviewed current utility canister loading operations and practices, including capabilities and constraints based primarily on first-hand experience. This included Exelon's experience operating PWR and BWR nuclear power plants that are currently dry storing SNF, Energy*Solutions*' experience loading 37-PWR DPCs at Zion and Energy*Solutions'* experience maintaining fuel pools at most of the US nuclear power plants. Existing information was reviewed including the canister-in-canister approach detailed in the Oak Ridge National Laboratory (ORNL) Letter Report: End-of-Year Status Report on Integrated Canister Design and Evaluation, ref. ORNL/LTR-2012/448) and the final reports from DOE A&AS contract Task Order 12 (Standardized Transportation, Aging and Disposal Canister Feasibility Study). Information on current SNF transfer operations was gathered and reviewed by the Team. On November 4 – 5, 2014, DOE and the Team participated in a facilitated workshop to discuss their reviews. During the workshop, the Team brainstormed options, ideas and recommendations for improving SNF transfers. Innovative approaches were given special attention. Energy*Solutions* turned output from the workshop into a series of work assignments for the remainder of Phase 1. The work assignments covered the three areas of design concepts, operations management and technology improvements. Phase 1 concluded with the Initial Progress Review (30% review) meeting with the DOE, which was held on January 6, 2015.

- **Phase 2** - Utilizing the feedback from the Initial Progress Review meeting, and focusing on maximizing the SNF throughput and identifying a base operational approach from the operational approaches identified at the workshop, the Team progressed work on developing a description of the standardized canister concept and associated storage system; a description of the set of tasks required to load canisters with SNF and move the required SNF throughput to dry-storage, including a work process flow diagram; the estimated durations for the tasks; and a listing of the major equipment items that would be required. Phase 2 concluded with the submission of the Preliminary Report to the DOE.

- **Phase 3** - The end goal of this phase was the production and submission to DOE of a Draft Final Report. The team used previously completed operational approaches and supporting reviews to feed parametric analyses. The parametric analyses captured how various approaches affect key work attributes (work duration, work dose, cost, etc.). The analyses also captured how these attributes varied as a function of the number of reactors at a given site, the type of reactors at the site and refueling frequency. The parametric analyses were conducted for all nine cases required by the SOW (see Appendix I, Section 2, Item 3). The Team recommended the optimum frequency for canister loading campaigns and operational approach for each of the nine cases based on the parametric analyses.

- **Phase 4** - This phase involved addressing and incorporating comments and feedback received at the Final Progress Review Meeting and from the DOE's review of the Draft Final Report. Phase 4 culminated in the submission to DOE of a Final Report and this Updated Final Report.

- **Phase 5** – In this phase the team completed the Task Order by preparing and issuing a Closeout Report, which summarized the results of the task order and offers suggestions to the Contracting Officer's Representative on ways to improve task order procedures.

This Updated Final Report documents the output from the above approach and is structured, as follows:

- **Section 3, Systems Engineering Approach**, outlines the phased approach that has been followed in order to complete the requirements of the Task Order 21 SOW.

- **Section 4, Design Concepts and Loading Processes**, describes the design concepts and loading processes for the small, medium and large Standardized Transportation, Aging and Disposal (STAD) canisters, including the STAD-in-Can and STAD-in-Carrier design concepts, which were identified as a means to gang load small STAD canisters in groups of four. This section also provides reasonable assurance regarding the capability of the design concepts to meet fundamental licensing requirements for 10 CFR 71 and 10 CFR 72.

- **Section 5, Parametric Studies**, describes the methodology, bases and results from the time and motion studies that have been performed for each of the operational approaches. This includes the results of process technology, operations management improvements and recommendations for which of these improvements constitute best practices. The results from these operational approaches are also compared (based on packaging an equivalent amount of spent nuclear fuel with like characteristics) with the same set of information for DPCs at or close to the largest capacities being used in industry today.

- **Section 6, Recommended Optimum Frequencies and Operational Approach for Canister Loading Campaigns**, summarizes, for the nine plant cases investigated, the recommended intervals for fuel loading campaigns and the frequencies for loading. This section also includes a discussion of the practicality of performing loading campaigns at the recommended frequencies. This discussion draws on the Team's plant operating experience and considers the configurations of various operating sites.

- **Section 7, Cost Estimates**, provides detailed cost estimates for the STAD canister systems, process equipment and operations associated with the loading processes evaluated for the Parametric Studies, including cost per spent fuel assembly and cost per STAD canister system.

- **Section 8, Research and Development Recommendations**, discusses recommendations pertaining to residual moisture removal using ultra-dry nitrogen, welding of multiple small STAD canisters in parallel and a standardized and optimized drying system for use with the STAD canister system in use.

- **Section 9, Conclusion**, documents the overall conclusions drawn from the work performed by the Energy*Solutions* Team in addressing the requirements for Task Order 21.

3 SYSTEMS ENGINEERING APPROACH

As indicated in the Technical Proposal submitted to the DOE on August 26, 2014, the intent was to follow a five-phase approach, in order to perform the scope of work for Task Order 21. Figure 3-1 shows a logic diagram of the systems engineering approach used by the team.

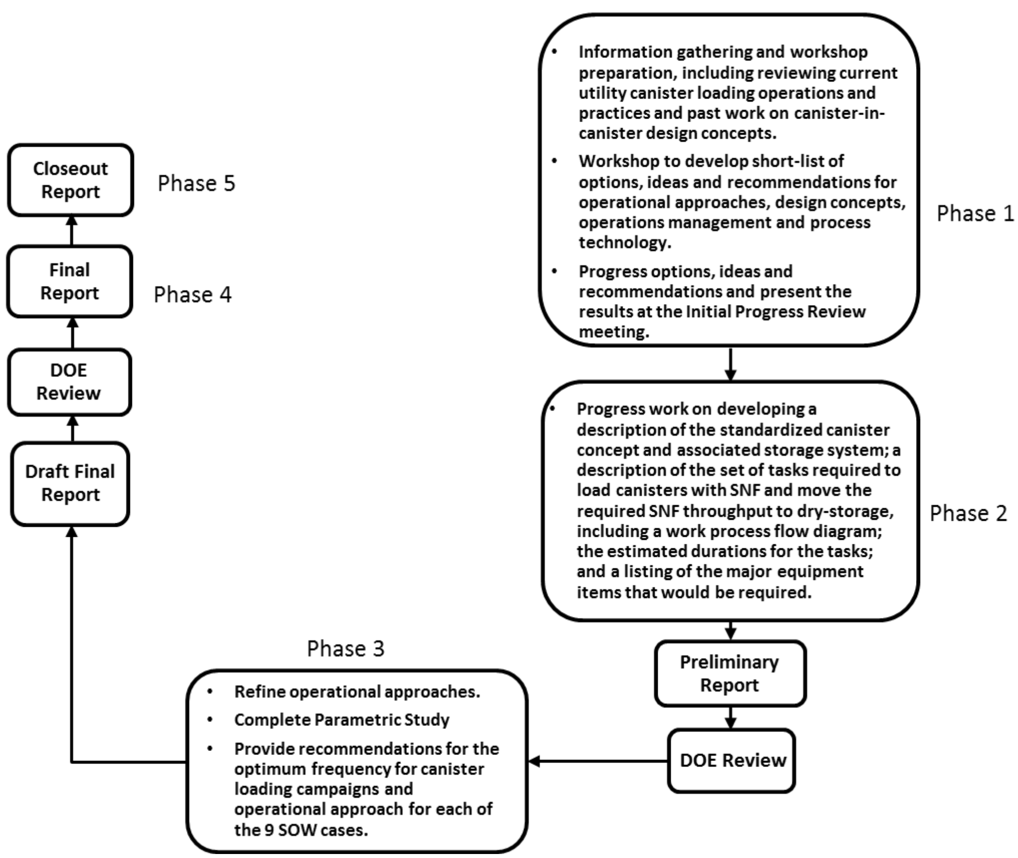


Figure 3-1. Logic Diagram Showing Systems Engineering Approach.

3.1 FACILITATED WORKSHOP

Fundamental to Phase 1 was a facilitated workshop, which was held from November 4 - 5, 2014, and was attended by representatives from each company within the Team, the DOE Task Order 21 Technical Monitor, and representatives from the DOE support team. The meeting notes for the workshop are provided in Appendix A and the key outputs from the workshop are summarized below.

The following operational approaches were identified for the different sizes of STAD canister:

- Load the medium (12-PWR/32-BWR) and large (21-PWR/44-BWR) STAD[3] canisters individually using a process that is similar to the process used by Zion*Solutions* to load sixty-one 37-PWR DPCs in less than 52 weeks at the shutdown Zion Nuclear Power Plant, Illinois.
- Gang load the small (4-PWR/9-BWR) STAD canisters and weld and dry them as a group.
    1. Could be accomplished by a "STAD-in-Can" approach, which is akin to the design concept developed by ORNL (ref. ORNL Letter Report ORNL/LTR-2012/448).
    2. Could be accomplished by a STAD-in-Carrier approach.
    3. The end goal for items i) and ii), above, being an integrated solution which optimizes the handling of multiple small STAD canisters from the spent fuel pool to the storage overpack and from the storage overpack to the transportation overpack.

Lessons learned, operations management, and operations data were gathered from the work performed by the Energy*Solutions* company, Zion*Solutions,* in loading sixty-one 37-PWR DPCs in less than 52 weeks once decommissioning of the Zion Nuclear Power Plant began. The loading process used was performed 24/7 and represents the current state-of-the-art for dry storage across the country. It was determined that the data from the Zion operations would serve as the "baseline" data for the time and motion studies performed under Task Order 21.

Recommendations and ideas were also gathered for the process technologies, which are fundamental elements of the loading process, i.e., welding and non-destructive examination (NDE) associated with sealing the shield plugs, top plates and vent and drain ports, and drying the canister internals, including performing this work on multiple small canisters in parallel.

[3] In this report the term "STAD" is used interchangeably with the term "STAD canister" and the term "STADs" is used interchangeably with the term "STAD canisters".

3.2 DESIGN CONCEPTS AND LOADING PROCESS

Building off the workshop, the team developed loading process flowsheets and design concepts for the STAD canister systems. The development of this information was an important prerequisite to performing the parametric studies as it provided:

- STAD canister dimensional data and design features, which allowed the baseline Zion data, e.g., welding time, canister drying time, to be scaled for use with the STAD canisters.
- Identified that the small STAD canisters would be gang loaded and processed in groups of four.
- The individual steps in each loading process.

The design concepts and loading process flowsheets are described in detail in Section 4.2 and in Appendix C (*Standard Canister Concepts*, Appendix L (*Design Concepts for STAD-in-Can and STAD-in-Carrier*) and Appendix E (*Loading Process Flowsheets*).

3.3 PROCESS TECHNOLOGIES

In-depth investigations were performed of welding/NDE and canister drying technologies. A summary of these studies is given below and details are provided in Appendix G (*Drying Processes*), Appendix K (*Moisture Removal*) and Appendix J (*Welding and NDE technologies*).

<u>Welding/NDE</u>

The objective for the welding/NDE technologies study was to evaluate candidate welding and NDE processes, with the goal of identifying hardware and processes that optimize welding operations. Optimization considered setup and processing times for each weld pass, the number of passes required, and inspection of the welds. The evaluation also included consideration of weld reliability and requirements for weld repair, if required. Another objective was to investigate the feasibility of a welding system that would allow all four small STADs in a carrier to be welded in parallel. The results of the investigation into welding and NDE processes are provided in Appendix J and are summarized below:

- At the present time, there are not enough advantages in other processes to consider anything other than the Gas Tungsten Arc Welding (GTAW) that is currently used. This process has a proven track record in the nuclear arena. It is very forgiving, provides welds that are capable of passing any NDE that is required and facilitates easy repair of defects of any shape or size. There are numerous manufacturers of automated GTAW machines for closure welds on radiation containers and some notable ones include Astro Arc Polysoude (used at the West Valley site for welding high level waste canisters), Liburdi Dimetrics (providing systems for welding high level vitrified waste canisters at the Waste Treatment Plant (WTP), Hanford Site) and Arc Machines (system used to weld DPCs at the Zion Nuclear Power Station).

- In addition to the basic GTAW welding process, other process adjustments that can offer faster weld times include:
  - optimizing the welding parameters for maximizing the weld deposition,
  - using hot wire GTAW, which has a higher deposition rate than cold wire GTAW, and
  - optimizing the weld design in order to minimize the amount of welding time (e.g., a "J" bevel weld can still provide a thin land for a controlled melt through, but have a narrower groove so the resultant weld volume will be less and the welding time will be decreased).
- Manual dye penetrant testing (PT) was chosen for the parametric studies. Previous work at Zion using a remote PT system had identified that the remote PT process was not proving to be a significant time saver.
- Considering the configuration of four small STAD canisters in a carrier and the feasibility of a welding system that would allow all four canisters to be welded in parallel, discussions were held with Liburdi Automation who are the suppliers for the WTP welding systems. Their response was that this was feasible with the proper welding equipment and parameter development, including the development of hardware and software controls such as interlocking the positions of the weld torches and the taking of parameter samples. It should also be noted that a welding machine would be assigned to each canister and the welding would be remotely performed by a welding technician. Thus, potentially, four welding technicians would be required. This also means four sets of control and monitoring equipment that could become cumbersome to install. The potential benefit is large enough that parallel welding of the four small STADs is included as a topic worth pursuing in the R&D section (Section 8.2) of this report. It should also be noted that the use of parallel welding for the small STAD canisters is assumed for the optimized loading processes described in Section 5.

<u>Canister Drying</u>

The objectives for this investigation were to provide a synopsis of the basic technology in use today for fuel storage canister drying as a means to reduce the overall canister loading duration. The results of the investigation are provided in Appendices G and K and are summarized below.

- In general, the vacuum drying process is used successfully with a wide variety of fuel types (PWR and BWR) and canister sizes, but drying durations have varied from hours to multiple days. The main contributing factors to this variability are:
  - Internal fuel basket design – Need to ensure that the gross collection area for free standing water is minimized and that draining to the bottom of the canister is maximized.
  - Neutron absorption material composition in the fuel basket cell - Borated metal matrix composite (MMC) materials reduce drying durations significantly compared with the more water-porous Boral™ or borated aluminum plate.
  - Age of each fuel assembly – Need to ensure that uniform (higher) heat loads are obtained during loading, in order to compensate for older fuel that usually has less residual heat compared with fuel more recently removed from the reactor. By mixing in some newer "hot" fuel with older "cold" fuel, this will allow the benefits of the decay heat from the fuel to be utilized during the drying process. Loading a canister with all older fuel will result in the drying process taking longer; irrespective of whether forced helium dehydration or vacuum drying systems are used.
  - Physical condition of the fuel cladding – Cracked or otherwise damaged fuel cladding, such as pin-hole leaks, may cause water retention in a fuel pin. There is a need to develop a loading plan that can deal with these anomalies in the most efficient way possible.
- Automated "Smart" vacuum drying systems have been demonstrated to reduce time (by 17%) when compared with the same non-automated vacuum drying system.

3.4 PARAMETRIC STUDIES

Utilizing the output from the work on design concepts, loading processes, and process technologies, parametric studies were performed which are documented in Section 5. The results from the parametric studies were then used to identify recommended optimum frequencies and operational approach for performing the loading campaigns (see Section 6). The steps performed for the parametric studies were:

- Step 1 - Determine the maximum number of assemblies that could be moved to dry storage in a 12-week window for each STAD canister variant beginning with currently understood dry storage operations ("Baseline") and then applying process technology and dual transfer cask (parallel processing opportunity) improvements ("Optimized"), as applicable.

- Step 2 - Determine whether each STAD variant can provide the throughput for each of the nine plant cases defined in the SOW and if so, identify the number of 12-week loading campaigns (assuming a maximum frequency of one campaign per calendar year) that are required over a 6-year period.
- Step 3 - Assess the margins between the required performance (based on SOW throughput requirements) and the achievable performance and provide recommended loading frequencies for each of the nine plant cases.

In concert with the time and motion studies performed for the parametric studies, work was performed to provide the estimated total cost and cost break-down for moving the required SNF throughput for the nine plant cases evaluated and the STAD canister system variants that were used. The cost estimates are provided in Section 7. As a final point, recommendations for future research and development that might decrease processing times were identified and are presented in Section 8.

4 DESIGN CONCEPTS AND LOADING PROCESSES

This section describes the design concepts (Sections 4.1.1, 4.1.2, and 4.1.3) and loading process flowsheets (Section 4.2) for the small, medium and large STAD canister systems, which were evaluated as part of the Parametric Studies described in Section 5. The design concepts are described in more detail in Appendix C, while the loading processes are detailed in Appendix E. In addition to the STAD canisters themselves, the designs for the STAD-in-Carrier and the STAD-in-Can configurations for small STAD canisters are also presented (Section 4.1.5), with the STAD-in-Carrier design concept being the approach recommended by the Team for processing the small STAD canisters. This is because the STAD-in-Can design presents many challenges that don't exist with the current storage of DPCs, e.g., ensuring adequate heat transfer to preclude fuel cladding damage, the need to dry the can, additional weight, and constraints on visual inspection of STAD canisters in storage. Details are also provided (Section 4.1.4) on the canister design parameters, which were used to derive the welding, NDE and drying times that were used for the Parametric Studies. In addition, details are provided (Section 4.1.6) on the capability of the design concepts to meet fundamental licensing requirements. Section 4 concludes with a discussion on the design concepts for storage and transportation overpacks; with a view to developing an integrated transfer, storage, and transportation system.

4.1 DESIGN CONCEPTS FOR THE STAD CANISTERS

The design concepts for the small, medium, and large STAD canisters are described below. Conceptual sketches for the small, medium, and large STAD canisters are provided in Appendix C.

4.1.1 Small STAD Canisters

For the small STAD canisters the Team has utilized information from Task Order 18 on the design concepts for a 4-PWR and a 9-BWR STAD canister; each of which has the same exterior dimensions and is a right-circular cylinder. Figure 4-1 shows the design concept for the small STAD Canister and the design parameters are summarized in Table 4-1.

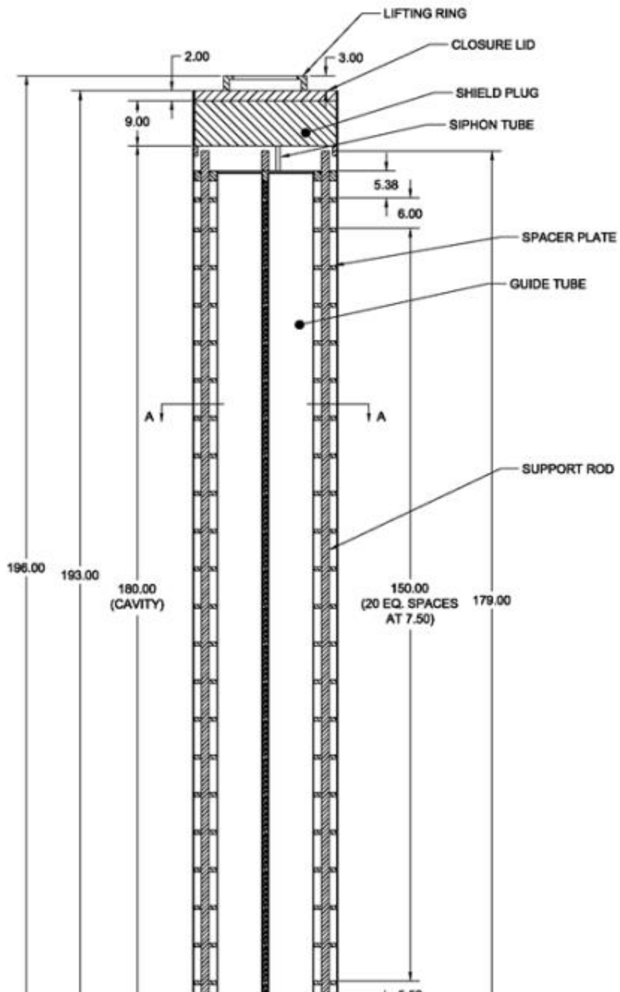


Figure 4-1. Design Concept for the Small STAD Canister

Table 4-1. Small STAD Canister Design Parameters.

Design Parameters	4P	9B
Shell Outer Diameter	29.0”	
Shell Thickness	0.25”	
Overall Length (w/ Lift Ring)	196”	
Cavity Length	180”	
Bottom Plate Thickness	2.0”	
Shield Plug Thickness	9.0”	
Lift Ring (O.D. x HT)	∅16.0” x 3.0”	
Guide Tube Opening	8.85” SQ.	5.85” SQ
Max. FA Weight	1,725 lb.	706 lb.
Weight (dry, loaded)	14,000 lb.	13,500 lb.
Canister Shell Material	Type 316L SS	Type 316L SS
Basket Structural Materials	Type 316L SS	Type 316L SS
Basket Neutron Absorbers	Borated SS	Borated SS
Basket Thermal Shunts	Aluminum	N/A

Key points to note about the conceptual design for the small STAD canister, as applicable to the STAD-in-Carrier design concept, are that the weld size for the canister lids and the canister shell thickness have been optimized following structural analyses performed for Task Order 18. In addition, the outer lid is designed to provide the redundant closures for both the welded inner lid and the welded vent and syphon port covers, thus obviating the need to weld outer covers over the welded inner covers for the vent and syphon ports.

The use of a right-circular cylinder shape for the small STAD canister reflects what has widely been used by the dry cask storage industry and is the default shape for Task Order 21. However, square STAD canisters would allow five small square STAD canisters to be packed into the same area as four small right-circular cylinders. Scoping level structural analyses have also determined that square STAD canisters can be designed to cope with internal loading pressures, albeit with the need to double the shell thickness of the right-circular cylinder STAD canisters with an accompanying weight penalty. This better packing efficiency would be useful if the required SOW throughputs were found not to be achievable with the use of right circular cylinders. However, this study has shown that the required SOW throughputs are achievable, so it was not necessary to pursue square STADs.

For the STAD-in-Can design concept, the design for the small STAD canister differs in that it excludes the top plate and instead, as shown in Figure 4-4, uses the welded shield plug as a single lid with a lifting ring. This is because closure of the can provides the required redundant second closure.

4.1.2 Medium STAD Canisters

Utilizing information from Task Order 12 [4], the design concept for the medium STAD canister is a right circular cylinder that is fitted with a fuel basket capable of holding 12 PWR assemblies or a fuel basket capable of holding 32 BWR assemblies. It uses borated stainless steel for the neutron poison. The lid design would also achieve the same functions as the small STAD canister; with the outer lid providing the redundant closures for the welded inner lid and the welded vent and syphon port covers. Figure 4-2 shows a 3-D image of the medium STAD canister and cross sections of the 12-PWR and 32-BWR fuel baskets. Key differences from the small STAD canister are that the medium STAD canister has an outside diameter of 52" and a shell thickness is 0.5". To weld the inner and outer lids, a 3/8" partial penetration groove weld has been assumed.

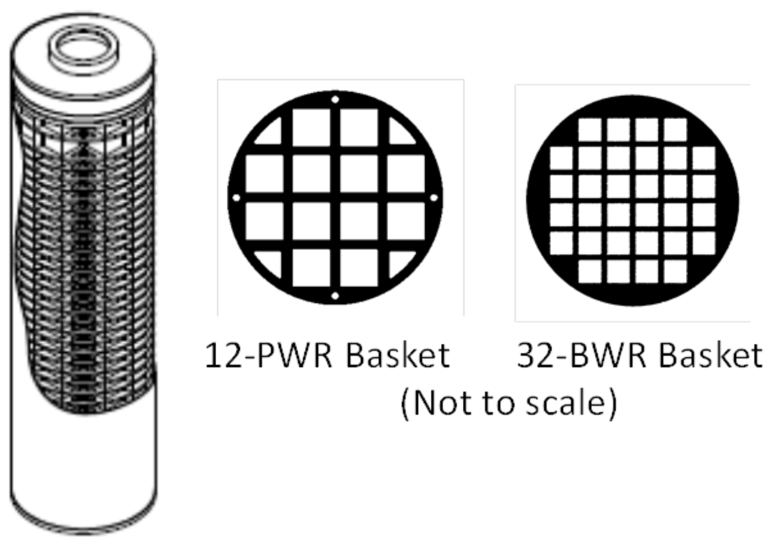


Figure 4-2. Design Concept for Medium STAD Canisters

4.1.3 Large STAD Canister

The design concept for the large STAD canister is a right circular cylinder that is fitted with a fuel basket capable of holding 21 PWR assemblies or a fuel basket capable of holding 44 BWR assemblies. These capacities are the same as the Transportation, Aging, and Disposal (TAD) canister, which was designed by industry for the DOE in 2008; with NAC International designing the 21-PWR and AREVA designing the 44-BWR. Key details for the 21-PWR design were that that it has an overall length of 199" (including lifting bail) and an outside diameter of 66.5". It also uses borated stainless steel for the neutron poison. Figure 4-3 shows the 21-PWR TAD canister designed by NAC International. For Task Order 12[4], a large STAD canister was

[4] DOE A&AS Contract Task Order 12, Standardized Transportation, Aging, and Disposal Canister Feasibility Study.

developed, which was capable of holding 24 PWR assemblies or 68 BWR assemblies and had an overall length (without the lift ring) of 195" and an outside diameter of 72". For this study, the larger diameter associated with the 24 PWR/68 BWR large canister was selected for the purpose of deriving parametric study welding and NDE times because it provides a more conservative assumption.

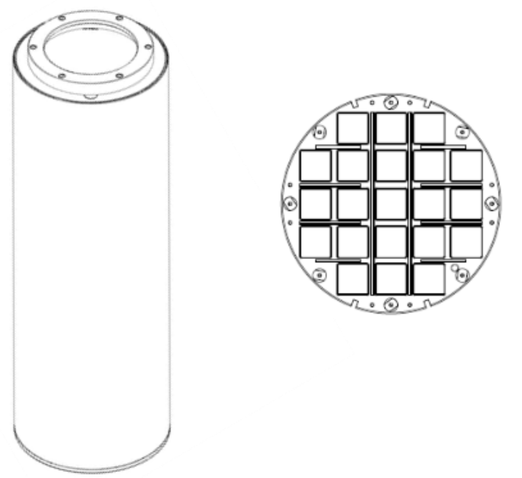


Figure 4-3. 21-PWR TAD Canister Designed by NAC International

4.1.4 STAD Canister Design Parameters Used to Derive Parametric Study Welding and NDE Times

As described in Section 5.1, the assumptions for the welding and NDE times for the small, medium and large canisters were derived using baseline data from the Zion dry fuel storage campaign and scaling it per key parameters of the STAD canister design concepts. The key parameters used are as follows, noting that the diameter used for the large STAD canister reflects the Task Order 12 design concept and was selected because it provided a more conservative assumption. Weld passes and layers correspond to the Task Order 18 design for the small STAD canisters, and to the Zion canister design for the medium and large STAD canisters.

<u>Small STAD canister:</u>

Inner Closure Weld:

- 1/4" effective throat partial penetration groove weld x 28.2" I.D.
- Assume 2 layers with progressive PT examination (root and final)

Port Cover Welds (2x):

- 1/8" effective throat partial penetration groove weld x 2.0" diameter
- Assume 1 layer with surface PT examination

Outer Closure Weld:

- 1/4" effective throat partial penetration groove weld x 28.2" I.D.
- Assume 2 layers with progressive PT examination (root and final)

<u>Medium and Large STAD Canisters:</u>

Inner Closure Weld:

- Partial penetration groove weld x 51" I.D. (medium) or 70.74" I.D. (large)
- Assume 3 layers with progressive PT examination (all layers)

Port Cover Welds (2x):

- 1/8" effective throat partial penetration groove weld x 2.5" diameter
- Assume 1 layer with surface PT examination

Outer Closure Weld:

- Assume 1 layer with surface PT examination (similar to Zion baseline)

4.1.5 Design Concepts for the STAD-in-Can and the STAD-in-Carrier

Building on the "STAD-in-Can" loading process for small STAD canisters, which was identified at the workshop (see Appendix A), the team developed and evaluated a design concept for this process. In addition, utilizing work performed under Task Order 18[5] , the team evaluated an alternative loading approach for small STAD canisters, which utilizes an open-frame carrier, rather than an overpack can; with this design concept referred to as the "STAD-in-Carrier". The results from the development and evaluation of these design concepts are described in detail in Appendix L and are summarized below.

The design concept for the STAD-in-Can is shown in Figure 4-4 and the end product loaded into a storage overpack is four small STAD canisters; each with their inner lids (shield plugs) installed and welded, which are contained within an overpack can that has a welded lid. As described in Appendix L, the STAD-in-Can design presents many challenges that don't exist with the current storage of DPCs, e.g., ensuring adequate heat transfer to preclude fuel cladding damage, effectively drying the inside of the overpack cans to prevent corrosion on the exterior surfaces of the STADs inside, excessive weight, and the difficulty of visual inspection of the STAD canisters in storage. It is not possible to visually inspect the external surfaces of the STADs stored in an overpack can unless the lid of the overpack can is removed. That may require removing the overpack can from the dry storage module in a transfer cask and relocating it to a contamination controlled work area to remove the overpack can lid (depending on the type of

[5] DOE A&AS Contract Task Order 18, Generic Design for Small Standardized Transportation, Aging, and Disposal Canister Systems.

STAD lid closure(s) and how redundant seal isolation of the fuel is performed). Even in the best case scenario with both confinement seals welded on the small STADs, visual inspection would require removal of the dry storage module lid and the overpack can lid to obtain visual access to the STAD surfaces through the small vent and drain ports in the overpack can shield plug. That is a cumbersome process. In comparison, the STAD-in-Carrier design concept (see Figure 4-5) provides an end product loaded into a storage overpack where four small canisters, each with their inner and outer lids installed and welded closed, are individually held within an open carrier. The STAD-in-Carrier design concept is the subject of design and engineering analyses under DOE A&AS Contract Task Order 18, *Generic Design for Small Standardized Transportation, Aging and Disposal Canister Systems*, and is the design concept that is recommended by the Team for processing the small STAD canisters. It eliminates many of the shortcomings of the overpack can and visual inspection of the external surfaces of the STAD canisters whilst in storage would be possible by simply inserting a video probe through the vent ports in the storage module. In addition, as detailed in Section 4.3, it is possible to design a system that could extract individual canisters from a stored carrier.

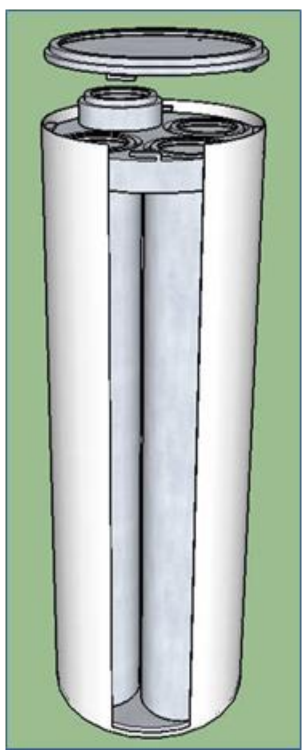


Figure 4-4. STAD-in-Can Design Concept.

Figure 4-5. STAD-in-Carrier Design Concept.

4.1.6 Reasonable Assurance that Design Concept has the Capability to Meet Fundamental Licensing Requirements for 10 CFR 71 and 10 CFR 72

The regulatory compliance of the small STAD canisters has been assessed under Task Order 18[5] and it was concluded that, subject to several considerations, U.S. Nuclear Regulatory Commission (NRC) approval of the STAD system design for both the initial 10 CFR Part 71 transport Certificate of Compliance and the initial 10 CFR Part 72 storage Certificate of Compliance would be anticipated. The considerations are described in detail in the Task Order 18 report and cover the areas of: aging management, high burnup fuel, multiple storage configurations (vertical and horizontal), multiple STAD canisters in storage and transportation overpacks (where four small STAD canisters are stored and transported whilst loaded in a carrier), and moderator exclusion. It was also stated in the Task Order 18 report that testing and/or modeling and analysis would be necessary to demonstrate the acceptability of the STAD canister transportation package to satisfy the routine, normal, and hypothetical accident conditions. Likewise modeling and analysis would also be necessary to demonstrate the acceptability of the STAD canister dry cask storage system and its multiple storage configurations under accident conditions.

The medium and large STAD canisters are intended to be stored and transported in single units and so would not be subject to any licensing considerations pertaining to storage or transportation of multiple canisters. However, the considerations pertaining to aging management, high burn up fuel and moderator exclusion (if employed as the primary means of criticality control for the transportation cask system) will be applicable. It is concluded that the medium and large STAD canister designs are capable of being licensed.

4.2 LOADING PROCESSES

For the small, medium and large STAD canister design concepts described in Section 4.1, loading processes were developed, which were primary inputs to the time and motion analyses studies detailed in Section 5. The loading processes were captured in the form of flowcharts, which are provided in Appendix E.

The loading processes developed are:

- ***Zion DPC Loading Process*** - This process reflects a prototypical SNF canister loading process (derived from the Zion*Solutions* loading process {loaded 37-PWR DPCs} for the shutdown Zion Nuclear Power Plant), which reflects the basic serial approach that is applicable to the medium and large STAD canisters and also serves as the starting position from which the STAD-in-Carrier and the STAD-in-Can operational approaches were derived.

- ***STAD-in-Can*** – This process for packaging small STAD canisters reflects the design concept described in Section 4.1.5. The end product that is loaded into a storage overpack for this design concept is an overpack can that that has a welded lid and contains four small STAD canisters. Prior to installing and welding the overpack lid, a single shield plug (with a lifting ring) is installed and welded in each small STAD canister. Note. As detailed in Section 4.1.5, the STAD-in-Can design concept offers several options to achieve dual welded closures, but thermal design limits require a welded closure on the overpack can to retain pressurized helium for heat transfer. This required the above configuration for processing small STAD canisters as part of a STAD-In-Can system.
- ***STAD-in-Carrier*** – This process for packaging small STAD canisters reflects the design concept also described in Section 4.1.5 and the end product loaded into a storage overpack is four small canisters; each with their inner (shield plug) and outer (top plate with lifting ring) lids installed and welded closed, which are jointly held within a single carrier. A simplified version of the STAD-in-Carrier loading process is shown in Figure 4-6. The number of heavy lifts (using a single failure proof crane) for the STAD-in-Carrier loading process are detailed in Table 4-2.

Table 4-2. Number of Heavy Lifts for STAD-in-Carrier Loading Process

Description of Heavy Lift	Number of Heavy Lifts (using a single failure proof crane)
Remove Storage Overpack Cask (SOC) lid	1
Move carrier with empty STAD canisters from SOC to transfer cask	1
Remove STAD canister shield plugs	4
Place transfer cask into the spent fuel pool	1
Install STAD canister shield plugs	4
Lift transfer cask from spent fuel pool and move to decontamination pit	1
Install transfer adapter on top of SOC	1
Move transfer cask to SOC	1
Load carrier into SOC	1
Move transfer cask to staging area	1
Remove transfer adapter	1
Install SOC Lid	1
TOTAL	**18**

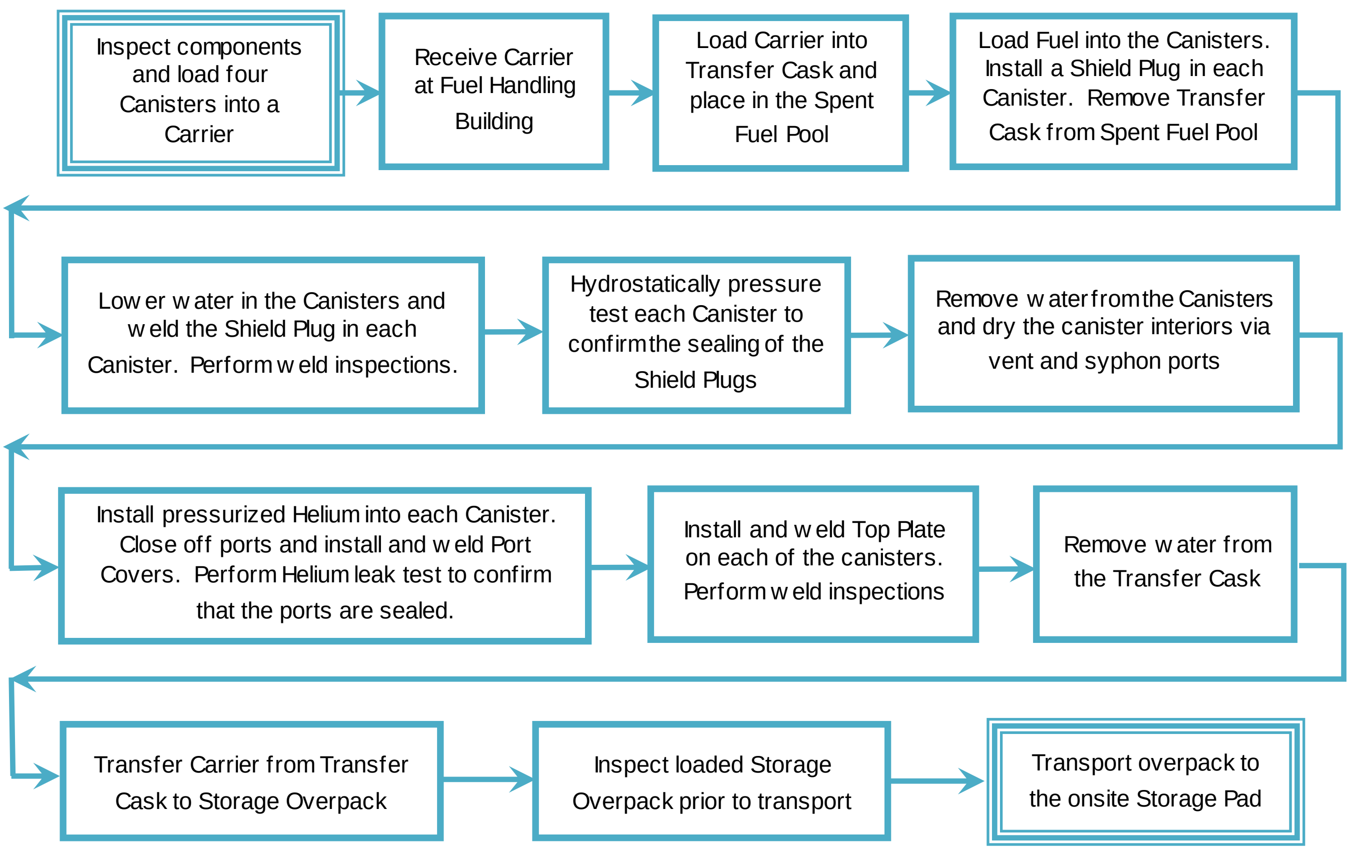


Figure 4-6. STAD-in-Carrier Loading Process (simplified)

4.3 DESIGN CONCEPTS FOR THE STORAGE AND TRANSPORTATION OVERPACKS

The operational processes for moving canisters of SNF to storage (whether large DPCs, large STADs, or small STADs in a carrier) are not amenable to design solutions that will decrease processing times. These operations primarily involve heavy onsite transport and heavy lifting activities. These are operations that proceed slowly for safety reasons. The number of lifting operations decreases somewhat for horizontal storage configurations, but the lifts are replaced by a slow rotational operation to transition storage systems from the vertical orientation as they are lowered from the FHB handling area to a horizontal position for storage. The Team did not identify any storage design modifications that would accelerate moving or lifting operations.

Based on the results from the workshop, the decision to process the medium and large STAD canisters as single units leads to options for storage and transportation overpacks akin to the DPCs in use today, i.e., stored and transported individually. One option considered for the medium size (12P) STAD canisters was storage in multiples of three as shown in Figure 4-7. This design approach would not speed processing since each STAD would still have to be transferred and loaded individually (medium STAD canisters are not designed to be handled in multiples), but there might be some hardware cost savings since fewer storage casks would be required.

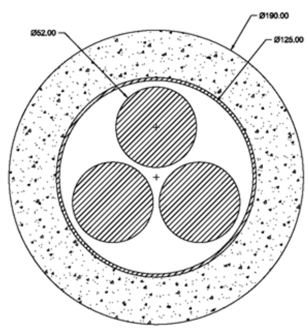


Figure 4-7. Idea for Storage of Multiple Medium STAD Canisters

Storage of multiple medium STADs in one cask also has implications for thermal performance. The thermal SNF design specifications for this Task Order result in an upper decay heat value of 2 kW/assembly. In a STAD with 12 PWR assemblies, that means 24 kW of decay heat per STAD. The highest performing dry storage systems in use today (the NAC MAGNASTOR system) can only handle a total of 35 kW of decay heat. A design is in NRC review (NUHOMS EOS) that, if approved, will handle up to 47 kW of decay heat. These high thermal capacity dry storage systems require optimal flow of the natural circulation cooling air to uniformly remove heat from all surfaces of the storage canister as shown in Figure 4-8.

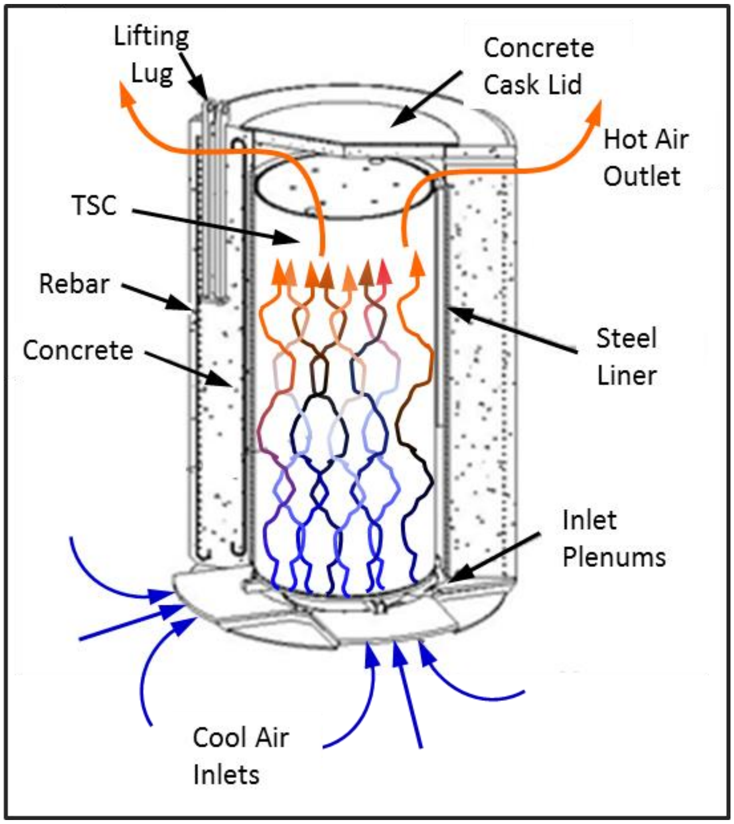


Figure 4-8. Ideal Mixing of Cooling Air Flow

This optimal airflow is only possible with a single storage canister in each storage cask. Adding additional canisters will create discontinuities in the natural circulation airflow that will reduce the effectiveness of the heat transfer.

Just two of the 12-PWR sized STADs with the specified SNF would exceed the thermal capacity of the highest thermal capacity storage systems under review, 47 kW. Storing three canisters in one storage cask would completely overwhelm the system's heat removal capacity, particularly with the less than optimal configuration for natural circulation airflow. More than one mid-sized STAD could be stored in a large storage cask if additional pool cooling time were allowed to reduce the total heat load, but that does not comply with the fuel specified for this work. Storing multiple medium sized STADs filled with fuel releasing the maximum specified decay heat is not practicable in a single storage cask.

Given the goal of speeding SNF processing times, there is no benefit to storing more than one large or medium STAD in a storage cask. Processing times for moving fuel from the pool to dry storage will not be affected by the number of STADs in each storage cask. That means there is no advantage to developing large storage casks that could handle more than one larger STAD. This is true even if more time were allowed for pool cooling to decrease the decay heat load per assembly. No innovative approaches to speed transport or loading the STADs into the storage casks were thus identified.

For the small STAD canisters, the options for storage and transportation overpacks are driven by either the carrier (STAD-in-Carrier) or the can (STAD-in-Can) that is used to package four canisters at a time in the fuel handling building. For the STAD-in-Can, the STAD canisters remain within the can until such time they can be removed at a repository or Interim Storage Facility (ISF). As described in Appendix L, the storage of small STAD canisters inside a can has many challenges, including ability to dry the can and contents, difficulties with visual inspection of the STAD canisters during storage, excessive weight, and issues with ensuring adequate heat transfer from the STADs to preclude fuel cladding damage. The overpack can also add noticeably to the overall diameter of the container that has to fit into transfer casks, storage overpacks and transportation casks, necessitating design and licensing of new, larger Type B transport casks. Although clearly preferable to the STAD-in-Can, the STAD-in-Carrier concept is also not immune from issues associated with an overall diameter that is too large for existing storage and transportation overpacks. It also has its own challenges with ensuring adequate natural cooling whilst in storage and the inspection of canisters during storage; all of which were progressed under Task Order 18, which selected the STAD-in-Carrier as the preferred approach for handling small STAD-in-Carrier canisters. However, unlike the STAD-in-Can, the STAD canisters each have redundant welded closures and the design of the carrier is such that, via a single STAD transfer cask and an indexed shielding arrangement, individual STAD canisters could be extracted from a carrier loaded in a storage overpack. One option for this arrangement would be for the STAD canisters to be transferred to a transportation cask that optimizes the loading of up to four small STAD canisters for transport via rail. Another option would be to extract single STAD canisters for R&D, or for placement in a horizontal NUHOMS-type aboveground storage module, or in a vault at a consolidated storage facility.

Operation of a transfer cask to move individual small STADs from the storage system to a transport cask would mirror the approach taken by NAC to load individual high level waste canisters into dry storage systems at the West Valley site. Although the STAD carrier is primarily designed for multiple STAD handling activities, each STAD remains independently accessible in this arrangement. Development of additional STAD handling equipment can allow for single STAD removal and placement for variations in transport and storage configurations. Figure 4-9 describes the systems for loading and unloading single STAD canisters from both storage and transportation casks. Note that a single STAD transfer cask can be designed to be capable of being laid down, transported and positioned for potential horizontal placement.

A system similar to that shown in Figure 4-9 allows for individual transfer operations while maintaining the necessary shielding. The system shown on the left demonstrates a transfer either into or from a STAD vertical concrete cask storage configuration. The system on the right demonstrates a transfer either into or from a STAD transport cask configuration. Both processes use small transfer casks integrated with special adapters on the storage or transport cask that rotate to index access to specific storage cells in the basket. Similarly, a single STAD transfer can be performed from or into individual in-ground caisson type storage or horizontally into bunker type storage positions.

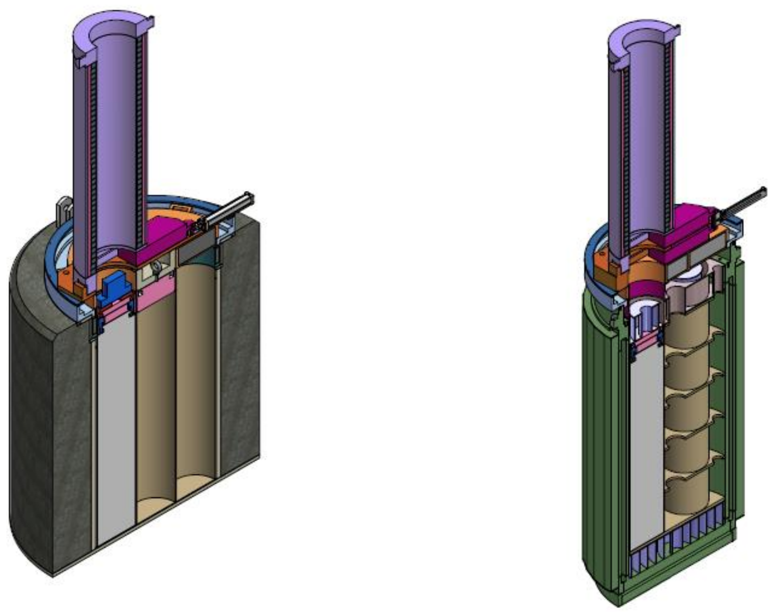


Figure 4-9. A Special Transfer Cask Being Used to Move One Small STAD from Storage to Transport

5 PARAMETRIC STUDIES

This section presents the parametric studies that were performed to investigate the impacts of STAD canister size as they relate to typical NPP operating cycles in the U.S. In addition, the study evaluates the impacts of certain specific improvements related to canister loading technology and operational process flow enhancements.

The objective of the parametric studies was, for each of the evaluated STAD configurations, to assess the maximum intervals between STAD loading campaign that can be utilized while still achieving the fuel throughput requirements necessary for plant operation. The throughput requirements are based on either 900 BWR or 370 PWR fuel assemblies being transferred to dry storage per plant unit, every six years. The calculated maximum loading campaign intervals are based on optimum process rates using improved technology and concurrent workflow

paths wherever possible. Recommendations for loading campaign intervals are presented in
paths wherever possible. Recommendations for loading campaign intervals are presented in
Section 6; and they consider the relative costs and benefits of the improved technology and parallel workflow paths options.

Table 5-1 provides a roadmap to the results of the parametric time studies.

Table 5-1. Roadmap to Results of Parametric Time Studies

Results	Refer to
Maximum STAD Loading Campaign Intervals	Section 5.2.1
Summary of Throughput Study Processing Rates	Section 5.2.2
Detailed Summary for Large BWR STADs	Section 5.2.3
Detailed Summary for Large PWR STADs	Section 5.2.4
Detailed Summary for Medium BWR STADs	Section 5.2.5
Detailed Summary for Medium PWR STADs	Section 5.2.6
Detailed Summary for Small BWR STADs-in-Can	Section 5.2.7
Detailed Summary for Small PWR STADs-in-Can	Section 5.2.8
Detailed Summary for Small BWR STADs-in-Carrier	Section 5.2.9
Detailed Summary for Small PWR STADs-in-Carrier	Section 5.2.10

5.1 METHODOLOGY, ASSUMPTIONS, AND CONSTRAINTS

The STAD system configuration options considered for these parametric studies include eight cases, covering six different STAD designs (3 PWR and 3 BWR). The large- and medium-sized STADs are sufficiently large that loading operations are anticipated to be similar to the operations currently used for commercial dry fuel storage systems. The small-sized STADs are assumed to be batched four at a time through the loading process to avoid unnecessarily long loading times, costs, and the associated personnel exposure. Two cases are investigated for each of the small STAD systems: four STADs sealed in a single larger canister ("STAD-in-Can"), and four STADs placed into an unsealed carrier ("STAD-in-Carrier"). The eight cases are therefore:

1. Large BWR STAD (44 fuel assemblies)
2. Large PWR STAD (21 fuel assemblies)
3. Medium BWR STAD (32 fuel assemblies)

4. Medium PWR STAD (12 fuel assemblies)
5. Small BWR STAD-in-Can (9 fuel assemblies x 4)
6. Small PWR STAD-in-Can (4 fuel assemblies x 4)
7. Small BWR STAD-in-Carrier (9 fuel assemblies x 4)
8. Small PWR STAD-in-Carrier (4 fuel assemblies x 4)

Lastly, two cases are included for reference purposes: a BWR DPC and PWR DPC case. The DPC baseline cases are assumed to be per the current commercial dry fuel loading best practices. Considering the nine plant operational cycles, there are a total of 36[6] combinations of STAD canister operational approaches and plant operational cases to be evaluated. The optimized case includes improvements in vacuum drying technology as discussed above, using two onsite transfer casks in order to run certain operational steps in parallel, and (in the case of the small STAD systems), carrying out canister draining, drying and sealing operations in parallel. The final results of the parametric studies, therefore, include 144[7] calculated maximum loading campaign intervals for each combination of plant operational cycle, STAD configuration, and STAD loading optimization.

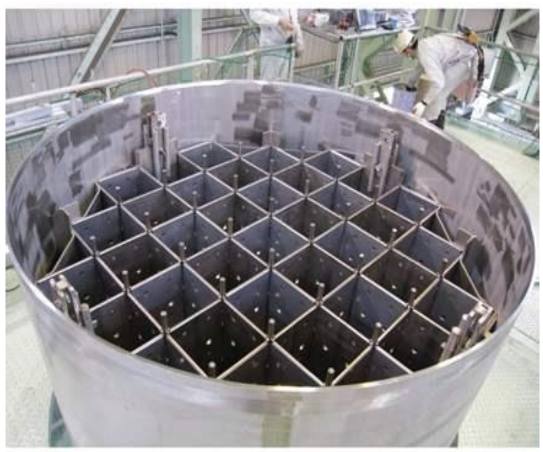


Figure 5-1. MAGNASTOR Canister Prior to Loading

The baseline throughput studies used input from the Zion dry fuel storage campaign. The two-reactor Zion Nuclear Power Station operated from 1974 to 1998 and decommissioning was performed by the Energy*Solutions* subsidiary, Zion*Solutions,* starting in 2010. The Zion dry fuel storage campaign was completed in January 2015, and was the largest loading campaign in the United States to date: 61 MAGNASTOR canisters were placed on a storage pad in less than

[6] 36 = 4 BWR plant operational cases × 4 BWR STAD systems + 5 PWR plant operational cases × 4 PWR STAD systems

[7] 144 = 36 STAD combinations (Baseline Case) + 36 STAD combinations (including technology savings only) + 36 STAD combinations (including parallel process savings only) + 36 STAD combinations (including technology and parallel savings)

52 weeks. Figure 5-1 shows a Zion MAGNASTOR canister prior to loading. The Zion MAGNASTOR canister has a capacity of 37 PWR fuel assemblies. The loading process at Zion represents the current state-of-the-art for dry storage across the country.

The size of the Zion loading campaign makes the loading operational experience data valuable for the parametric studies. An extended loading campaign at a decommissioned nuclear power plant represents the best opportunity for well streamlined operating procedures and practices, minimization of delays due to operating plant schedules, and the development of a skilled, dedicated loading staff. Based on data obtained from Zion*Solutions*, typical times for the Zion loading data were captured in a sequence of over 70 operational steps. The operational times are realistic in that they include real-world considerations such as the time required to get personnel and equipment in and out of radiation areas, the time required to fill out necessary quality assurance paperwork, the time required to perform work in a safe and repeatable manner, etc.

The Zion baseline data shows that 130 hours are required to load a MAGNASTOR DPC, or about 3.5 hours per fuel assembly. This time excludes certain preparation tasks which were presumed to occur “off the clock” for the purposes of the timing studies. In order to better understand the distribution of task hours, each operational step was binned into one of five groups consisting of:

- general handling and preparation activities
- fuel movement/verification
- canister draining, drying, backfilling
- welding
- NDE and other testing activities

Figure 5-2 shows the Zion task activities broken into these categories. General handling and preparation activities take 58.3 hours (approximately 45% of the time budget). Canister draining, drying, backfilling, and welding activities consume another 38% of the remaining time. The time required for fuel movement and verification consumes the remaining time about equally, together with a small amount required for NDE and other testing activities.

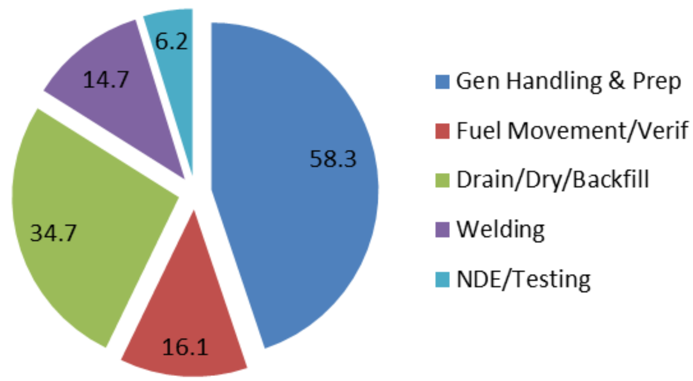


Figure 5-2. Zion Loading Times (hours) by Category

Durations for some of the operational steps used in Zion were used directly in the parametric studies, when applicable. Examples of these include fuel assembly movement and verification times, times to install equipment such as lids, lifting fixtures, etc., and durations for moving equipment within the fuel handling building or out to the storage pad. In these cases, the size of the canister does not have a significant impact on the time required to complete operations. Many other steps are dependent on the size of the canister, or on its closure configuration. In those cases, Zion operational durations were scaled as appropriate for the nature of the operational step.

- Zion fuel assembly movement and verification times were scaled by the number of fuel assemblies in the STAD as compared to the MAGNASTOR canister.

- The first step in evacuating a canister is to pump a small amount of water out of the cavity so that the first canister weld may be placed. Zion pump-down data was scaled by the cross sectional area ratio of the particular STAD design and the MAGNASTOR canister. This assumes that the operational pumping capacity is similar between the STAD system and the MAGNASTOR system, and that the wetted cross sectional area scales proportionally with the radius squared. For the parallel operating scenario, scaled pump down times are divided by the number of STADs and an allowance is made for the extra set up time required to stage the four canisters for simultaneous pump-down.

- Welding times are scaled by the circumference of the weld. Zion operational experience indicates that the amount of time necessary to lay the intermediate and final weld layers are approximately the same, even though the amount of weld metal deposited is somewhat different. This approximation appears to be a good one for the large and medium STAD systems, where the weld sizes are similar to the MAGNASTOR system. The small STAD welds, however, will be much smaller because the smaller lid diameter will result in much lower loads on the canister lid welds. Scaling by the circumference of the weld in these cases may slightly overestimate the actual torch time required to weld small STAD lids. This conservatism will have negligible impact on the results of the parametric studies because of the relatively small portion of time necessary to weld the small STADs. For the parallel operating scenario, welding times are divided by the number of STADs (assuming that each STAD has a dedicated welding machine and operator) and an allowance is made for the extra set up time required to stage the four canisters for simultaneous welding.

- NDE times are scaled by the circumference of the weld.
- After welding the first canister lid, most of the remaining water in the canister is evacuated by pressurizing the canister cavity. The time required for this blowdown process is scaled by the ratio of the STAD canister volume to that of MAGNASTOR. Similar to canister pump-down, this assumes that the ratio of the cross sectional area of the fuel within the canister to the cross sectional area of the canister (without fuel) is approximately the same. For the parallel operating scenario, scaled blowdown times are divided by the number of STADs and an allowance is made for the extra set up time required to stage the four canisters for simultaneous blowdown.
- The time required to dry the canister represents the largest of any of the operational canister loading steps. The required time is a complex function of the amount of free water remaining within the canister after blowdown, the free volume of the canister, the thermal output of the used fuel, the materials of construction of the canister basket, the particular design geometry of the basket, and other factors. Factors affecting vacuum drying times are further discussed in Section 3.3. For the purpose of the parametric studies, vacuum drying times were scaled linearly by the internal volume of the canister shell, realizing that other factors important to vacuum drying times also scale roughly with shell cavity volume, such as: the number of fuel assemblies and their wetted surface area, the wetted area of other canister internals, and the wetted area of the bottom of the canister. It should be noted that some of the MAGNASTOR canisters loaded at Zion had metal matrix neutron absorbing panels, which have been noted to have significantly shorter vacuum drying times than the more porous design alternatives such as Boral™. The Zion vacuum drying times used as the baseline data for this study are for the DPCs that had metal matrix neutron absorbers, which is acceptable because the STAD canisters will contain borated stainless steel; a neutron absorber that will have a similar drying time. It is a recommendation of this study that STAD canisters incorporate materials and design features that minimize the amount of residual water after canister blowdown, thus no further factors are applied to Zion drying times to

account for differences in neutron absorber materials or basket geometry. One reduction factor is applied to the Zion vacuum drying times as a candidate technology improvement. This is based on operational observations at other plants, and achieves a reduction factor of approximately 17% by using "smart vacuum drying system" technology, as discussed in Section 3.3. For the parallel operating scenario, scaled vacuum drying times are divided by the number of STADs and an allowance is made for the extra set up time required to stage the four canisters for simultaneous vacuum drying.

- Vacuum drying is complete when the negative pressure stabilizes to an acceptable level. If the negative pressure is maintained and does not decay, that indicates no additional moisture is available to vaporize. At that point canisters are backfilled with helium, or a similar inert gas. Zion helium backfill times are scaled by the STAD canister volumes.

- The parametric studies point out that, as we take credit for enhancements in parallel processing and technology improvements, the remainder of the operations necessary to load a canister make up the largest portion of the loading time budget. The study, therefore, takes credit for the use of a second transfer cask so that the effective durations for activities like fuel movement and verification, and moving loaded storage casks to the ISFSI pad can be reduced by a factor of two when a duplicate cask allows actions to proceed in parallel rather than in series.

A credit of 50% savings on certain operational steps was taken for assuming two transfer casks. These steps are isolated in Table 5-2, as taken from the large BWR STAD timing study in Appendix H, Table H-1 (similar steps are credited for all of the STAD cases). With reference to Table 5-2, the column headed "Time saved per STAD by Parallel Ops (hrs.)" reflects a savings of 19 hours. In order to validate the assumptions, a critical-path study was performed to assure that the credited steps were truly independent. Using scheduling software, the timing study steps and durations were applied over a series of three consecutive loads, i.e., one transfer cask scenario and parallel loads (using two transfer casks). For completeness, confirmatory schedules were made for PWR and BWR fuels for all sizes of STADs. The results validate the 50% credit assumption taken for selected operational steps. As an example, the results from the scheduling software for the Large BWR STAD canister are provided in Appendix M, and it can be seen that the average savings per load is 18.84 hours, which is in close agreement with the time savings identified in Table 5-2.

Table 5-3 summarizes the key process times by STAD system type. These values represent the key scaling assumptions used to map baseline Zion data to the other STAD systems. Although these factors drive many of the process times in the study, the per-assembly and per-STAD data appearing below in this report (e.g., Figure 5-3) do not scale directly with the data in Table 5-3 because there may be other "overhead" tasks, like welder setup time, that do not scale with weld circumference. Times shown in Table 5-3 include technology and parallel operations savings for all STAD systems. The DPC cases are reference cases for current best-practices and do not include the time savings enhancements.

Table 5-4 summarizes the key scaling parameters by STAD system type. These are the underlying assumed physical attributes that drive many of the times in Table 5-3. They can help explain relationships between process times. For example, Table 5-3 says that the Can lid weld (Small STAD-in-Can concept) takes about three times the time required for the reference DPC cases. Table 5-4 shows that the diameters are nearly the same, but that the Can weld has three layers vs. the DPC which has one (the Can lid is a structural weld that must bear the entire lifting loads, while the DPC outer seal plate weld is not a load bearing weld).

Table 5-2. Time-Saving Steps for Dual Transfer Cask Assumptions

Step	Operation	Task Category Code	Linear Step Time Baseline (hrs)	Percent on Clock (parallel savings)	Time saved per STAD by Parallel Ops (hrs)
11	Start fuel moves	B	0.5	50%	0.3
12	Fuel moves	B	16.9	50%	8.5
13	Fuel verification	B	2.2	50%	1.1
40	Transfer STAD to SC	A	1.0	50%	0.5
41	Remove rigging	A	1.5	50%	0.8
42	Close transfer adapter	A	0.5	50%	0.3
43	Install yoke	A	0.5	50%	0.3
44	Disengage TC seismic restraint	A	1.0	50%	0.5
45	Move TC to decon pit	A	0.5	50%	0.3
46	Remove rigging from STAD	A	1.0	50%	0.5
47	Remove transfer adapter	A	1.5	50%	0.8
48	Set SC lid	A	2.0	50%	1.0
49	Check SC vents	A	0.5	50%	0.3
50	Perform fire hazards walkdown	A	1.0	50%	0.5
51	Move SC to Transporter	A	0.5	50%	0.3
52	Perform SC dose rates	A	1.0	50%	0.5
53	Move support equipment to ISFSI	A	0.5	50%	0.3
54	Move Transporter to haul road	A	1.3	50%	0.7
55	Replace security barriers	A	0.3	50%	0.2
56	Move Transporter/SC/STAD to ISFSI pad	A	3.0	50%	1.5
57	The security barrier at ISFSI and open gate	A	0.3	50%	0.2
58	Move Transporter into position at ISFSI	A	0.5	50%	0.3
59	Position SC on pad	A	0.5	50%	0.3
60	Install vent screens	A	0.5	50%	0.3
61	Move equipment from ISFSI	A	0.5	50%	0.3
62	Replace security barriers	A	0.3	50%	0.2

Table 5-3. Summary of Key Scaled Process Times by STAD System

	BWR DPC	PWR DPC	Large BWR STAD	Large PWR STAD	Medium BWR STAD	Medium PWR STAD	Small BWR STADs-in-Can	Small PWR STADs-in-Can	Small BWR STAD-in-Carrier	Small PWR STAD-in-Carrier
Fuel movement time, hours	33.4	14.0	16.9	8.1	12.3	4.6	13.8	6.1	13.8	6.1
Fuel verification time, hours	4.4	1.6	2.2	1.1	1.6	0.6	1.8	0.8	1.8	0.8
Water pump downtime, hours	45	45	44	44	23	23	7	7	7	7
Water blowdown time, minutes	60	60	60	60	30	30	12	12	12	12
Vacuum drying time, hours	27	30	28	28	14	14	4	4	4	4
Helium backfill time, hours	2.0	2.0	2.1	2.1	1.1	1.1	0.3	0.3	0.3	0.3
Total welding* time for inner lid, hrs	4.5	4.5	4.4	4.4	3.2	3.2	1.2	1.2	1.2	1.2
Total NDE time for inner lid*, hours	3.0	3.0	2.9	2.9	2.1	2.1	0.8	0.8	0.8	0.8
Total welding* time for outer lid**, hrs	1.5	1.5	1.5	1.5	1.1	1.1	4.6	4.6	1.2	1.2
Total NDE time for outer lid**, hours	1.0	1.0	1.0	1.0	0.7	0.7	3.0	3.0	0.8	0.8

Notes: * Values represent arc-time only. Welding times elsewhere in the report include fit-up, welder installation, and similar related activities.
**Outer DPC or STAD lid, or the Can lid for STAD-in-Can concepts.

Table 5-4. Summary of Key Scaling Parameters by STAD System

	BWR DPC	PWR DPC	Large BWR STAD	Large PWR STAD	Medium BWR STAD	Medium PWR STAD	Small BWR STADs-in-Can	Small PWR STADs-in-Can	Small BWR STAD-in-Carrier	Small PWR STAD-in-Carrier
STAD cavity ID, inches	72.0	72.0	70.7	70.7	51.0	51.0	28.2	28.2	28.2	28.2
STAD cavity length, inches	173.0	173.0	183.0	183.0	183.0	183.0	183.0	183.0	183.0	183.0
STAD cavity area, square feet	28.3	28.3	27.3	27.3	14.2	14.2	4.3	4.3	4.3	4.3
STAD cavity volume, cubic feet	407.6	408.0	416.2	416.2	216.3	216.3	66.3	66.3	66.3	66.3
STAD cavity circumference, inches	226.2	226.0	222.2	222.2	160.2	160.2	88.7	88.7	88.7	88.7
Can ID, inches							72.6	72.6		
Can circumference, inches							228.1	228.1		
Weld layers for inner STAD lid	3	3	3	3	3	3	2	2	2	2
Weld layers for outer STAD lid	1	1	1	1	1	1			2	2
Weld layers for Can lid							3	3		

5.2 RESULTS OF PARAMETRIC TIME STUDIES

5.2.1 Maximum STAD Loading Campaign Intervals

Table 5-5 shows the results of the timing studies in units of DPCs, large/medium STADs, or small STAD can/carriers per hour. The equivalent data is shown in Table 5-6 in units of hours per fuel assembly for each system option. All STAD data are presented both with ("optimized") and without ("baseline") credit for technology and parallel operations time-saving measures.

Table 5-5. Summary of Loading Process Rates (Hours/STAD)

System	Hours per DPC, Large/Medium STAD, or Can/Carrier			
	Baseline		Optimized	
	BWR	PWR	BWR	PWR
DPC (ref)	145	130		
Large STAD	127	117	102	97
Medium STAD	103	95	84	79
Small STAD-in-Can	148	139	96	91
Small STAD-in-Carrier	136	128	82	78

Table 5-6. Summary of Loading Process Rates (Hours/Assembly)

System	Hours Per Assembly			
	Baseline		Optimized	
	BWR	PWR	BWR	PWR
DPC (ref)	1.66	3.51		
Large STAD	2.88	5.57	2.32	4.63
Medium STAD	3.23	7.88	2.61	6.60
Small STAD-in-Can	4.11	8.70	2.66	5.72
Small STAD-in-Carrier	3.79	7.98	2.29	4.87

Assuming a 24/7 operational schedule, the number of STADs and corresponding number of assemblies that can be processed in the model 12-week loading campaign are shown in Table 5-7 and Table 5-8.

Table 5-7. Summary of Throughput (STADs)

System	DPC, Large/Medium STAD, or Can/Carrier Per 12-Week Campaign			
	Baseline		Optimized	
	BWR	PWR	BWR	PWR
DPC (ref)	13	15		
Large STAD	15	17	19	20
Medium STAD	19	21	24	25
Small STAD-in-Can	13	14	21	22
Small STAD-in-Carrier	14	15	24	25

Table 5-8. Summary of Throughput (Assemblies)

System	Assemblies Per 12-Week Campaign			
	Baseline		Optimized	
	BWR	PWR	BWR	PWR
DPC (ref)	1131	555		
Large STAD	660	357	836	420
Medium STAD	608	252	768	300
Small STAD-in-Can	468	224	756	352
Small STAD-in-Carrier	504	240	864	400

The parametric time studies shows that each of the eight STAD system configurations evaluated has the potential to meet the throughput requirements for each of the nine operating cycle cases investigated (see Table 5-9), assuming the fully optimized parallel processing and vacuum drying improvements are used.

Table 5-9. Summary of the Plant Operational Cases Investigated

Case	Reactor Type	Number of Reactors On Site	Operating Cycle Length (months)	Per Reactor Number of Assemblies to be loaded to Dry Storage every Six Years	Total Number of Assemblies to be Loaded to Dry Storage every Six Years
1	BWR	1	18	900	900
2	BWR	1	24	900	900
3	BWR	2	24	900	1800
4	BWR	3	24	900	2700
5	PWR	1	18	370	370
6	PWR	1	24	370	370
7	PWR	2	18	370	740
8	PWR	2	24	370	740
9	PWR	3	18	370	1110

Note: A maximum of 12 continuous weeks is assumed to mobilize, perform a cask loading campaign, and demobilize. Mobilization and demobilization that occurs outside of the power plant (even if elsewhere on site) is not considered in the 12-week window. A maximum frequency of one campaign per calendar year is assumed.

Table 5-10 through Table 5-13 show how each STAD system performs when loaded on a 12, 18, 24, or 36-month fuel loading campaign cycle, respectively. Each table shows the details of the plant operational scenario, the total number of assemblies required to be loaded per campaign cycle, the DPC or STAD capacity, the number of DPCs or STADs that must be loaded in a campaign to meet plant needs, and finally a calculation of the margin between plant throughput needs and the DPC or peak STAD loading rate determined by the timing studies (described in more detail below).

The studies conclude that, with 12- or 18-month loading campaigns, the required throughputs could be achieved for each operating cycle case and each STAD canister system option, using the time-saving optimizations discussed below in Sections 5.2.3 through Section 5.2.10. However, as discussed below, as the frequency of loading campaigns is decreased to every two years and then every three years, then certain STAD canister system options are unable to meet the required throughputs for specific operating cycle cases. Longer intervals between loading campaigns are possible for some combinations of STAD canister systems and operating cycle cases and these are discussed in the detailed results for the STAD canister systems (Section 5.2.3 through Section 5.2.10), and in the Recommendations (Section 6).

- Table 5-10 shows that all STAD system options can achieve the required throughput for each of the nine operating cycle cases when 12-month intervals between loading campaigns are used. All STAD cases show very good margins, the lowest being 56% for the medium PWR STAD system at a three-unit plant. For reference, the two DPC cases all show a margin of 200% or greater.

- Table 5-11 shows that all STAD system options can achieve the required throughput for each of the nine operating cycle cases when 18-month intervals between loading campaigns are used. All STAD cases show satisfactory margins, the lowest being 4% for the medium PWR STAD system at a three-unit plant. For reference, the two DPC cases all show a margin of 88% or greater.

- Table 5-12 shows that in the 24-month interval fuel loading campaign cycle, several combinations do not meet plant operational requirements and others have an estimated margin of less than 10% (all highlighted in red). All of the cases that do not meet plant operational throughput requirements are for the three-unit plant scenarios. The DPC reference cases for the three-unit plants still have margins of 50% or better.

- Table 5-13 shows that, for a 36-month fuel storage campaign interval, many of the STAD systems are unable to meet throughput requirements for the two- and three-unit plant scenarios. The medium STAD systems are the poorest performers, having acceptable margins for only the single unit plants, but as much as a 47% shortfall for the multiple-unit plant scenarios. By comparison, the DPC reference cases still show 200% margin for the single-unit plants, but as low as break-even for Scenario 9, the three-unit PWR plant.

Table 5-10. STAD Loading Performance: 12-Month Campaign Cycle

Operational Case Number	Fuel Type	Number of Reactors On Site	Operating cycle length (months)	Required throughput, all units (Assy/6yrs)	Req'd Assys per 12-mo campaign	Excess Time Capacity Margin for 12 Month Loading Campaign Cycle																			
						DPC (Reference)				Large STAD				Medium STAD				Small STAD-in-Can				Small STAD-in-Carrier			
						Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 12-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 12-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 12-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 12-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 12-mo campaign	Margin
1		1	18	900	150			2	800%			4	375%			5	380%			17	394%			17	465%
2	BWR	1	24	900	150	87	18	2	800%	44	19	4	375%	32	24	5	380%	9	84	17	394%	9	96	17	465%
3		2	24	1800	300			4	350%			7	171%			10	140%			34	147%			34	182%
4		3	24	2700	450			6	200%			11	73%			15	60%			50	68%			50	92%
5		1	18	370	62			2	650%			3	567%			6	317%			16	444%			16	563%
6		1	24	370	62			2	650%			3	567%			6	317%			16	444%			16	563%
7	PWR	2	18	740	124	37	15	4	275%	21	20	6	233%	12	25	11	127%	4	87	31	181%	4	106	31	242%
8		2	24	740	124			4	275%			6	233%			11	127%			31	181%			31	242%
9		3	18	1110	185			5	200%			9	122%			16	56%			47	85%			47	126%

Table 5-11. STAD Loading Performance: 18-Month Campaign Cycle

Operational Case Number	Fuel Type	Number of Reactors On Site	Operating cycle length (months)	Required throughput, all units (Assy/6yrs)	Req'd Assys per 12-mo campaign	Excess Time Capacity Margin for 18 Month Loading Campaign Cycle																			
						DPC (Reference)				Large STAD				Medium STAD				Small STAD-in-Can				Small STAD-in-Carrier			
						Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 18-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 18-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 18-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 18-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 18-mo campaign	Margin
1		1	18	900	225			3	500%			6	217%			8	200%			25	236%			25	284%
2	BWR	1	24	900	225	87	18	3	500%	44	19	6	217%	32	24	8	200%	9	84	25	236%	9	96	25	284%
3		2	24	1800	450			6	200%			11	73%			15	60%			50	68%			50	92%
4		3	24	2700	675			8	125%			16	19%			22	9%			75	12%			75	28%
5		1	18	370	93			3	400%			5	300%			8	213%			24	263%			24	342%
6		1	24	370	93			3	400%			5	300%			8	213%			24	263%			24	342%
7	PWR	2	18	740	185	37	15	5	200%	21	20	9	122%	12	25	16	56%	4	87	47	85%	4	106	47	126%
8		2	24	740	185			5	200%			9	122%			16	56%			47	85%			47	126%
9		3	18	1110	278			8	88%			14	43%			24	4%			70	24%			70	51%

Table 5-12. STAD Loading Performance: 24-Month Campaign Cycle

Operational Case Number	Fuel Type	Number of Reactors On Site	Operating cycle length (months)	Required throughput, all units (Assy/6yrs)	Req'd Assys per 24-mo campaign	Excess Time Capacity Margin for 24 Month Loading Campaign Cycle																			
						DPC (Reference)				Large STAD				Medium STAD				Small STAD-in-Can				Small STAD-in-Carrier			
						Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 24-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 24-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 24-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 24-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 24-mo campaign	Margin
1		1	18	900	300			4	350%			7	171%			10	140%			34	147%			34	182%
2	BWR	1	24	900	300	87	18	4	350%	44	19	7	171%	32	24	10	140%	9	84	34	147%	9	96	34	182%
3		2	24	1800	600			7	157%			14	36%			19	26%			67	25%			67	43%
4		3	24	2700	900			11	64%			21	-10%			29	-17%			100	-16%			100	-4%
5		1	18	370	124			4	275%			6	233%			11	127%			31	181%			31	242%
6		1	24	370	124			4	275%			6	233%			11	127%			31	181%			31	242%
7	PWR	2	18	740	247	37	15	7	114%	21	20	12	67%	12	25	21	19%	4	87	62	40%	4	106	62	71%
8		2	24	740	247			7	114%			12	67%			21	19%			62	40%			62	71%
9		3	18	1110	370			10	50%			18	11%			31	-19%			93	-6%			93	14%

Table 5-13. STAD Loading Performance: 36-Month Campaign Cycle

						Excess Time Capacity Margin for 36 Month Loading Campaign Cycle																			
						DPC (Reference)				Large STAD				Medium STAD				Small STAD-in-Can				Small STAD-in-Carrier			
Operational Case Number	Fuel Type	Number of Reactors On Site	Operating cycle length (months)	Required throughput, all units (Assy/6yrs)	Req'd Assys per 36-mo campaign	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 36-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 36-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 36-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 36-mo campaign	Margin	Assy/STAD	Peak Throughput (STADs/campaign)	Req'd STADs per 36-mo campaign	Margin
1	BWR	1	18	900	450	87	18	6	200%	44	19	11	73%	32	24	15	60%	9	84	50	68%	9	96	50	92%
2		1	24	900	450			6	200%			11	73%			15	60%			50	68%			50	92%
3		2	24	1800	900			11	64%			21	-10%			29	-17%			100	-16%			100	-4%
4		3	24	2700	1350			16	13%			31	-39%			43	-44%			150	-44%			150	-36%
5	PWR	1	18	370	185	37	15	5	200%	21	20	9	122%	12	25	16	56%	4	87	47	85%	4	106	47	126%
6		1	24	370	185			5	200%			9	122%			16	56%			47	85%			47	126%
7		2	18	740	370			10	50%			18	11%			31	-19%			93	-6%			93	14%
8		2	24	740	370			10	50%			18	11%			31	-19%			93	-6%			93	14%
9		3	18	1110	555			15	0%			27	-26%			47	-47%			139	-37%			139	-24%

Section 5.2.2 summarizes the results from the individual timing studies that are detailed in Sections 5.2.3 through 5.2.10, breaking down the data by the types of loading activities on a per-assembly basis and a per-STAD basis. The benefits of the proposed technology and parallel process time savings are quantified. The detailed timing studies draw on the data presented in Appendix F (*Key Characteristics of Dry Cask Storage Systems at Operational Nuclear Power Stations*) and Appendix H (*Detailed Time Calculations*). A key point to note is that, although fully optimized STAD canister dry storage loading processes and drying/welding equipment can be in place, the benefits of the optimized loading process and equipment will be diminished if attention is not paid to optimizing and choreographing the general handling and preparation activities, which account for around 50% of the total duration.

5.2.2 Summary of Throughput Study Processing Rates

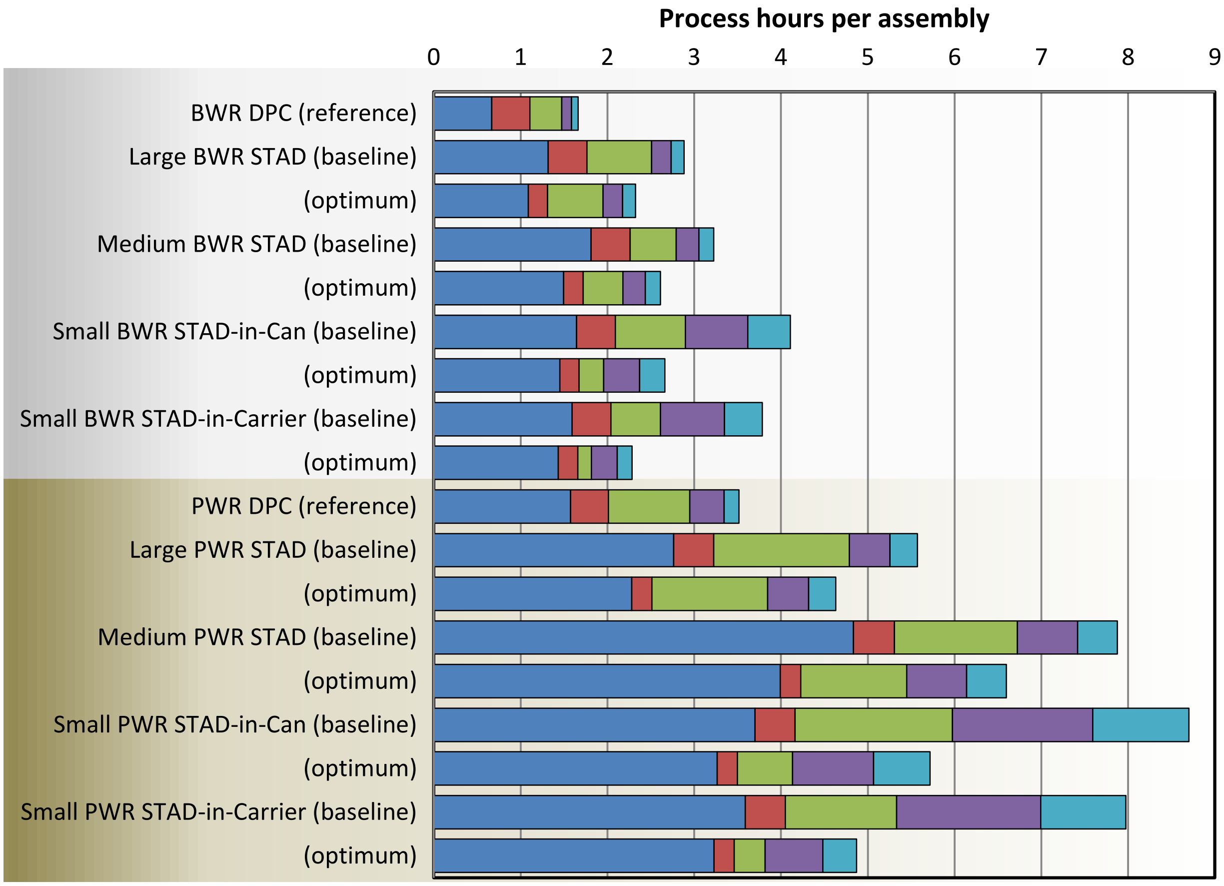
Figure 5-3 provides a top level summary of the estimated STAD processing rates (by fuel assembly) for each of the STAD system options investigated. Throughput rates are compared on a time per fuel assembly basis. Because the small STAD options are based on batching for STADs per can or carrier, comparisons must be made based on time per fuel assembly for consistency.

The bar graphs in Figure 5-3 compare the process hours per assembly two ways for each of the STAD system options. The BWR and PWR DPC cases are also shown for reference. Each bar is subdivided to show total time broken out into the six task categories. Two bars are shown for each STAD system option. The first bar represents a baseline time that corresponds to a series workflow process using typical modern dry fuel storage best practices (i.e., scaled directly from the Zion workflow data). The second bar shows the optimum durations including using "smart" vacuum drying technology, parallel transfer casks, and (in the case of the small STAD systems) using parallel processing during welding, testing, and draining/drying operations. Note that the data presented in Figure 5-3 assume that four STADs are processed in parallel per each can or carrier; therefore, some tasks such as fuel verification appear shorter on the per-assembly basis due to parallel operations.

Directly below the bar graphs in Figure 5-3 is a table containing the raw data for each bar, plus the color coding key for the task categories.

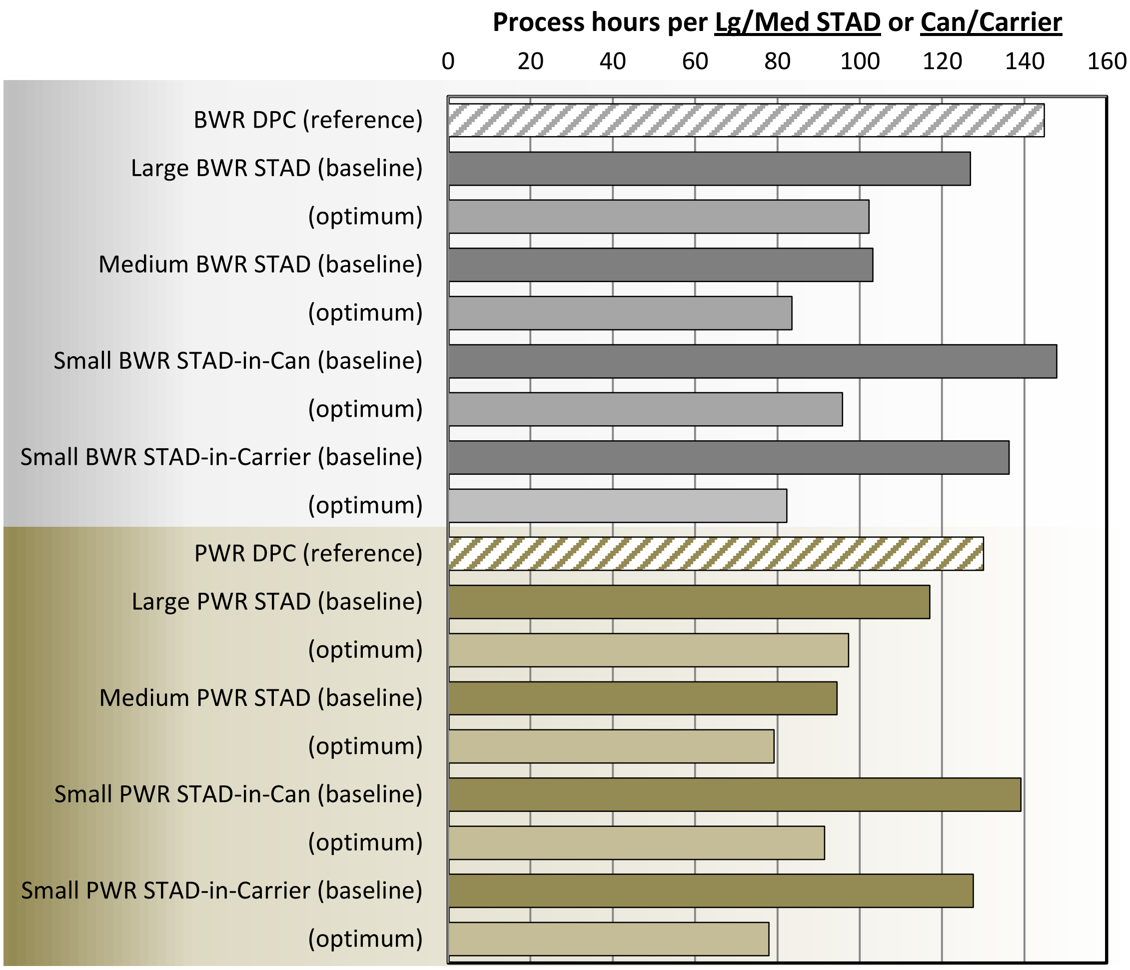
Because of the relative physical sizes of BWR and PWR fuel assemblies, the STAD capacities differ and, therefore, the throughput metrics for BWR fuel appear superior when compared on a per fuel assembly basis. The processing time for BWR fuel ranges from 2.3 to 4.1 hours per assembly. Likewise, PWR fuel ranges from 4.6 to 8.7 hours per assembly.

Figure 5-4 provides a top level summary of the estimated throughput rates by large STAD canister, medium STAD canister or can/carrier containing 4 small STAD canisters. The DPC cases are also shown for reference (crosshatched bars).



System	Hours per assembly: Gen Handling & Preparation	Fuel Movement/ Verification	Drain/Dry/ Backfill	Welding	NDE/ Testing	Total	Improvm't
BWR DPC (reference)	0.67	0.44	0.37	0.11	0.08	1.66	
Large BWR STAD (baseline)	1.32	0.45	0.75	0.23	0.15	2.88	
(optimum)	1.09	0.22	0.64	0.23	0.15	2.32	19%
Medium BWR STAD (baseline)	1.81	0.45	0.53	0.26	0.17	3.23	
(optimum)	1.50	0.23	0.46	0.26	0.17	2.61	19%
Small BWR STAD-in-Can (baseline)	1.64	0.45	0.81	0.72	0.49	4.11	
(optimum)	1.45	0.22	0.28	0.41	0.29	2.66	35%
Small BWR STAD-in-Carrier (baseline)	1.59	0.45	0.57	0.74	0.44	3.79	
(optimum)	1.43	0.22	0.16	0.30	0.17	2.29	40%
PWR DPC (reference)	1.58	0.44	0.94	0.40	0.17	3.51	
Large PWR STAD (baseline)	2.76	0.46	1.56	0.47	0.31	5.57	
(optimum)	2.28	0.23	1.34	0.47	0.31	4.63	17%
Medium PWR STAD (baseline)	4.83	0.48	1.42	0.69	0.46	7.88	
(optimum)	3.99	0.24	1.22	0.69	0.46	6.60	16%
Small PWR STAD-in-Can (baseline)	3.70	0.46	1.81	1.62	1.11	8.70	
(optimum)	3.27	0.23	0.64	0.93	0.65	5.72	34%
Small PWR STAD-in-Carrier (baseline)	3.59	0.46	1.28	1.66	0.98	7.98	
(optimum)	3.23	0.23	0.36	0.67	0.39	4.87	39%

Figure 5-3. Throughput Study Processing Rate Summary (by Fuel Assembly)



STAD System	Hours per Lg/Med STAD or Can/Carrier		
	Baseline	Optimum	Improvm't
BWR DPC (reference)	145		
Large BWR STAD	127	102	19%
Medium BWR STAD	103	84	19%
Small BWR STAD-in-Can	148	96	35%
Small BWR STAD-in-Carrier	136	82	40%
PWR DPC (reference)	130		
Large PWR STAD	117	97	17%
Medium PWR STAD	95	79	16%
Small PWR STAD-in-Can	139	91	34%
Small PWR STAD-in-Carrier	128	78	39%

Figure 5-4. Throughput Study Processing Rate Summary (by Large/Medium STAD or Can/Carrier Containing Four Small STAD Canisters)

5.2.3 Detailed Summary for Large BWR STADs

The timing study for large BWR STADs was performed using the following key parameters (see Appendices F and H for details of these parameters for this study and for the ones described in Sections 5.2.4 through 5.2.10):

- STAD capacity...44 BWR fuel assemblies
- Loading campaign..12 weeks
- Operating hours per week 168
- Number of transfer casks 2
- Parallel pump-down operations........................not applicable for large STAD canisters
- Parallel welding operations ....not applicable for large STAD canisters
- Parallel NDE operations ....not applicable for large STAD canisters
- Parallel drain/dry/backfill operations...............not applicable for large STAD canisters

The key results of the large BWR STAD timing study are:

- Total estimated baseline time..........................127 hours per STAD
- Total estimated time (optimized).....................102 hours per STAD
  ....2.3 hours per assembly
- Maximum STADs per campaign (optimized)......19

Figure 5-5 provides the time savings analyses for the large (44-BWR) STAD canisters.

Table 5-14 summarizes the calculations of the maximum loading campaign intervals for large BWR STADs. For each of the four timing study cases representing plant operational scenarios and associated fuel assembly throughput requirements, the calculations are performed to determine the minimum number of loading campaigns necessary to meet throughput requirements, and the associated maximum loading campaign intervals. The last two blocks of columns summarize the various throughput requirements and indicate the margin between those throughput requirements and throughput rate possible according to the timing study results.

Note that the calculations in Table 5-14 are necessarily "top-down" calculations that begin with plant requirements and conclude the maximum loading campaign frequency and throughput margin. STAD loads take essentially the same amount of time; and it is therefore important to round up the required number of STADs required per six years. Furthermore, the methods of calculating the required numbers of loading campaigns and campaign intervals have significant impact on the calculated margins. If a "bottom-up" approach is taken, the results do not accurately reflect the throughput requirements for the plant scenarios. For example, the calculations for large BWR STADs in a plant operating cycle scenario 4 are as follows.

$$3\,reactors \times 900\,\frac{assy}{reactor \cdot 6yrs} = 2700\,\frac{assy}{6yrs}$$

$$\frac{2700\,\frac{assy}{6yrs}}{44\,\frac{assy}{STAD}} = 62\,\frac{STADs}{6yrs}$$

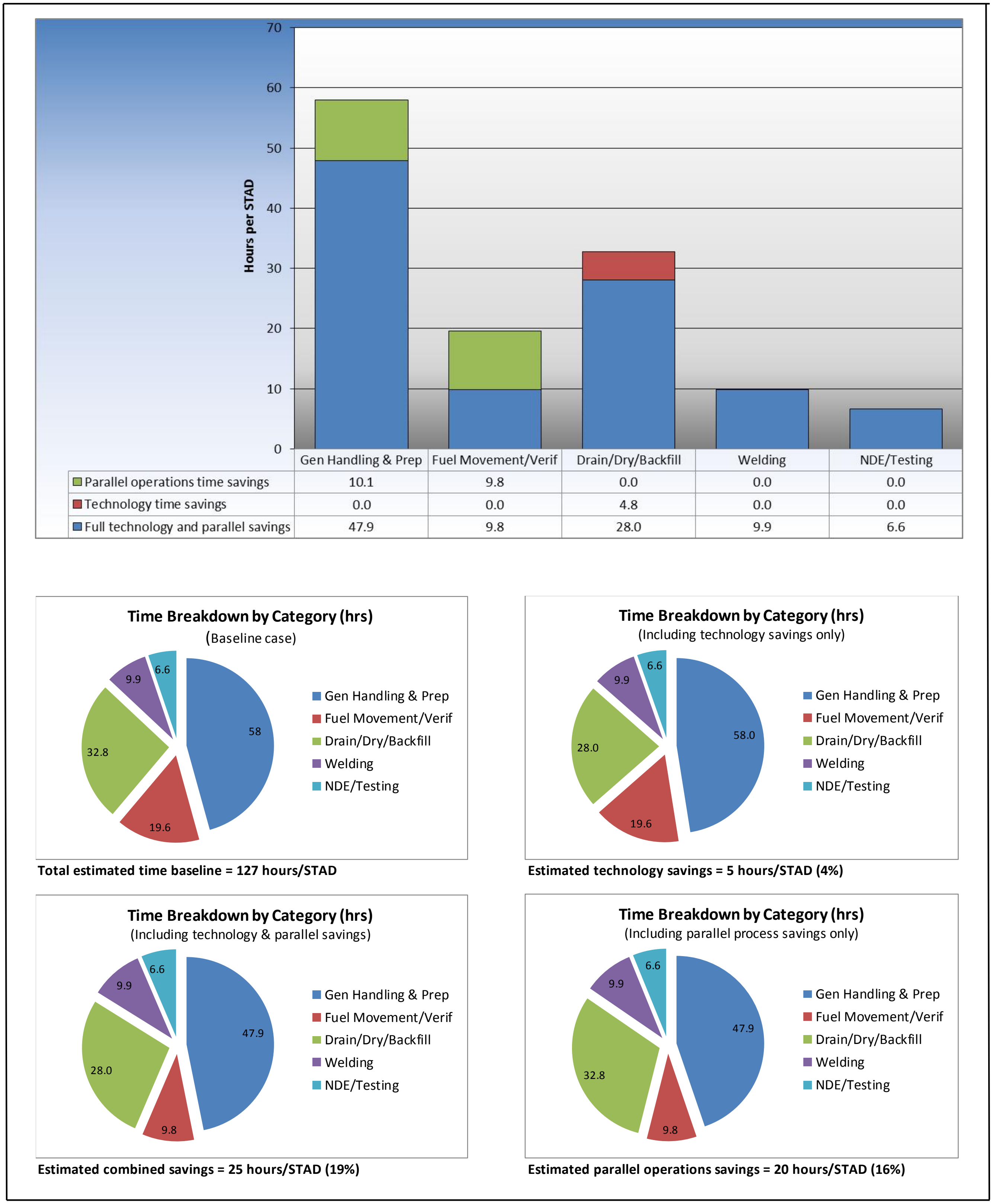
$$\frac{62\,\frac{STADs}{6yrs}}{19\,\frac{STADs}{campaign}} = 4\,\frac{campaigns}{6\,yrs}$$

The loading campaign frequency for the large BWR STADs under operating cycle 4 is therefore four campaigns every 6 years. If 62 STADs are required every six years, the required throughput in any single campaign is 62 STADs/4 campaigns = 16 STADs/campaign. And if four campaigns are required every six years, the campaigns must be performed once every 18 months. The values 2700, 62, 4 and 18 can be seen on the bottom row of Table 5-14. With this target throughput rate established, the margin between the plant throughput needs and the maximum rate at which STADs can be processed can be calculated as follows. For large BWR STADs, the maximum processing rate is estimated by the timing studies to be 19 STADs per 12-week campaign. But only 11 STADs must be processed every 12-week campaign in order to meet the plant throughput needs at one campaign per 12 months. The margin is therefore (19-11)/11 = 73%.

Appendix H, Table H-1 contains a detailed listing of the large BWR STAD timing study.

Table 5-14. Maximum Loading Campaign Intervals for Large BWR STADs

Reactor Operating Cycle Case	Fuel type	Number or Reactors On Site	Operating cycle length (months)	Fuel assembly throughput requirements		Required STADs per 6 years	Minimum number of loading campaigns to process required number of STADs/6 yrs	Corresponding maximum loading campaign interval (months)	Required throughput for processing STADs at maximum loading campaign interval			Margin between required throughput and peak predicted rate (%) (STAD/campaign basis)
				per 6 yrs per reactor	per 6 yrs				STADs / campaign	Hrs / STAD	Hrs / Assy	
1	BWR	1	18	900	900	21	2	36	11	183	4.2	**73%**
2	BWR	1	24	900	900	21	2	36	11	183	4.2	**73%**
3	BWR	2	24	900	1,800	41	3	24	14	144	3.3	**36%**
4	BWR	3	24	900	2,700	62	4	18	16	126	2.9	**19%**



	Gen Handling & Prep	Fuel Movement/Verif	Drain/Dry/Backfill	Welding	NDE/Testing
Parallel operations time savings	10.1	9.8	0.0	0.0	0.0
Technology time savings	0.0	0.0	4.8	0.0	0.0
Full technology and parallel savings	47.9	9.8	28.0	9.9	6.6

Figure 5-5. Time Savings Analysis for Large BWR STADs

5.2.4 Detailed Summary for Large PWR STADs

The timing study for large PWR STADs was performed using the following key parameters:

- STAD capacity..21 PWR fuel assemblies
- Loading campaign...12 weeks
- Operating hours per week...............................168
- Number of transfer casks.................................2
- Parallel pump-down operations.......................not applicable for large STAD canister
- Parallel welding operations.............................not applicable for large STAD canister
- Parallel NDE operations..................................not applicable for large STAD canister
- Parallel drain/dry/backfill operations...............not applicable for large STAD canister

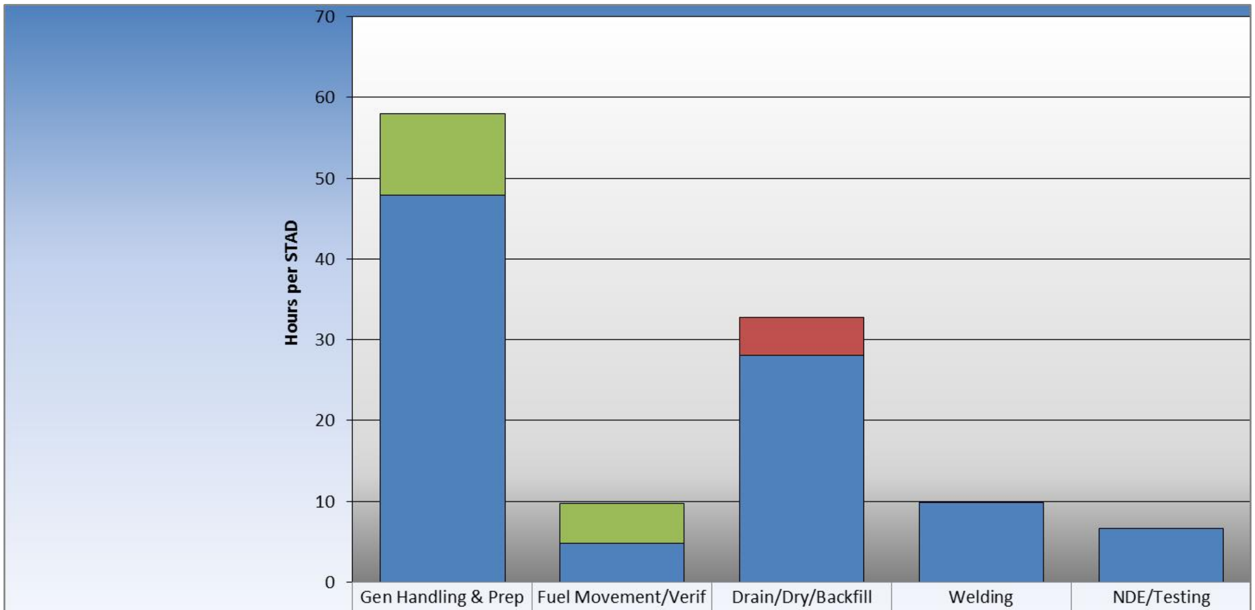
The key results of the large PWR STAD timing study are:

- Total estimated baseline time..........................117 hours per STAD
- Total estimated time (optimized).....................97 hours per STAD
  ....4.6 hours per assembly
- Maximum STADs per campaign (optimized)......20

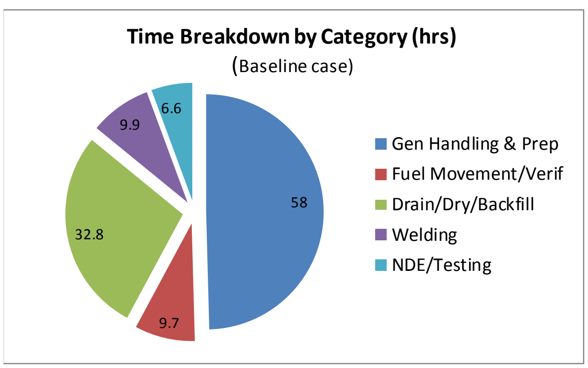
Figure 5-6 provides the time savings analyses for the large (21-PWR) STAD canisters. Table 5-15 summarizes the calculations of the maximum loading campaign intervals for large PWR STADs. For each of the five timing study cases representing plant operational scenarios and associated fuel assembly throughput requirements, the calculations are performed to determine the minimum number of loading campaigns necessary to meet throughput requirements, and the associated maximum loading campaign intervals. The last two blocks of columns summarize the various throughput requirements and indicate the margin between those throughput requirements and throughput rate possible according to the timing study results. Appendix H, Table H-2 contains a detailed listing of the large PWR STAD timing study.

Table 5-15. Maximum Loading Campaign Intervals for Large PWR STADs

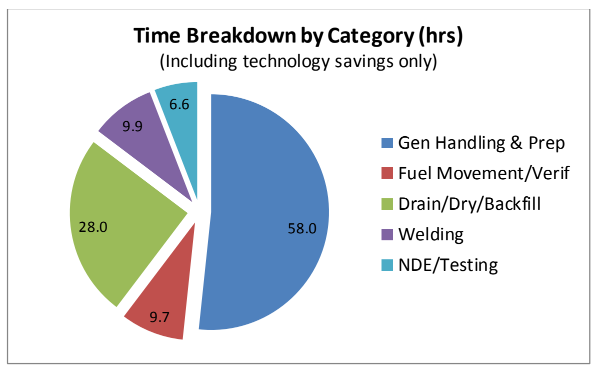
Reactor Operating Cycle Case	Fuel type	Number or Reactors On Site	Operating cycle length (months)	Fuel assembly throughput requirements		Required STADs per 6 years	Minimum number of loading campaigns to process required number of STADs/6 yrs	Corresponding maximum loading campaign interval (months)	Required throughput for processing STADs at maximum loading campaign interval			Margin between required throughput and peak predicted rate (%) (STAD/campaign basis)
				per 6 yrs per reactor	per 6 yrs				STADs / campaign	Hrs / STAD	Hrs / Assy	
5	PWR	1	18	370	370	18	1	72	18	112	5.3	**11%**
6	PWR	1	24	370	370	18	1	72	18	112	5.3	**11%**
7	PWR	2	18	370	740	36	2	36	18	112	5.3	**11%**
8	PWR	2	24	370	740	36	2	36	18	112	5.3	**11%**
9	PWR	3	18	370	1,110	53	3	24	18	112	5.3	**11%**



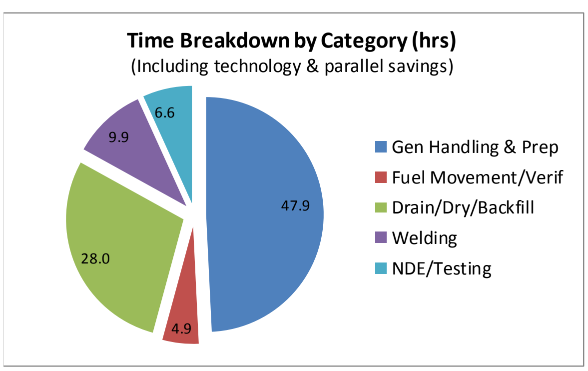
	Gen Handling & Prep	Fuel Movement/Verif	Drain/Dry/Backfill	Welding	NDE/Testing
Parallel operations time savings	10.1	4.9	0.0	0.0	0.0
Technology time savings	0.0	0.0	4.8	0.0	0.0
Full technology and parallel savings	47.9	4.9	28.0	9.9	6.6



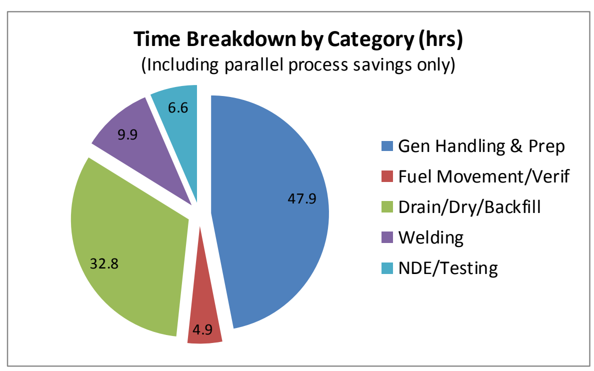
Total estimated time baseline = 117 hours/STAD



Estimated technology savings = 5 hours/STAD (4%)



Estimated combined savings = 20 hours/STAD (17%)



Estimated parallel operations savings = 15 hours/STAD (13%)

Figure 5-6. Time Savings Analysis for Large PWR STADs

5.2.5 Detailed Summary for Medium BWR STADs

The timing study for medium BWR STADs was performed using the following key parameters:

- STAD capacity .... 32 BWR fuel assemblies
- Loading campaign .... 12 weeks
- Operating hours per week 168
- Number of transfer casks 2
- Parallel pump-down operations .... not applicable for medium STAD canister
- Parallel welding operations .... not applicable for medium STAD canister
- Parallel NDE operations .... not applicable for medium STAD canister
- Parallel drain/dry/backfill operations .... not applicable for medium STAD canister

The key results of the medium BWR STAD timing study are:

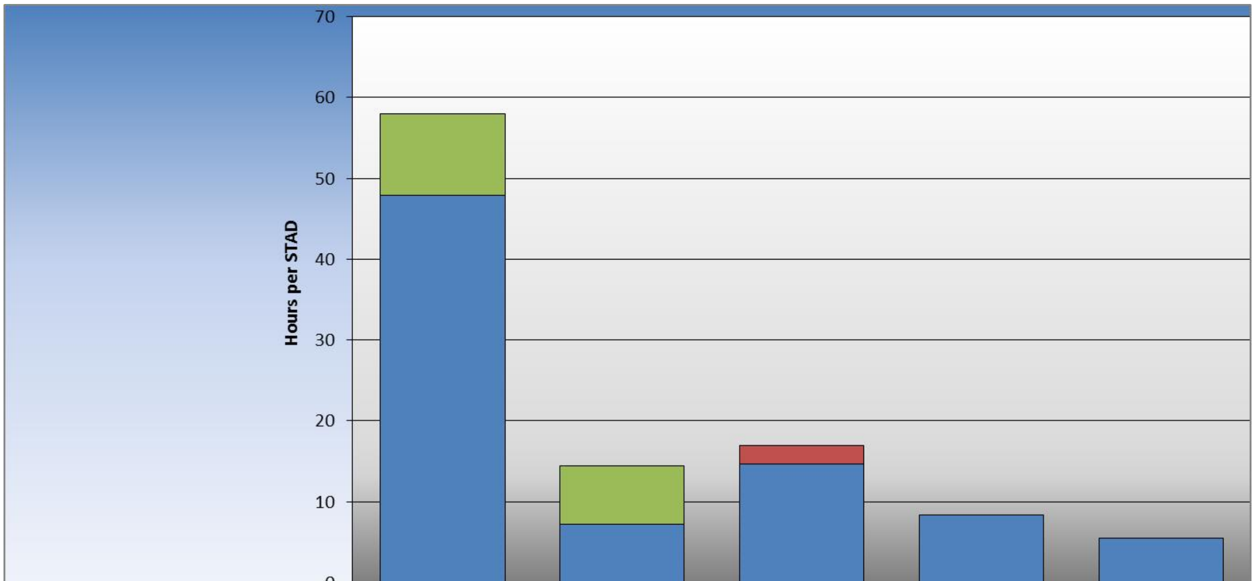
- Total estimated baseline time .... 103 hours per STAD
- Total estimated time (optimized) .... 84 hours per STAD
  .... 2.6 hours per assembly
- Maximum STADs per campaign (optimized) 24

Figure 5-7 provides the time savings analyses for the medium (32-BWR) STAD canisters.

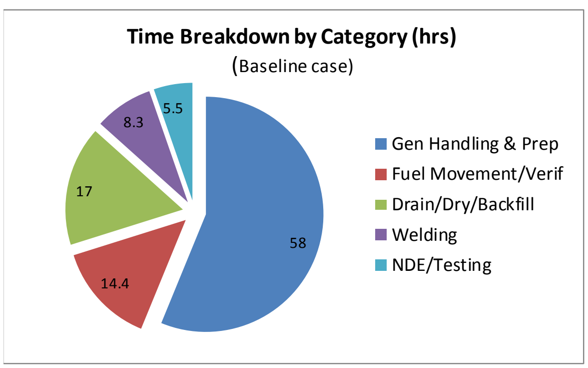
Table 5-16 summarizes the calculations of the maximum loading campaign intervals for medium BWR STADs. For each of the four timing study cases representing plant operational scenarios and associated fuel assembly throughput requirements, the calculations are performed to determine the minimum number of loading campaigns necessary to meet throughput requirements, and the associated maximum loading campaign intervals. The last two blocks of columns summarize the various throughput requirements and margins. Appendix H, Table H-3 contains a detailed listing of the medium BWR STAD timing study.

Table 5-16. Maximum Loading Campaign Intervals for Medium BWR STADs

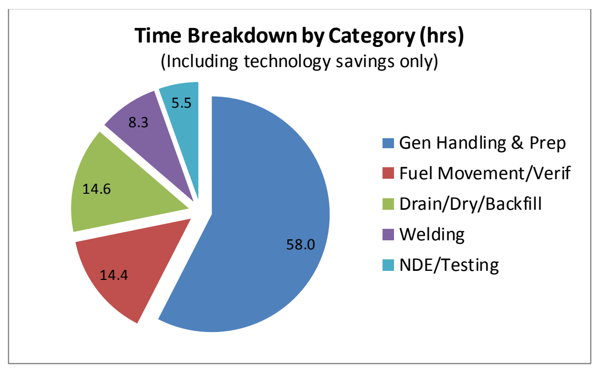
Reactor Operating Cycle Case	Fuel type	Number or Reactors On Site	Operating cycle length (months)	Fuel assembly throughput requirements		Required STADs per 6 years	Minimum number of loading campaigns to process required number of STADs/6 yrs	Corresponding maximum loading campaign interval (months)	Required throughput for processing STADs at maximum loading campaign interval			Margin between required throughput and peak predicted rate (%) (STAD/campaign basis)
				per 6 yrs per reactor	per 6 yrs				STADs / campaign	Hrs / STAD	Hrs / Assy	
1	BWR	1	18	900	900	29	2	36	15	134	4.2	**60%**
2	BWR	1	24	900	900	29	2	36	15	134	4.2	**60%**
3	BWR	2	24	900	1,800	57	3	24	19	106	3.3	**26%**
4	BWR	3	24	900	2,700	85	4	18	22	92	2.9	**9%**



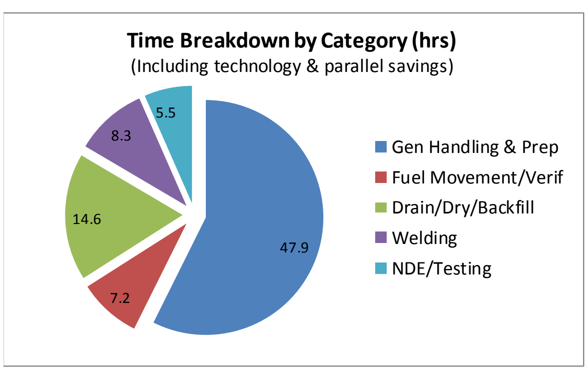
	Gen Handling & Prep	Fuel Movement/Verif	Drain/Dry/Backfill	Welding	NDE/Testing
Parallel operations time savings	10.1	7.2	0.0	0.0	0.0
Technology time savings	0.0	0.0	2.4	0.0	0.0
Full technology and parallel savings	47.9	7.2	14.6	8.3	5.5



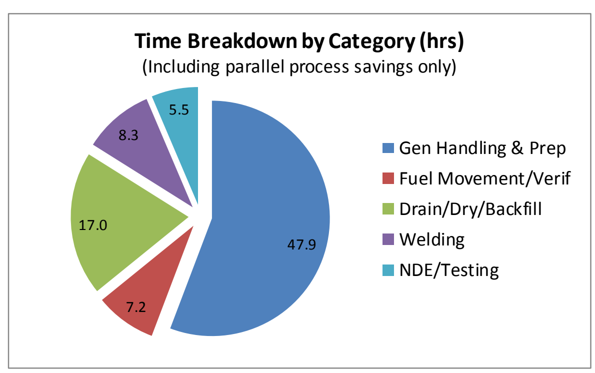
Total estimated time baseline = 103 hours/STAD



Estimated technology savings = 2 hours/STAD (2%)



Estimated combined savings = 20 hours/STAD (19%)



Estimated parallel operations savings = 17 hours/STAD (17%)

Figure 5-7. Time Savings Analysis for Medium BWR STADs

5.2.6 Detailed Summary for Medium PWR STADs

The timing study for Medium PWR STADs was performed using the following key parameters:

- STAD capacity .... 12 PWR fuel assemblies
- Loading campaign .... 12 weeks
- Operating hours per week 168
- Number of transfer casks 2
- Parallel pump-down operations .... not applicable for medium STAD canister
- Parallel welding operations .... not applicable for medium STAD canister
- Parallel NDE operations .... not applicable for medium STAD canister
- Parallel drain/dry/backfill operations .... not applicable for medium STAD canister

The key results of the medium PWR STAD timing study are:

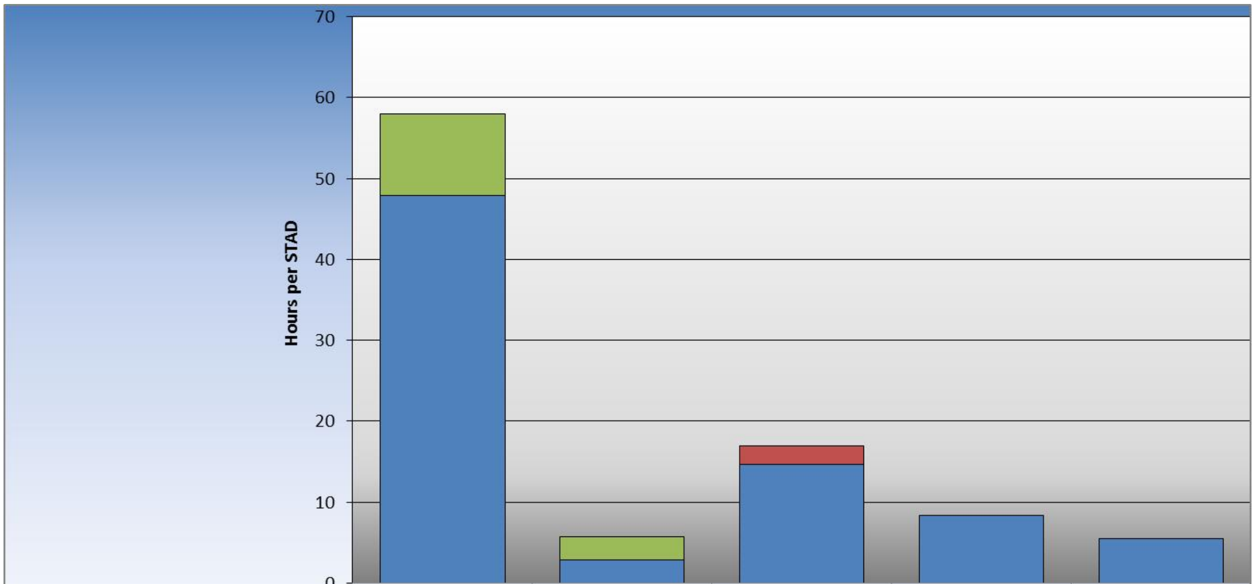
- Total estimated baseline time .... 95 hours per STAD
- Total estimated time (optimized) .... 79 hours per STAD
  .... 6.6 hours per assembly
- Maximum STADs per campaign (optimized) 25

Figure 5-8 provides the time savings analyses for the medium (12-PWR-) STAD canisters.

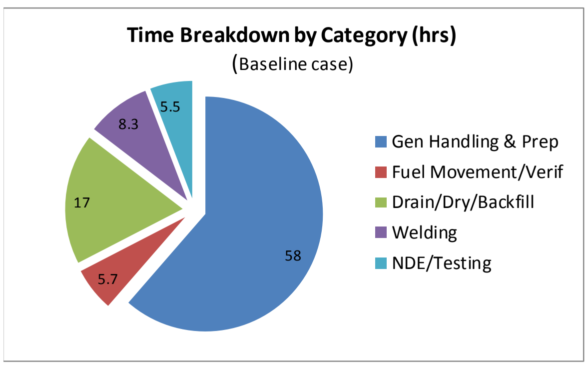
Table 5-17 summarizes the calculations of the maximum loading campaign intervals for medium PWR STADs. For each of the five timing study cases representing plant operational scenarios and associated fuel assembly throughput requirements, the calculations are performed to determine the minimum number of loading campaigns necessary to meet throughput requirements, and the associated maximum loading campaign intervals. The last two blocks of columns summarize the various throughput requirements and indicate the margin between those throughput requirements and throughput rate possible according to the timing study results. Appendix H, Table H-4 contains a detailed listing of the medium PWR STAD timing study.

Table 5-17. Maximum Loading Campaign Intervals for Medium PWR STADs

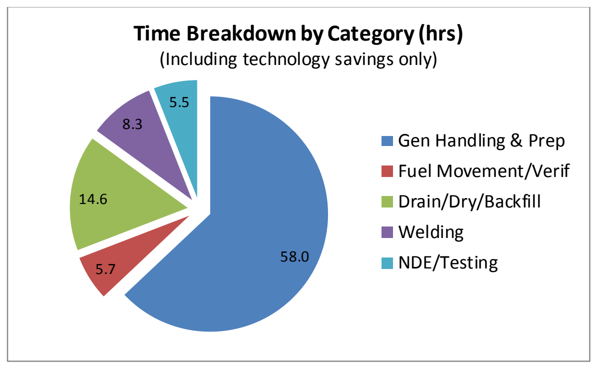
Reactor Operating Cycle Case	Fuel type	Number or Reactors On Site	Operating cycle length (months)	Fuel assembly throughput requirements		Required STADs per 6 years	Minimum number of loading campaigns to process required number of STADs/6 yrs	Corresponding maximum loading campaign interval (months)	Required throughput for processing STADs at maximum loading campaign interval			Margin between required throughput and peak predicted rate (%) (STAD/campaign basis)
				per 6 yrs per reactor	per 6 yrs				STADs / campaign	Hrs / STAD	Hrs / Assy	
5	PWR	1	18	370	370	31	2	36	16	126	10.5	**56%**
6	PWR	1	24	370	370	31	2	36	16	126	10.5	**56%**
7	PWR	2	18	370	740	62	3	24	21	96	8.0	**19%**
8	PWR	2	24	370	740	62	3	24	21	96	8.0	**19%**
9	PWR	3	18	370	1,110	93	4	18	24	84	7.0	**4%**



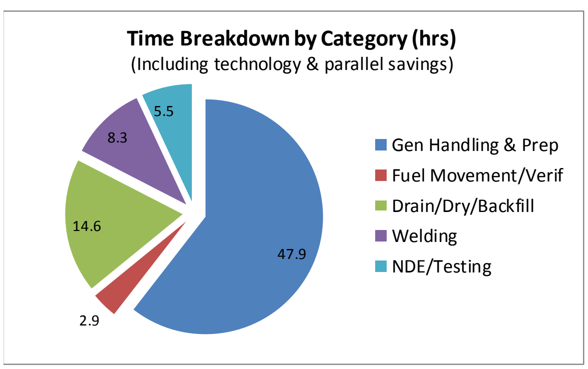
	Gen Handling & Prep	Fuel Movement/Verif	Drain/Dry/Backfill	Welding	NDE/Testing
Parallel operations time savings	10.1	2.9	0.0	0.0	0.0
Technology time savings	0.0	0.0	2.4	0.0	0.0
Full technology and parallel savings	47.9	2.9	14.6	8.3	5.5



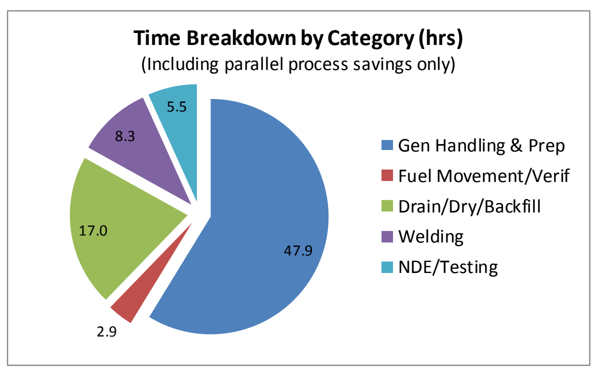
Total estimated time baseline = 95 hours/STAD



Estimated technology savings = 2 hours/STAD (3%)



Estimated combined savings = 15 hours/STAD (16%)



Estimated parallel operations savings = 13 hours/STAD (14%)

Figure 5-8. Time Savings Analysis for Medium PWR STADs

5.2.7 Detailed Summary for Small BWR STADs-in-Can

The timing study for small BWR STADs-in-Can was performed using the following key parameters:

- STAD capacity ....9 BWR fuel assemblies
- Loading campaign ....12 weeks
- Operating hours per week 168
- Number of transfer casks 2
- Number of STADs per Can 4
- Parallel pump-down operations ....4 at a time
- Parallel welding operations ....4 at a time
- Parallel NDE operations ....4 at a time
- Parallel drain/dry/backfill operations...............4 at a time

The key results of the small BWR STAD timing study are:

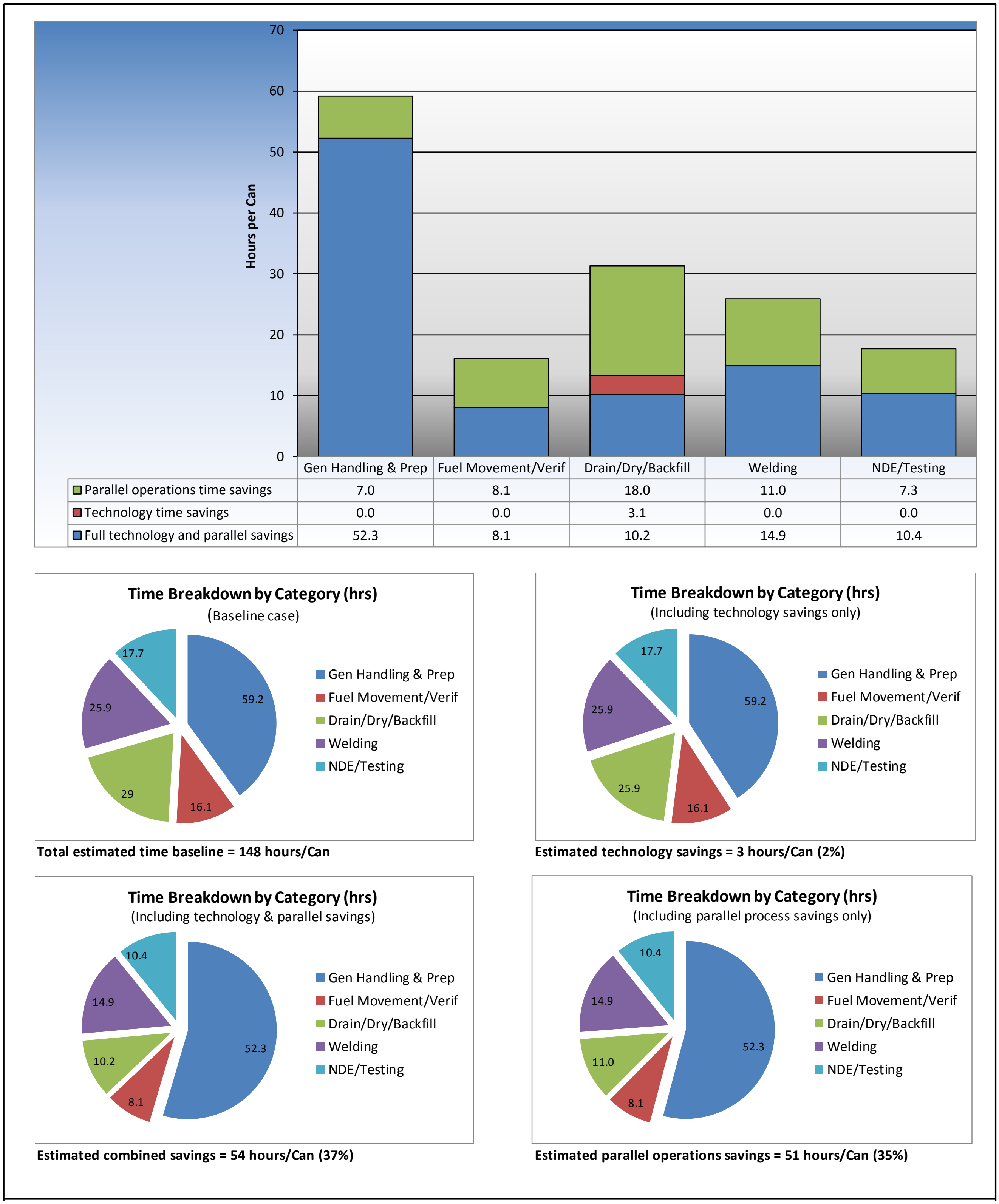
- Total estimated baseline time..........................148 hours per STAD (4 STADs)
- Total estimated time (optimized).....................96 hours per Can (4 STADs)
  ....2.7 hours per assembly
- Maximum STADs per campaign (optimized)......84

Figure 5-9 provides the time savings analyses for the small BWR STADs-in-Can. With reference to this figure and the pie chart showing the "Estimated parallel operations savings", it should be noted that the saved hours reflect the use of dual transfer casks and an assumption that the four small STAD canisters are welded and dried in parallel.

Table 5-18 summarizes the calculations of the maximum loading campaign intervals for small BWR STADs-in-Can. For each of the four timing study cases representing plant operational scenarios and associated fuel assembly throughput requirements, the calculations are performed to determine the minimum number of loading campaigns necessary to meet throughput requirements, and the associated maximum loading campaign intervals. The last two blocks of columns summarize the various throughput requirements and indicate the margin between those throughput requirements and throughput rate possible according to the timing study results. Appendix H, Table H-5 contains a detailed listing of the small BWR STADs-in-Can timing study.

Table 5-18. Maximum Loading Campaign Intervals for Small BWR STADs-in-Can

Reactor Operating Cycle Case	Fuel type	Number or Reactors On Site	Operating cycle length (months)	Fuel assembly throughput requirements		Required STADs per 6 years	Minimum number of loading campaigns to process required number of STADs/6 yrs	Corresponding maximum loading campaign interval (months)	Required throughput for processing STADs at maximum loading campaign interval			Margin between required throughput and peak predicted rate (%) (STAD/campaign basis)
				per 6 yrs per reactor	per 6 yrs				STADs / campaign	Hrs / STAD	Hrs / Assy	
1	BWR	1	18	900	900	100	2	36	50	40	4.5	**68%**
2	BWR	1	24	900	900	100	2	36	50	40	4.5	**68%**
3	BWR	2	24	900	1,800	200	3	24	67	30	3.3	**25%**
4	BWR	3	24	900	2,700	300	4	18	75	27	3.0	**12%**



	Gen Handling & Prep	Fuel Movement/Verif	Drain/Dry/Backfill	Welding	NDE/Testing
Parallel operations time savings	7.0	8.1	18.0	11.0	7.3
Technology time savings	0.0	0.0	3.1	0.0	0.0
Full technology and parallel savings	52.3	8.1	10.2	14.9	10.4

Figure 5-9. Time Savings Analysis for Small BWR STADs-in-Can

5.2.8 Detailed Summary for Small PWR STADs-in-Can

The timing study for small PWR STADs-in-Can was performed using the following key parameters:

- STAD capacity .... 4 PWR fuel assemblies
- Loading campaign .... 12 weeks
- Operating hours per week 168
- Number of transfer casks 2
- Number of STADs per Can 4
- Parallel pump-down operations .... 4 at a time
- Parallel welding operations .... 4 at a time
- Parallel NDE operations .... 4 at a time
- Parallel drain/dry/backfill operations .... 4 at a time

The key results of the small PWR STAD timing study are:

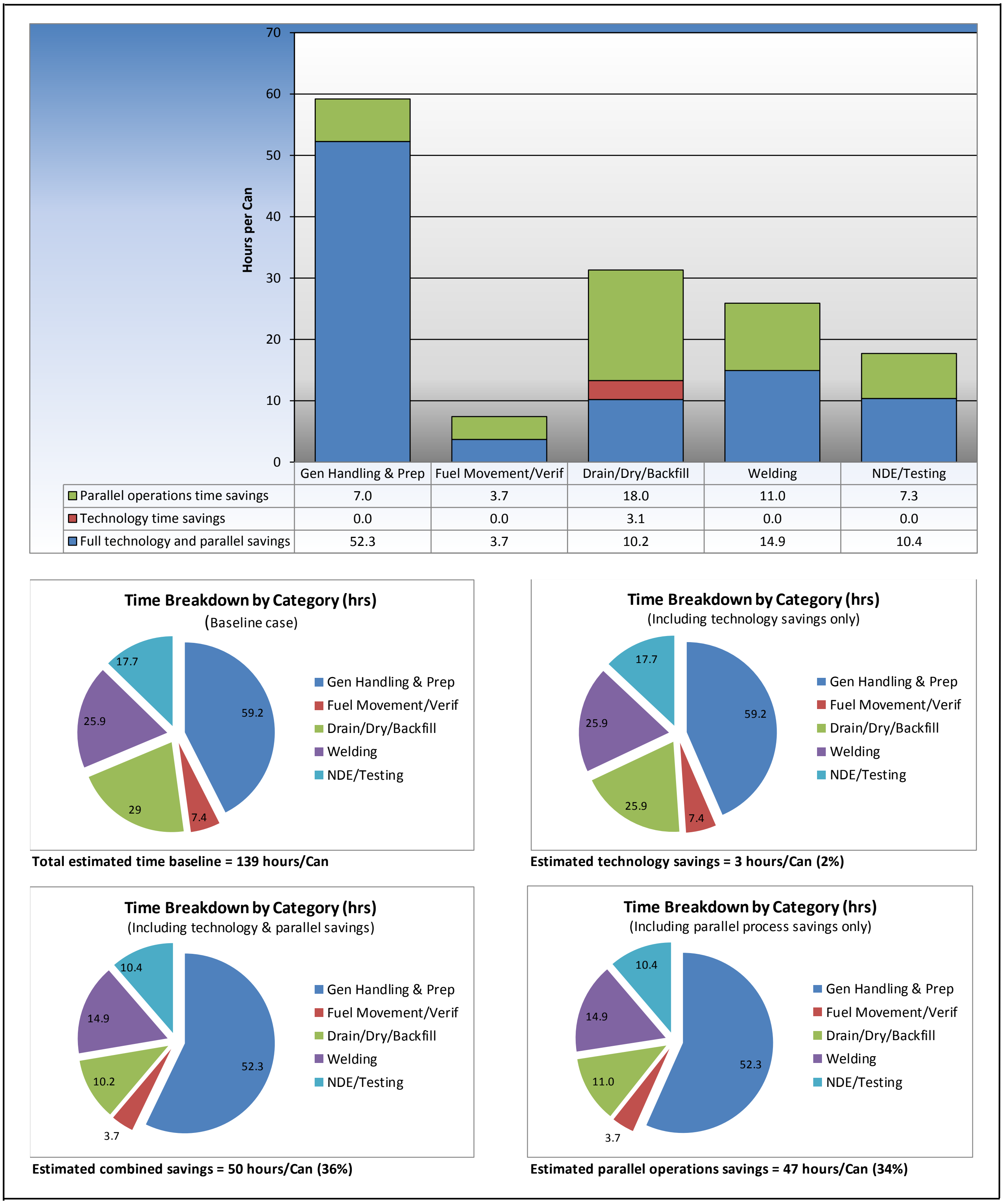
- Total estimated baseline time .... 139 hours per Can (4 STADs)
- Total estimated time (optimized) .... 91 hours per Can (4 STADs)
  .... 5.7 hours per assembly
- Maximum STADs per campaign (optimized) 87

Figure 5-10 provides the time savings analyses for the small PWR STADs-in-Can. With reference to this figure and the pie chart showing the "Estimated parallel operations savings", it should be noted that the saved hours reflect the use of dual transfer casks and an assumption that the four small STAD canisters are welded and dried in parallel.

Table 5-19 summarizes the calculations of the maximum loading campaign intervals for small PWR STADs-in-Can. For each of the five timing study cases representing plant operational scenarios and associated fuel assembly throughput requirements, the calculations are performed to determine the minimum number of loading campaigns necessary to meet throughput requirements, and the associated maximum loading campaign intervals. The last two blocks of columns summarize the various throughput requirements and indicate the margin between those throughput requirements and throughput rate possible according to the timing study results. Appendix H, Table H- 6 contains a detailed listing of the small PWR STADs-in-Can timing study.

Table 5-19. Maximum Loading Campaign Intervals for Small PWR STADs-in-Can

Reactor Operating Cycle Case	Fuel type	Number or Reactors On Site	Operating cycle length (months)	Fuel assembly throughput requirements		Required STADs per 6 years	Time required to load required number of STADs (hrs/6 yrs)	Minimum number of loading campaigns to process required number of STADs/6 yrs	Corresponding maximum loading campaign interval (months)	Required throughput for processing STADs at maximum loading campaign interval			Margin between required throughput and peak predicted rate (%) (STAD/campaign basis)
				per 6 yrs per reactor	per 6 yrs					STADs / campaign	Hrs / STAD	Hrs / Assy	
5	PWR	1	18	370	370	93	2,139	2	36	47	43	10.7	**85%**
6	PWR	1	24	370	370	93	2,139	2	36	47	43	10.7	**85%**
7	PWR	2	18	370	740	185	4,255	3	24	62	33	8.1	**40%**
8	PWR	2	24	370	740	185	4,255	3	24	62	33	8.1	**40%**
9	PWR	3	18	370	1,110	278	6,394	4	18	70	29	7.2	**24%**



	Gen Handling & Prep	Fuel Movement/Verif	Drain/Dry/Backfill	Welding	NDE/Testing
Parallel operations time savings	7.0	3.7	18.0	11.0	7.3
Technology time savings	0.0	0.0	3.1	0.0	0.0
Full technology and parallel savings	52.3	3.7	10.2	14.9	10.4

Figure 5-10. Time Savings Analysis for Small PWR STADs-in-Can

5.2.9 Detailed Summary for Small BWR STADs-in-Carrier

The timing study for small BWR STADs-in-Carrier was performed using the following key parameters:

- STAD capacity .... 9 BWR fuel assemblies
- Loading campaign .... 12 weeks
- Operating hours per week 168
- Number of transfer casks 2
- Number of STADs per Carrier 4
- Parallel pump-down operations .... 4 at a time
- Parallel welding operations .... 4 at a time
- Parallel NDE operations .... 4 at a time
- Parallel drain/dry/backfill operations .... 4 at a time

The key results of the small BWR STAD timing study are:

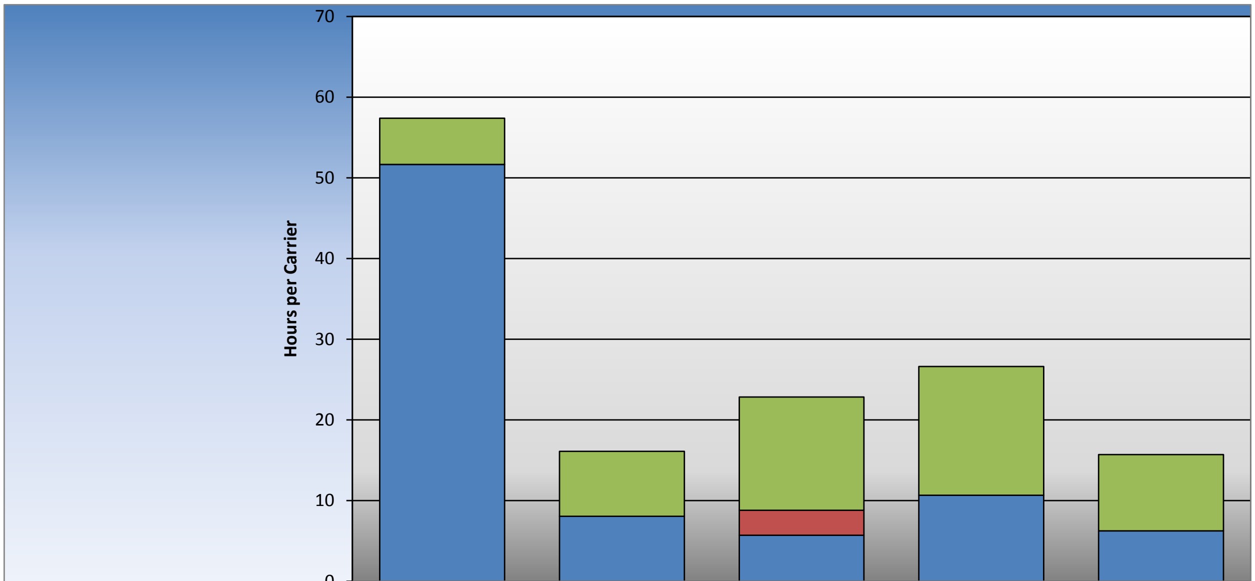
- Total estimated baseline time .... 136 hours per Carrier (4 STADs)
- Total estimated time (optimized) .... 82 hours per Carrier (4 STADs)
  .... 2.3 hours per assembly
- Maximum STADs per campaign (optimized) 96

Figure 5-11 provides the time savings analyses for the small BWR STADs-in-Carrier. With reference to this figure and the pie chart showing the "Estimated parallel operations savings", it should be noted that the saved hours reflect the use of dual transfer casks and an assumption that the four small STAD canisters are welded and dried in parallel.

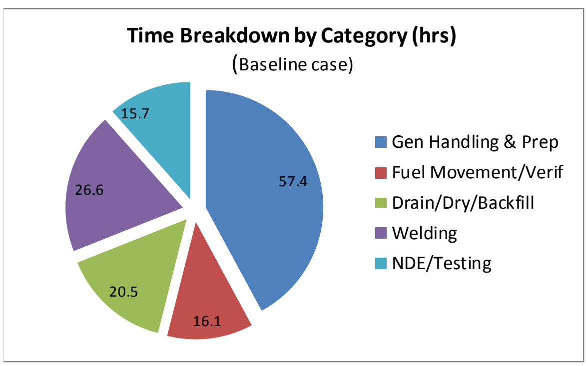
Table 5-20 summarizes the calculations of the maximum loading campaign intervals for small BWR STADs-in-Carrier. For each of the four timing study cases representing plant operational scenarios and associated fuel assembly throughput requirements, the calculations are performed to determine the minimum number of loading campaigns necessary to meet throughput requirements, and the associated maximum loading campaign intervals. The last two blocks of columns summarize the various throughput requirements and indicate the margin between those throughput requirements and throughput rate possible according to the timing study results. Appendix H, Table H-7 contains a detailed listing of the small BWR STADs-in-Carrier timing study.

Table 5-20. Maximum Loading Campaign Intervals for Small BWR STADs-in-Carrier

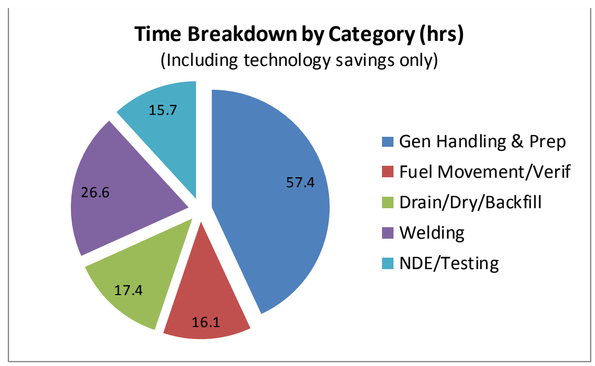
Reactor Operating Cycle Case	Fuel type	Number or Reactors On Site	Operating cycle length (months)	Fuel assembly throughput requirements		Required STADs per 6 years	Minimum number of loading campaigns to process required number of STADs/6 yrs	Corresponding maximum loading campaign interval (months)	Required throughput for processing STADs at maximum loading campaign interval			Margin between required throughput and peak predicted rate (%) (STAD/campaign basis)
				per 6 yrs per reactor	per 6 yrs				STADs / campaign	Hrs / STAD	Hrs / Assy	
1	BWR	1	18	900	900	100	2	36	50	40	4.5	**92%**
2	BWR	1	24	900	900	100	2	36	50	40	4.5	**92%**
3	BWR	2	24	900	1,800	200	3	24	67	30	3.3	**43%**
4	BWR	3	24	900	2,700	300	4	18	75	27	3.0	**28%**



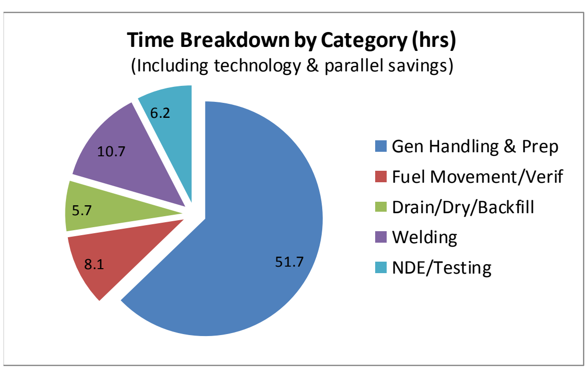
	Gen Handling & Prep	Fuel Movement/Verif	Drain/Dry/Backfill	Welding	NDE/Testing
Parallel operations time savings	5.8	8.1	14.0	16.0	9.5
Technology time savings	0.0	0.0	3.1	0.0	0.0
Full technology and parallel savings	51.7	8.1	5.7	10.7	6.2



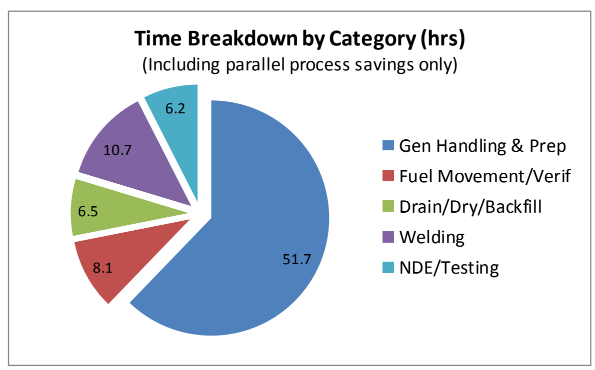
Total estimated time baseline = 136 hours/Carrier



Estimated technology savings = 3 hours/Carrier (2%)



Estimated combined savings = 56 hours/Carrier (41%)



Estimated parallel operations savings = 53 hours/Carrier (39%)

Figure 5-11. Time Savings Analysis for Small BWR STADs-in-Carrier

5.2.10 Detailed Summary for Small PWR STADs-in-Carrier

The timing study for small PWR STADs-in-Carrier was performed using the following key parameters:

- STAD capacity ....4 PWR fuel assemblies
- Loading campaign ....12 weeks
- Operating hours per week 168
- Number of transfer casks 2
- Number of STADs per Carrier 4
- Parallel pump-down operations ....4 at a time
- Parallel welding operations ....4 at a time
- Parallel NDE operations ....4 at a time
- Parallel drain/dry/backfill operations...............4 at a time

The key results of the small PWR STAD timing study are:

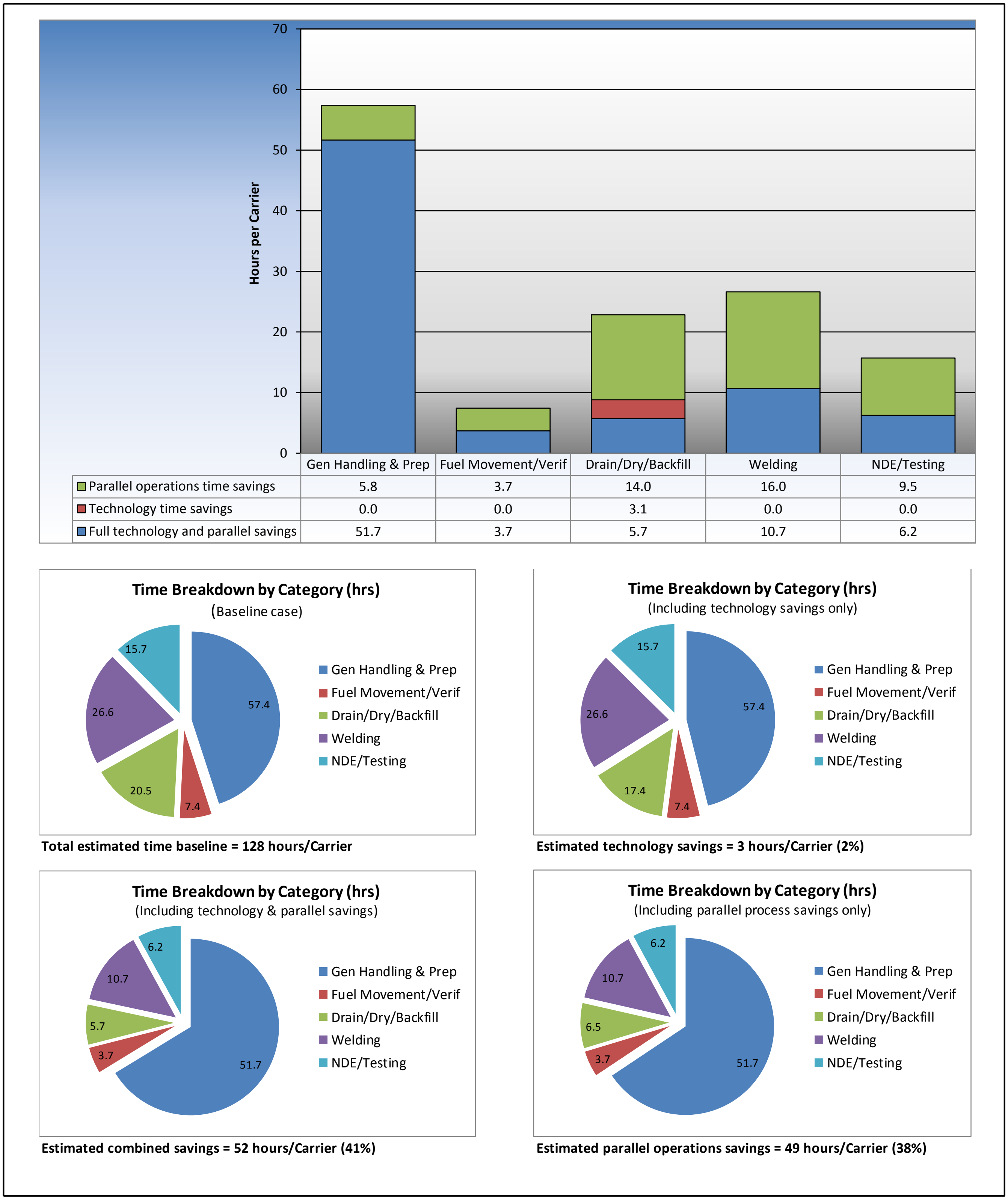
- Total estimated baseline time..........................128 hours per Carrier (4 STADs)
- Total estimated time (optimized).....................78 hours per Carrier (4 STADs)
  ....4.9 hours per assembly
- Maximum STADs per campaign (optimized) 106

Figure 5-12 provides the time savings analyses for the small PWR STADs-in-Carrier. With reference to this figure and the pie chart showing the "Estimated parallel operations savings", it should be noted that the saved hours reflect the use of dual transfer casks and an assumption that the four small STAD canisters are welded and dried in parallel.

Table 5-21 summarizes the calculations of the maximum loading campaign intervals for small PWR STADs-in-Carrier. For each of the five timing study cases representing plant operational scenarios and associated fuel assembly throughput requirements, the calculations are performed to determine the minimum number of loading campaigns necessary to meet throughput requirements, and the associated maximum loading campaign intervals. The last two blocks of columns summarize the various throughput requirements and indicate the margin between those throughput requirements and throughput rate possible according the timing study results. Appendix H, Table H-8 contains detailed listing of the small PWR STADs-in-Carrier timing study.

Table 5-21. Maximum Loading Campaign Intervals for Small PWR STADs-in-Carrier

Reactor Operating Cycle Case	Fuel type	Number or Reactors On Site	Operating cycle length (months)	Fuel assembly throughput requirements		Required STADs per 6 years	Minimum number of loading campaigns to process required number of STADs/6 yrs	Corresponding maximum loading campaign interval (months)	Required throughput for processing STADs at maximum loading campaign interval			Margin between required throughput and peak predicted rate (%) (STAD/campaign basis)
				per 6 yrs per reactor	per 6 yrs				STADs / campaign	Hrs / STAD	Hrs / Assy	
5	PWR	1	18	370	370	93	1	72	93	22	5.4	**14%**
6	PWR	1	24	370	370	93	1	72	93	22	5.4	**14%**
7	PWR	2	18	370	740	185	2	36	93	22	5.4	**14%**
8	PWR	2	24	370	740	185	2	36	93	22	5.4	**14%**
9	PWR	3	18	370	1,110	278	3	24	93	22	5.4	**14%**



	Gen Handling & Prep	Fuel Movement/Verif	Drain/Dry/Backfill	Welding	NDE/Testing
Parallel operations time savings	5.8	3.7	14.0	16.0	9.5
Technology time savings	0.0	0.0	3.1	0.0	0.0
Full technology and parallel savings	51.7	3.7	5.7	10.7	6.2

Figure 5-12. Time Savings Analysis for Small PWR STADs-in-Carrier

5.3 PERSONNEL EXPOSURE EVALUATION

Personnel exposure occurs due to a combination of radiation field intensity, operational steps, and the time required to complete those steps. In order to compare the various STAD options against their DPC reference counterparts, the relative operational durations from the timing studies were used to scale actual exposure budgets from the Zion operational experience to arrive at estimates by fuel assembly, canister, or 12-week loading campaign as shown in Figure 5-13.

The baseline data are actual exposure estimates measured during the Zion fuel loading campaigns. These data are organized by radiation work permit, and so their details are coarser than the operating steps in the timing studies and some are divided by organizational lines. Table 5-22 shows the baseline data, describes the scaling assumptions made for each step, and presents the resulting scaling factors and person-mrem totals for each of the steps.

Similar to the timing studies, the exposure studies show a great variation in exposure per fuel assembly because of the wide range of capacities for the various system options and because of the portions of the loading process that represent a relatively uniform "overhead" such as transfer and storage cask operations. The results vary from 6.6 to 33.0 mrem/assembly. On a per STAD or can/carrier basis, the differences are reduced (357-561 mrem). When the results are compiled over a 12-week loading campaign, the differences are shown to be approximately similar (7.5-9.9 rem/campaign).

System	Person-mrem Per Assembly	
	BWR	PWR
DPC (ref)	6.6	15.2
Large STAD	11.5	23.2
Medium STAD	12.9	33.0
Small STAD-in-Can	11.4	24.8
Small STAD-in-Carrier	10.3	22.3

System	Person-mrem per DPC, Large/Medium STAD, or Can/Carrier	
	BWR	PWR
DPC (ref)	574	561
Large STAD	505	487
Medium STAD	412	397
Small STAD-in-Can	412	397
Small STAD-in-Carrier	372	357

System	Person-REM per 12-Week Campaign	
	BWR	PWR
DPC (ref)	7.5	8.4
Large STAD	9.6	9.7
Medium STAD	9.9	9.9
Small STAD-in-Can	8.2	8.3
Small STAD-in-Carrier	8.9	8.9

Figure 5-13. Personnel Exposure Estimates

Table 5-22. Exposure Analysis Details

Zion baseline data			Basis for factor	BWR DPC		Large BWR STAD		Large PWR STAD		Medium BWR STAD		Medium PWR STAD		Small BWR Stad-in-Can		Small PWR Stad-in-Can		Small BWR Stad-in-Carrier		Small PWR Stad-in-Carrier	
Task		TEDE		Factor	TEDE	Factor	TEDE	Factor	TEDE	Factor	TEDE	Factor	TEDE	Factor	TEDE	Factor	TEDE	Factor	TEDE	Factor	TEDE
1	Move ancillary equipment into fuel handling building	20	Same for any load- not a function of STAD type.	1.00	20.0	1.00	20.0	1.00	20.0	1.00	20.0	1.00	20.0	1.00	20.0	1.00	20.0	1.00	20.0	1.00	20.0
2	Move new components into the proper fuel handling building locations for the start of each canister and repeat for each successive canister	5	Same for any load- not a function of STAD type.	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0
3	Place the canister into the transfer cask located in the decontamination pit	2	Same for any load- not a function of STAD type.	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0
4	Prepare the transfer cask/canister for placement into the spent fuel pool	4	Same for any load- not a function of STAD type.	1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0	1.00	4.0
5	Place the transfer cask/canister into the spent fuel pool	1	Same for any load- not a function of STAD type.	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0	1.00	1.0
6	Commence fuel moves and verify fuel loading	12	Scale by number of assemblies	2.35	28.2	1.19	14.3	0.57	6.8	0.86	10.4	0.32	3.9	0.97	11.7	0.43	5.2	0.97	11.7	0.43	5.2
7	Install lids and remove rigging	7	Same for any load- not a function of STAD type.	1.00	7.0	1.00	7.0	1.00	7.0	1.00	7.0	1.00	7.0	1.00	7.0	1.00	7.0	1.00	7.0	1.00	7.0
8	Remove transfer cask/canister from spent fuel pool and place in Decon pit for decontamination and closure processing	87	Same for any load- not a function of STAD type.	1.00	87.0	1.00	87.0	1.00	87.0	1.00	87.0	1.00	87.0	1.00	87.0	1.00	87.0	1.00	87.0	1.00	87.0
9	Drain, dry, seal, and test canisters	108	Scale by operational time.	1.04	111.8	1.00	107.9	1.00	107.9	0.54	58.1	0.54	58.1	0.25	26.8	0.25	26.8	0.18	19.7	0.18	19.7
10	Remove shielding, install transfer cask retaining ring, and prepare transfer cask/canister for stack up	8	Same for any load- not a function of STAD type.	1.00	8.0	1.00	8.0	1.00	8.0	1.00	8.0	1.00	8.0	1.00	8.0	1.00	8.0	1.00	8.0	1.00	8.0
11	Move transfer cask/canister from decontamination pit to the transfer cask seismic restraint for stack up, and prepare Crane hook for stack up	10	Same for any load- not a function of STAD type.	1.00	10.0	1.00	10.0	1.00	10.0	1.00	10.0	1.00	10.0	1.00	10.0	1.00	10.0	1.00	10.0	1.00	10.0
12	Transfer canister to storage cask, remove rigging from crane hook, close transfer adapter doors, and disengage transfer cask and seismic restraint	15	Same for any load- not a function of STAD type.	1.00	15.0	1.00	15.0	1.00	15.0	1.00	15.0	1.00	15.0	1.00	15.0	1.00	15.0	1.00	15.0	1.00	15.0
13	Install yoke on Crane hook and move transfer cask to decontamination pit for the next fuel canister starting at Task 3 above	2	Same for any load- not a function of STAD type.	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0	1.00	2.0
14	Remove the storage cask rigging and transfer adapter from the canister and storage cask	3	Same for any load- not a function of STAD type.	1.00	3.0	1.00	3.0	1.00	3.0	1.00	3.0	1.00	3.0	1.00	3.0	1.00	3.0	1.00	3.0	1.00	3.0
15	Set the storage cask lid, check vents, prepare for storage cask move to the heavy haul path, complete radiological survey of the storage cask	12	Scale by total hours per Large/Med STAD or Can/Carrier	0.98	11.7	0.79	9.4	0.75	9.0	0.64	7.7	0.61	7.3	0.75	9.0	0.72	8.6	0.63	7.6	0.60	7.2
16	Support storage cask move to the ISFSI	5	Same for any load- not a function of STAD type.	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0	1.00	5.0
17	RP coverage for all evolutions (inside and outside)	80	Scale by total hours per Large/Med STAD or Can/Carrier	0.98	78.1	0.79	62.9	0.75	59.9	0.64	51.4	0.61	48.7	0.75	60.2	0.72	57.5	0.63	50.6	0.60	47.9
18	Decontamination activities	50	Scale by total hours per Large/Med STAD or Can/Carrier	0.98	48.8	0.79	39.3	0.75	37.4	0.64	32.1	0.61	30.4	0.75	37.6	0.72	35.9	0.63	31.6	0.60	30.0
19	Security coverage for all evolutions (inside and outside)	5	Scale by total hours per Large/Med STAD or Can/Carrier	0.98	4.9	0.79	3.9	0.75	3.7	0.64	3.2	0.61	3.0	0.75	3.8	0.72	3.6	0.63	3.2	0.60	3.0
20	Fuels group support activities	100	Scale by total hours per Large/Med STAD or Can/Carrier	0.98	97.6	0.79	78.6	0.75	74.8	0.64	64.2	0.61	60.9	0.75	75.2	0.72	71.9	0.63	63.3	0.60	59.9
21	QA support activities	25	Scale by total hours per Large/Med STAD or Can/Carrier	0.98	24.4	0.79	19.7	0.75	18.7	0.64	16.1	0.61	15.2	0.75	18.8	0.72	18.0	0.63	15.8	0.60	15.0
		561			574		505		487		412		397		412		397		372		357

6 RECOMMENDED OPTIMUM FREQUENCIES AND OPERATIONAL APPROACH FOR CANISTER LOADING CAMPAIGNS

Section 5 discussed the results of the timing studies, developed estimated throughput rates for each of the STAD system concepts, quantified the potential time savings for loading STADs, and demonstrated that all of the STAD system sizes have the potential to meet the throughput requirements for the nine plant operational scenarios investigated when the appropriate optimization actions are taken. This section summarizes the recommended intervals for fuel loading campaigns and the frequencies for loading and draws on the Loading Process flowsheets shown in Appendix E. These recommendations are for the assumed discharge rates in Table 5-9 plus the assumption that loading campaigns will be made regularly on 12, 18, 24, or 36 month intervals.

Table 6-1 summarizes the maximum campaign intervals, number of campaigns per six years, and the amount of schedule margin associated with each case analyzed. All systems evaluated have the potential to meet plant needs; however two of the medium STAD cases (4 and 9) have small margins (less than 10%) at four loading campaigns per six years and are therefore recommended only with caution. The margins could be increased by moving to five or six loading campaigns per six years.

Table 6-1. Process Time Margins at Maximum Campaign Intervals

Operational Case Number	Fuel Type	Number of Reactors On Site	Operating cycle length (months)	Recommended Fuel Loading Campaign Intervals and Frequencies														
				DPC (reference)			Large STAD			Medium STAD			Small STAD-in-Can			Small STAD-in-Carrier		
				Interval (months)	Campaigns/6 yrs	Margin	Interval (months)	Campaigns/6 yrs	Margin	Interval (months)	Campaigns/6 yrs	Margin	Interval (months)	Campaigns/6 yrs	Margin	Interval (months)	Campaigns/6 yrs	Margin
1	BWR	1	18	72	1	64%	36	2	73%	36	2	60%	36	2	68%	36	2	92%
2		1	24	72	1	64%	36	2	73%	36	2	60%	36	2	68%	36	2	92%
3		2	24	36	2	64%	24	3	36%	24	3	26%	24	3	25%	24	3	43%
4		3	24	36	2	13%	18	4	19%	18	4	9%	18	4	12%	18	4	28%
5	PWR	1	18	72	1	44%	72	1	11%	36	2	56%	36	2	85%	72	1	14%
6		1	24	72	1	44%	72	1	11%	36	2	56%	36	2	85%	72	1	14%
7		2	18	36	2	44%	36	2	11%	24	3	19%	24	3	40%	36	2	14%
8		2	24	36	2	17%	36	2	11%	24	3	19%	24	3	40%	36	2	14%
9		3	18	36	2	0%	24	3	11%	18	4	4%	18	4	24%	24	3	14%

The Team has also drawn on its plant operating experience and looked at the configurations of operating sites with regards to the practicality of performing the frequencies of loading campaigns identified in Table 6-1.

The consensus for single unit PWR or BWR sites (Cases 1, 2, 5, and 6) is that the proposed loading frequencies could be accommodated, noting that 18 month operating cycles do lead to more refueling outages over time, and thus allow less time to perform other large projects and often shorter windows to do so.

Dual unit BWR sites running on 24-month operating cycles (Case 3) require one refueling outage per year alternating between the two units and the Refueling Floor time available for spent fuel load out is limited, so a large dry storage loading campaign every other year is desirable. This equates to three loading campaigns over a six year period and is consistent with what is shown in Table 6-1 for the STAD canister system variants.

For dual unit PWR sites running on 18 month refueling cycles (Case 7), refuel outages alternate between the two units for two years and during the third year the site needs to implement an outage for both of the units. It is not desirable to perform a loading campaign during a year when both units will be executing a refueling outage. Thus, the ideal plan is to load fuel to dry storage for two consecutive years and then skip a year to enable the site to execute the outages for both units. This would equate to loading campaigns being performed during four of the 6 years. Table 6-1 shows that each of STAD variants will be able to support this frequency.

Regarding why it is not desirable to perform a loading campaign during a year when both units will be executing a refueling outage, it is important to note that refuels are a priority at all operating sites. A refuel can take from 3 to 4 months[8] and thus, two refuels in a calendar year will not leave sufficient time to perform a 12-week loading campaign, in addition to time for mobilization and demobilization. Conducting shorter loading campaigns between refuel outages is also not desirable because the mobilization/demobilization costs for a loading campaign are high (several $100K) and utilities want to minimize them. It should also be noted that during single refuel outage years, utilities could (and do) choose to extend a loading campaign.

For dual unit PWR sites running on 24 month refueling cycles (Case 8), an outage will be executed every year; alternating between the two units. There is no year where an outage is executed for both units. Thus, it is possible for these sites to perform three loading campaigns during each six year cycle. Table 6-1 shows that each of the STAD variants will be able to support this frequency.

For the three unit PWR site that runs on an 18 month refueling cycle (Case 9), the Team's knowledge of operations at the Palo Verde site is that it typically loads to dry storage twice a year between outages; of which there are two a year. Table 6-1 shows that each of the STAD

[8] A refuel is typically comprised of the following items: (i) Four weeks to stage new fuel in the pool, (ii) two weeks to mobilize equipment, (iii) four to eight weeks for the refuel outage, and (iv) two weeks to demobilize equipment.

variants will be able to support this frequency. It is also important to note that the configuration of the three PWR reactors at Palo Verde is such that each reactor has its own spent fuel pool and overhead crane, which explains why they are able to perform loading campaigns at the above frequency.

For the three unit BWR site that runs on a 24 month refueling cycle (Case 4), the Team's knowledge of operations at Browns Ferry is that it currently loads to dry storage every year. Table 6-1 shows that each of the STAD variants will be able to support this frequency. Regarding Browns Ferry, it is important to note that although there are three BWR reactors, two of them function as a dual-unit installation with a shared spent fuel pool, and the other reactor functions as a single-unit installation and has a dedicated spent fuel pool. This provides Browns Ferry with the ability to load annually based on the refueling outage schedules for what are effectively two separate power plants.

The unique configurations for Browns Ferry and Palo Verde emphasize the important part that the configuration of multi-unit reactor sites will ultimately play in determining if loading campaigns utilizing smaller capacity (compared with DPCs) STAD canisters will be able to support the required throughput rates.

In conclusion, in general, the medium STAD canister systems had the lowest overall performance and would not be recommended for the plant scenarios with higher throughput requirements. But each STAD canister system option appears capable of working at most, if not all, sites, depending on the loading campaign frequency.

7 COST ESTIMATES

The Cost Estimate section is divided into six subsections, including:

1. Operations Costs per Assembly, STAD and 12-week Campaign (Section 7.1);
2. Operations Costs for Entire Period with 12, 24 and 36 Month Loading Campaign Cycles (Section 7.2)
3. Summary Baseline and Optimum Throughput Costs by Task Category and Per Campaign (Section 7.3);
4. Cost Allocations for the Eight STAD Cases (Section 7.4);
5. Cask Systems and Other Capital Costs (Section 7.5); and
6. Comparison of Operational Costs for the Entire Six Years under the Recommended Approach (Section 7.6).

In addition, Appendix D includes detailed estimates of the operational costs for the two benchmark cases as well as the eight STAD cases.

The cost estimates are consistent with the parametric studies presented in Sections 5 and 6. Table 7-1, below, provides a roadmap to the cost study results and also provides references to the pertinent sections in the parametric studies.

Table 7-1. Roadmap to Cost Study Results

Results	Section 7 Reference	Section 5/6 Reference
Parametric Cost Study Summary Results, including loading process costs per STAD, assembly, and 12-week campaign	Section 7.1	Section 5.2.1
Parametric Cost Study Summary Results, including operations costs for the entire period with 12, 18, 24, and 36-month campaigns	Section 7.2	Section 5.2.1
Summary of Throughput Loading Process Costs	Section 7.3	Section 5.2.2
Cost Allocations for Large BWR STADs	Section 7.4.1	Section 5.2.3
Cost Allocations for Large PWR STADs	Section 7.4.2	Section 5.2.4
Cost Allocations for Medium BWR STADs	Section 7.4.3	Section 5.2.5
Cost Allocations for Medium PWR STADs	Section 7.4.4	Section 5.2.6
Cost Allocations for Small BWR STADs-in-Can	Section 7.4.5	Section 5.2.7
Cost Allocations for Small PWR STADs-in-Can	Section 7.4.6	Section 5.2.8
Cost Allocations for Small BWR STADs-in-Carrier	Section 7.4.7	Section 5.2.9
Cost Allocations for Small PWR STADs-in-Carrier	Section 7.4.8	Section 5.2.10
STAD Cask Systems and Other Capital Costs	Section 7.5	N/A
Process Costs at Recommended Campaign Intervals	Section 7.6	Section 6

The operational cost tables and figures in this section are similar in structure to, and based on, the quantities and hours in corresponding tables and figures presented in Sections 5 and 6. Where appropriate, the tables and figures in this section reference those in Sections 5 and 6. As needed, refer to the referenced tables and associated explanations to understand how pertinent quantities and hours were derived.

Consistent with the parametric studies, cost is being evaluated for two reference cases and eight STAD cases. The two reference cases are:

1. BWR DPC (87 fuel assemblies)
2. PWR DPC (37 fuel assemblies)

The eight STAD cases are:

1. Large BWR STAD (44 fuel assemblies)
2. Large PWR STAD (21 fuel assemblies)
3. Medium BWR STAD (32 fuel assemblies)
4. Medium PWR STAD (12 fuel assemblies)
5. Small BWR STADs-in-Can (9 fuel assemblies x 4)
6. Small PWR STADs-in-Can (4 fuel assemblies x 4)
7. Small BWR STADs-in-Carrier (9 fuel assemblies x 4)
8. Small PWR STADs-in-Carrier (4 fuel assemblies x 4)

Each of the eight STAD cases is comprised of a baseline and an optimum scenario. The optimized case includes both technology and parallel improvements, such as vacuum drying technology, using two on-site transfer casks in order to run certain operational steps in parallel, and (in the case of the Small STAD systems), carrying out canister draining drying and sealing operations in parallel.

Initially, costs are presented in various summary forms for both the base line and optimized cases. Further along in the section, costs are shown broken down by technology and parallel savings, and also by operational steps. Operational step categories include:

- general handling and preparation activities
- fuel movement/verification
- canister draining, drying, backfilling
- welding
- NDE and other testing activities

Appendix D provides further breakdowns by operational step and labor category for both the two DPC reference and the eight STAD cases.

7.1 OPERATIONS COSTS PER ASSEMBLY, STAD, AND 12-WEEK CAMPAIGN

The tables in this section contain operations costs per assembly, STAD, and 12-week campaign. Table 7-2 provides operations costs which correlate to results of the timing studies in hours per DPC, large/medium STAD, and small STAD can/carrier. The equivalent data are shown in Table 7-3 which provides operations costs per assembly for each system option. All STAD optimized times and costs include credit for technology and parallel operations time-saving measures.

Table 7-2. Summary of Loading Process Costs ($/STAD)
(current year 2015 $; includes contingency)

System	Dollars per DPC, Lg/Med STAD, or Small STAD Can/Carrier [ref. Table 5-5] [current year 2015 $; includes contingency]							
	Baseline				Optimized			
	BWR		PWR		BWR		PWR	
	Hours	Dollars	Hours	Dollars	Hours	Dollars	Hours	Dollars
DPC (ref)	145	$161,067	130	$130,953				
Large STAD	127	$135,185	117	$126,046	102	$109,308	97	$104,780
Medium STAD	103	$113,395	95	$105,291	84	$92,176	79	$88,124
Small STADs-in-Can	148	$182,836	139	$175,529	96	$123,359	91	$119,705
Small STADs-in-Carrier	136	$159,787	128	$150,679	82	$109,943	78	$105,389

Table 7-3. Summary of Loading Process Costs ($/Assembly)
(current year 2015 $; includes contingency)

System	Dollars per Assembly [ref. Table 5-6] [current year 2015 $; includes contingency]							
	Baseline				Optimized			
	BWR		PWR		BWR		PWR	
	Hours	Dollars	Hours	Dollars	Hours	Dollars	Hours	Dollars
DPC (ref)	1.66	$1,851	3.51	$3,539				
Large STAD	2.88	$3,072	5.57	$6,002	2.32	$2,484	4.63	$4,990
Medium STAD	3.23	$3,544	7.88	$8,774	2.61	$2,880	6.60	$7,344
Small STADs-in-Can	4.11	$5,079	8.70	$10,971	2.66	$3,427	5.72	$7,482
Small STADs-in-Carrier	3.79	$4,439	7.98	$9,417	2.29	$3,054	4.87	$6,587

Assuming a 24/7 operational schedule, the number of STADs and corresponding number of assemblies that can be processed in the model 12-week loading campaign are shown in Table 7-4.

Table 7-4. Summary of Throughput Loading Process Costs ($/12-Week Campaign) (current year 2015 $; includes contingency)

System	Dollars per 12-Week Campaign [ref. Tables 5-7 & 5-8] [current year 2015 $; includes contingency]											
	Baseline						Optimized					
	BWR			PWR			BWR			PWR		
	# DPCs/ STADs	# Assem-blies	Dollars	# DPCs/ STADs	# Assem-blies	Dollars	# DPCs/ STADs	# Assem-blies	Dollars	# DPCs/ STADs	# Assem-blies	Dollars
DPC (ref)	13	1,131	$2,093,867	15	555	$1,964,301						
Large STAD	15	660	$2,027,772	17	357	$2,142,778	19	836	$2,076,853	20	420	$2,095,599
Medium STAD	19	608	$2,154,504	21	252	$2,211,109	24	768	$2,212,217	25	300	$2,203,092
Small STADs-in-Can	13	468	$2,376,871	14	224	$2,457,407	21	756	$2,590,534	22	352	$2,633,514
Small STADs-in-Carrier	14	504	$2,237,015	15	240	$2,260,181	24	864	$2,638,642	25	400	$2,634,736

7.2 OPERATIONS COSTS FOR ENTIRE PERIOD WITH 12, 18, 24, AND 36-MONTH LOADING CAMPAIGN CYCLES

The tables below show cost for each STAD system when loaded on a 12-, 18-, 24-, or 36-month fuel loading campaign cycle. Each table provides details of the plant operational scenario, the total number of assemblies required to be loaded per campaign cycle, the DPC or STAD capacity, the number of DPCs or STADs that must be loaded in a campaign cycle to meet plant needs, and finally the operational loading cost based on the activities defined for each in Appendix D.

The tables contain operations costs for the entire six year period. Table 7-5 provides operations costs for six 12-month campaign cycles; Table 7-6 shows operations costs for four 18-month campaign cycles; Table 7-7 provides operations costs for three 24-month campaign cycles; and Table 7-8 shows operations costs for two 36-month operating cycles.

Table 7-5. STAD Loading Costs: 12–Month Campaign Cycles (current year 2015 $; includes contingency)

Cost for 12-Month Loading Campaign Cycle [ref. Table 5-10] [current year 2015 $; includes contingency]																		
Opera-tional Case #	Fuel Type	# Reactors On-site	Operating Cycle Length (months)	DPC (Reference)			Large STAD			Medium STAD			Small STAD-in-Can			Small STAD-in-Carrier		
				Assemblies per DPC	Required DPCs per 12-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 12-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 12-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 12-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 12-month Campaign	Total Cost
1	BWR	1	18	87	2	$1,932,800	44	4	$2,623,394	32	5	$2,765,272	9	17	$3,145,648	9	17	$2,803,557
2		1	24		2	$1,932,800		4	$2,623,394		5	$2,765,272		17	$3,145,648		17	$2,803,557
3		2	24		4	$3,865,601		7	$4,590,939		10	$5,530,543		34	$6,291,296		34	$5,607,115
4		3	24		6	$5,798,401		11	$7,214,333		15	$8,295,815		50	$9,251,906		50	$8,245,757
5	PWR	1	18	37	2	$1,571,441	21	3	$1,886,039	12	6	$3,172,453	4	16	$2,872,925	4	16	$2,529,346
6		1	24		2	$1,571,441		3	$1,886,039		6	$3,172,453		16	$2,872,925		16	$2,529,346
7		2	18		4	$3,142,881		6	$3,772,078		11	$5,816,164		31	$5,566,292		31	$4,900,608
8		2	24		4	$3,142,881		6	$3,772,078		11	$5,816,164		31	$5,566,292		31	$4,900,608
9		3	18		5	$3,928,601		9	$5,658,117		16	$8,459,875		47	$8,439,217		47	$7,429,955

Table 7-6. STAD Loading Costs: 18–Month Campaign Cycles (current year 2015 $; includes contingency)

Cost for 18-Month Loading Campaign Cycle [ref. Table 5-11]																		
				DPC (Reference)			Large STAD			Medium STAD			Small STAD-in-Can			Small STAD-in-Carrier		
Opera-tional Case #	Fuel Type	# Reactors On-site	Operating Cycle Length (months)	Assemblies per DPC	Required DPCs per 12-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 12-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 12-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 12-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 12-month Campaign	Total Cost
1		1	18		3	$1,932,800		6	$2,623,394		8	$1,106,109		25	$3,083,969		25	$2,748,586
2	BWR	1	24	87	3	$1,932,800	44	6	$2,623,394	32	8	$1,106,109	9	25	$3,083,969	9	25	$2,748,586
3		2	24		6	$3,865,601		11	$4,809,555		15	$2,073,954		50	$6,167,938		50	$5,497,171
4		3	24		8	$5,154,134		16	$6,995,717		22	$3,041,799		75	$9,251,906		75	$8,245,757
5		1	18		3	$1,571,441		5	$2,095,599		8	$2,819,958		24	$2,872,925		24	$2,529,346
6		1	24		3	$1,571,441		5	$2,095,599		8	$2,819,958		24	$2,872,925		24	$2,529,346
7	PWR	2	18	37	5	$2,619,068	21	9	$3,772,078	12	16	$5,639,916	4	47	$5,626,144	4	47	$4,953,303
8		2	24		5	$2,619,068		9	$3,772,078		16	$5,639,916		47	$5,626,144		47	$4,953,303
9		3	18		8	$4,190,508		14	$5,867,677		24	$8,459,875		70	$8,379,364		70	$7,377,260

Table 7-7. STAD Loading Costs: 24–Month Campaign Cycles (current year 2015 $; includes contingency)

Cost for 24-Month Loading Campaign Cycle [ref. Table 5-12]																		
				DPC (Reference)			Large STAD			Medium STAD			Small STAD-in-Can			Small STAD-in-Carrier		
Opera-tional Case #	Fuel Type	# Reactors On-site	Operating Cycle Length (months)	Assemblies per DPC	Required DPCs per 24-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 24-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 24-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 24-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 24-month Campaign	Total Cost
1		1	18		4	$1,932,800		7	$2,295,470		10	$2,765,272		34	$3,145,648		34	$2,803,557
2	BWR	1	24	87	4	$1,932,800	44	7	$2,295,470	32	10	$2,765,272	9	34	$3,145,648	9	34	$2,803,557
3		2	24		7	$3,382,401		14	$4,590,939		19	$5,254,016		67	$6,198,777		67	$5,524,657
4		3	24		11	$5,315,201		21	$6,886,409		29	$8,019,288		100	$9,251,906		100	$8,245,757
5		1	18		4	$1,571,441		6	$1,886,039		11	$2,908,082		31	$2,783,146		31	$2,450,304
6		1	24		4	$1,571,441		6	$1,886,039		11	$2,908,082		31	$2,783,146		31	$2,450,304
7	PWR	2	18	37	7	$2,750,021	21	12	$3,772,078	12	21	$5,551,793	4	62	$5,566,292	4	62	$4,900,608
8		2	24		7	$2,750,021		12	$3,772,078		21	$5,551,793		62	$5,566,292		62	$4,900,608
9		3	18		10	$3,928,601		18	$5,658,117		31	$8,195,504		93	$8,349,438		93	$7,350,913

Table 7-8. STAD Loading Costs: 36-Month Campaign Cycles (current year 2015 $; includes contingency)

Cost for 36-Month Loading Campaign Cycle [ref. Table 5-12]																		
				DPC (Reference)			Large STAD			Medium STAD			Small STAD-in-Can			Small STAD-in-Carrier		
Opera-tional Case #	Fuel Type	# Reactors On-site	Operating Cycle Length (months)	Assemblies per DPC	Required DPCs per 36-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 36-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 36-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 36-month Campaign	Total Cost	Assemblies per STAD	Required STADs per 36-month Campaign	Total Cost
1		1	18		6	$1,932,800		11	$2,404,778		15	$2,765,272		50	$3,083,969		50	$2,748,586
2	BWR	1	24	87	6	$1,932,800	44	11	$2,404,778	32	15	$2,765,272	9	50	$3,083,969	9	50	$2,748,586
3		2	24		11	$3,543,467		21	$4,590,939		29	$5,346,192		100	$6,167,938		100	$5,497,171
4		3	24		16	$5,154,134		31	$6,777,101		43	$7,927,112		150	$9,251,906		150	$8,245,757
5		1	18		5	$1,309,534		9	$1,886,039		16	$2,819,958		47	$2,813,072		47	$2,476,652
6		1	24		5	$1,309,534		9	$1,886,039		16	$2,819,958		47	$2,813,072		47	$2,476,652
7	PWR	2	18	37	10	$2,619,068	21	18	$3,772,078	12	31	$5,463,669	4	93	$5,566,292	4	93	$4,900,608
8		2	24		10	$2,619,068		18	$3,772,078		31	$5,463,669		93	$5,566,292		93	$4,900,608
9		3	18		15	$3,928,601		27	$5,658,117		47	$8,283,627		139	$8,319,512		139	$7,324,565

7.3 SUMMARY BASELINE AND OPTIMUM THROUGHPUT COSTS BY TASK CATEGORY AND PER CAMPAIGN

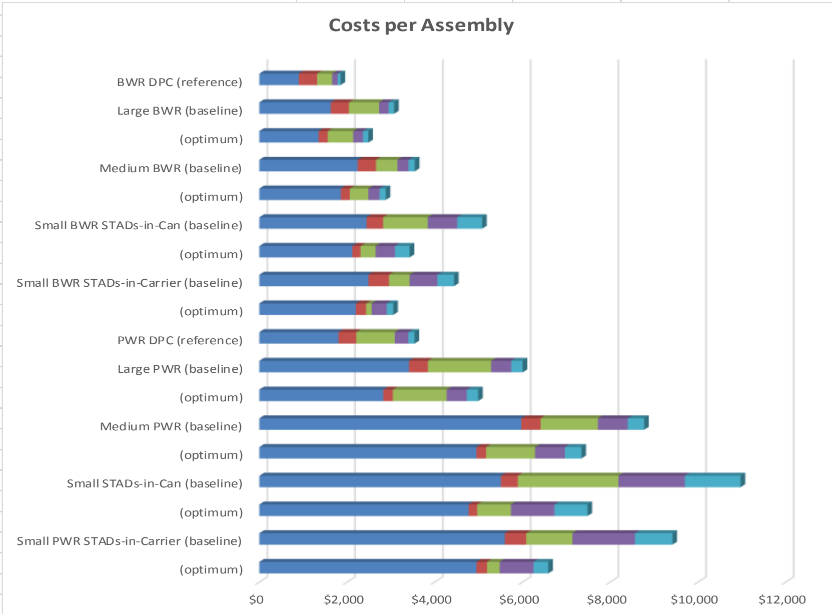
This section provides baseline and optimum summary throughput costs by task category and per campaign.

The summary costs within this section are captured in Figure 7-1 and Figure 7-2. Figure 7-1 provides baseline and optimum costs per assembly by task category for each of the STAD system options investigated. The bar graphs in the figure compare the cost per assembly in total and by task categories for each of the STAD system options. The BWR and PWR DPC reference cases also are shown. Each bar is subdivided to show total cost broken out into the six task categories. Two bars are shown for each of the STAD system options. The first bar represents a baseline cost that corresponds to a series workflow process using typical modern dry fuel storage best practices, and the second bar shows the optimum durations. Directly below the bar graphs is a table containing the raw data for each bar, plus the color coding key for the task categories.

Consistent with the areas of emphasis in the baseline versus optimum evaluations, the greatest costs and improvements are in General Handling & Prep (use of a second transfer cask), Drain/Dry/Backfill ("smart" vacuum drying), and welding (parallel welder - for the Small STADs).

Figure 7-2 provides baseline and optimum costs per STAD, including a top level summary of the estimated costs per large STAD canister, medium STAD canister or Can/Carrier containing 4 small STAD canisters. Here, too, the DPC reference cases are shown.

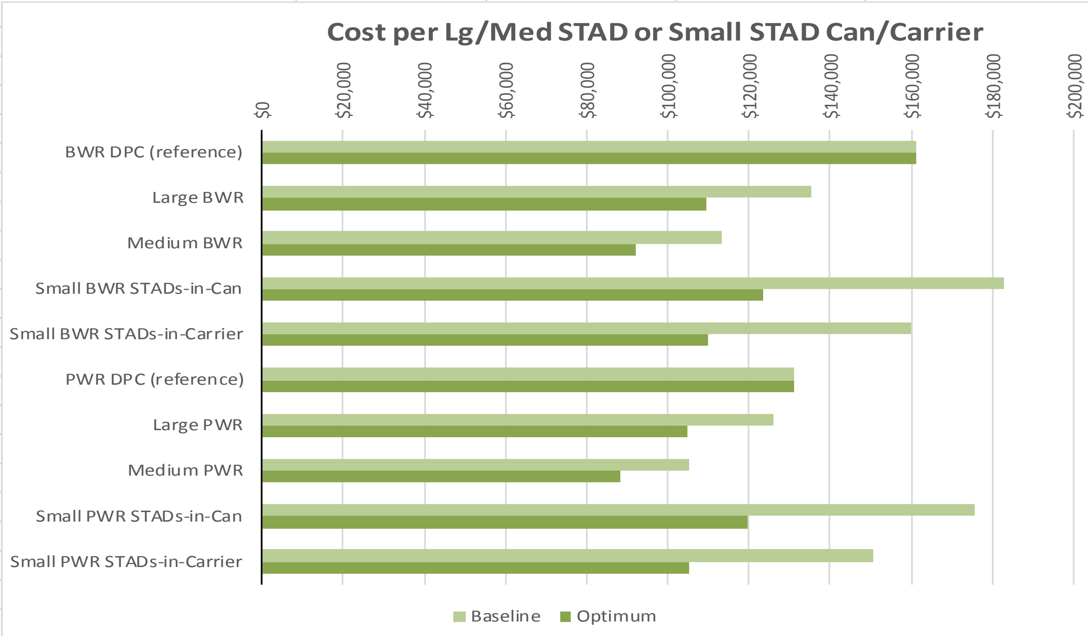
Process Cost per DPC, Lg/Med STAD, or Small STAD Can/Carrier [ref. Figure 5-3]



STAD System	Cost in $ per Assembly						
	A - Gen Handling & Prep	B - Fuel Movement/ Verification	C - Drain/Dry/ Backfill	D - Welding	E - NDE/ Testing	Total	Improve-ment
BWR DPC (reference)	$899	$416	$345	$126	$65	$1,851	na
Large BWR (baseline)	$1,629	$415	$686	$219	$124	$3,072	
(optimum)	$1,350	$207	$585	$219	$124	$2,484	19%
Medium BWR (baseline)	$2,239	$419	$489	$255	$142	$3,544	
(optimum)	$1,856	$210	$419	$255	$142	$2,880	19%
Small BWR STADs-in-Can (baseline)	$2,447	$375	$1,019	$672	$566	$5,079	
(optimum)	$2,120	$188	$341	$442	$335	$3,427	33%
Small BWR STADs-in-Carrier (baseline)	$2,487	$469	$468	$635	$380	$4,439	
(optimum)	$2,199	$235	$128	$343	$150	$3,054	31%
PWR DPC (reference)	$1,805	$406	$878	$310	$141	$3,539	na
Large PWR (baseline)	$3,412	$430	$1,442	$459	$259	$6,002	
(optimum)	$2,828	$215	$1,229	$459	$259	$4,990	17%
Medium PWR (baseline)	$5,971	$442	$1,303	$679	$378	$8,774	
(optimum)	$4,948	$221	$1,117	$679	$378	$7,344	16%
Small STADs-in-Can (baseline)	$5,505	$388	$2,293	$1,512	$1,273	$10,971	
(optimum)	$4,771	$194	$768	$996	$753	$7,482	32%
Small PWR STADs-in-Carrier (baseline)	$5,596	$487	$1,052	$1,428	$854	$9,417	
(optimum)	$4,947	$244	$289	$771	$336	$6,587	30%

Figure 7-1. Throughput Study Processing Cost Summary

Process Cost per DPC, Lg/Med STAD, or Small STAD Can/Carrier [ref. Figure 5-4]



STAD System	Cost per Lg/Med STAD or Small STAD Can/Carrier		
	Baseline	Optimum	Improvement
BWR DPC (reference)	$161,067		na
Large BWR	$135,185	$109,308	19%
Medium BWR	$113,395	$92,176	19%
Small BWR STADs-in-Can	$182,836	$123,359	33%
Small BWR STADs-in-Carrier	$159,787	$109,943	31%
PWR DPC (reference)	$130,953		na
Large PWR	$126,046	$104,780	17%
Medium PWR	$105,291	$88,124	16%
Small PWR STADs-in-Can	$175,529	$119,705	32%
Small PWR STADs-in-Carrier	$150,679	$105,389	30%

Figure 7-2. Throughput Study Processing Cost Summary (by STAD)
(by DPC, Lg/Med STAD, or Small STAD Can/Carrier Containing 4 Small STAD Canisters)

7.4 COST ALLOCATIONS FOR THE EIGHT STAD CASES

This section provides cost allocations for the eight STAD cases. Information in this table is supported by Appendix D, Tables 15-3 through 15-10, which includes operations costs broken down by labor category and task for the eight STAD cases.

The following methodology was employed to arrive at the operational cost estimates:

- Detailed operational estimates were developed for each of the DPC reference and STAD cask types from estimated labor category FTEs for each task.
- Cost estimates were developed using the tasks and corresponding time estimates from the parametric study for each cask type.

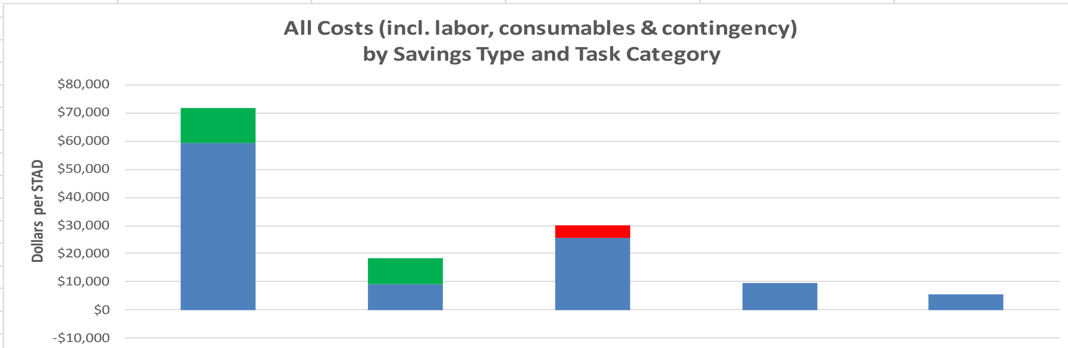
- Labor categories were developed that could be applied to each task; for each labor category and task, a staff count and a fully-loaded labor rate were assigned.
    - Labor categories include Crane Operators, Other Heavy Equipment Operators, Mechanics, Riggers, Welders, Other Operations Staff, Supervisors/Foremen, Deconners, Radiation Protection, RXS Techs, Quality Assurance/Quality Control, Health Physics, Security, Planners, Trainers, Procedure Writers and Management
    - Fully-loaded labor rates are costed at $75 per hour, with the exception of Health Physics and Supervisors/Foremen ($100 per hour), and Management ($125 per hour). Labor rates are based on engineering judgment and are intended to account for overhead as well as regular and overtime pay on a 24/7 schedule
- Total staff count times the labor rate times the number of hours was used to calculate the total labor dollars for each task.
- Each DPC, large/medium STAD, or STADs-in-Can/Carrier total cost was then divided by the number of assemblies to arrive at a cost per assembly.
- Estimates include consumables at 15% but do not include mobilization or demobilization; estimates also include contingency of 20% [the latter consistent with DOE guidance of 10 percent to 40 percent for budget or preliminary estimates (i.e., from DOE G 413.3-21, *Cost Estimating Guide*)].
- Summary cost allocations are provided within this section, and the detailed operational estimates can be found in Appendix D. Results for the STAD options are provided for the baseline, technology improvements only, parallel improvements only, and fully optimized cases.

Estimates were developed using labor categories and associated FTE levels and costs based on the prior operational experience of analysts at Exelon.

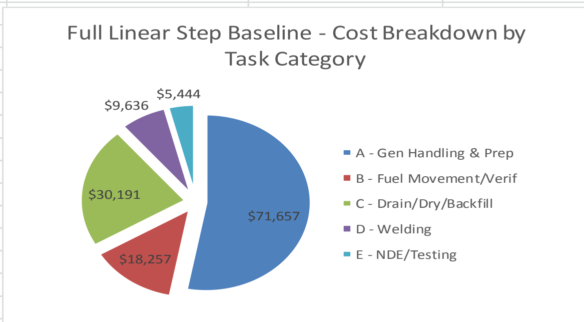
Also note that the "RXS Techs" mentioned above are those staff that load the fuel, do the in-water work for the cask, and do some cask processing such as drying, backfill, etc.

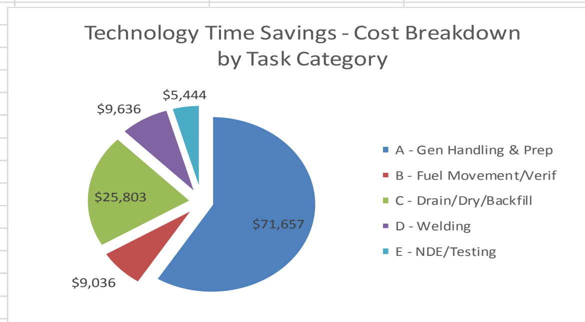
7.4.1 Cost Allocations for Large BWR STADs

Figure 7-3 includes cost allocations for Large BWR STADs (reference Figure 5-5).



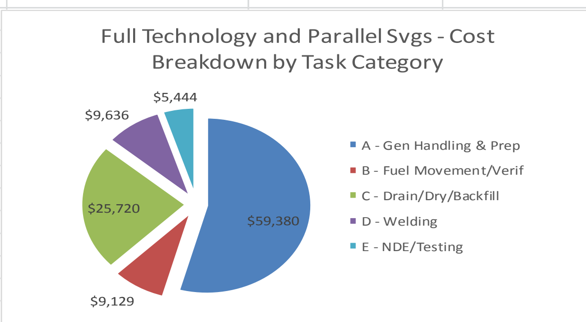
	A - Gen Handling & Prep	B - Fuel Movement/Verif	C - Drain/Dry/Backfill	D - Welding	E - NDE/Testing
Parallel Operations Time Savings	$12,277	$9,129	$0	$0	$0
Technology Time Savings	$0	$0	$4,471	$0	$0
Full Technology and Parallel Svgs	$59,380	$9,129	$25,720	$9,636	$5,444

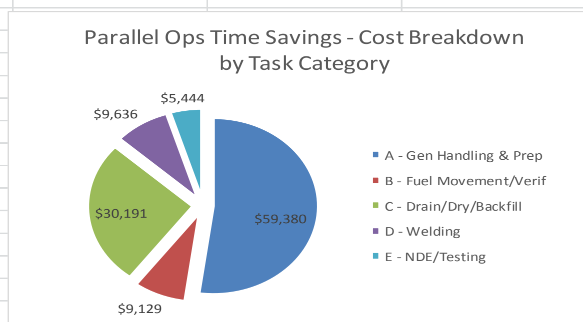




Total Estimated Cost Baseline = $135185 per STAD

Total Estimated Technology Cost Savings = $4471 per STAD





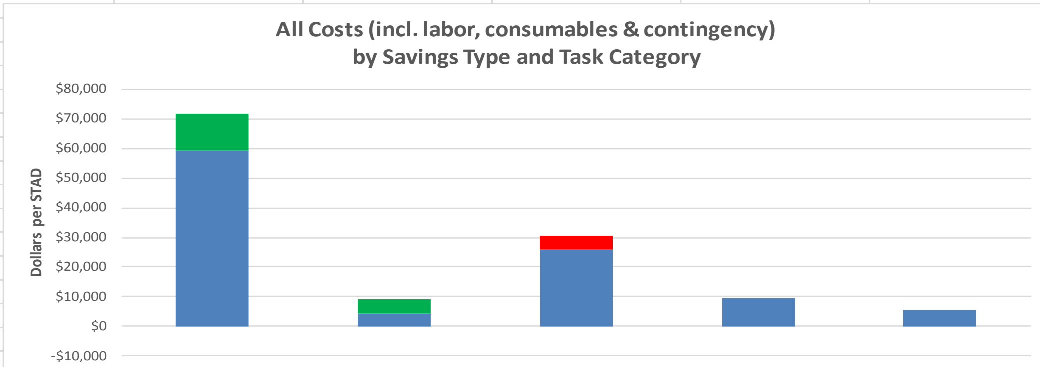
Total Estimated Technology and Parallel Cost Savings = $109308 per STAD

Total Estimated Parallel Cost Savings = $21406 per STAD

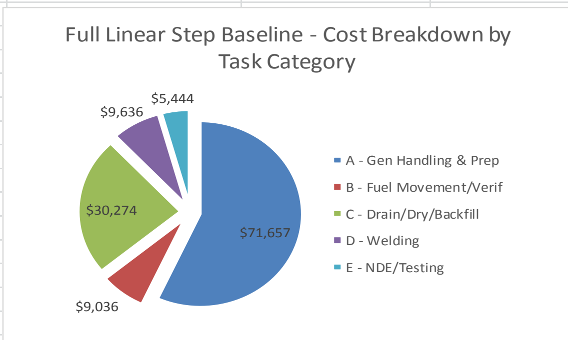
Figure 7-3. Cost Allocations for Large BWR STADs

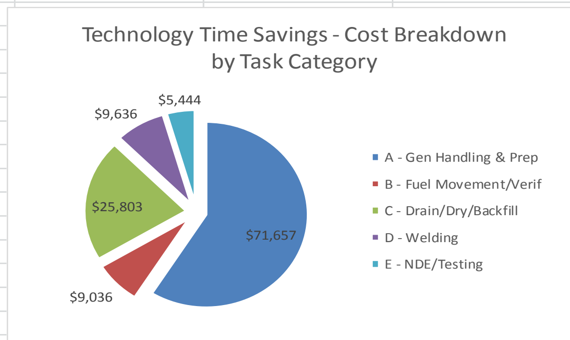
7.4.2 Cost Allocations for Large PWR STADs

Figure 7-4 includes cost allocations for Large PWR STADs (reference Figure 5-6).



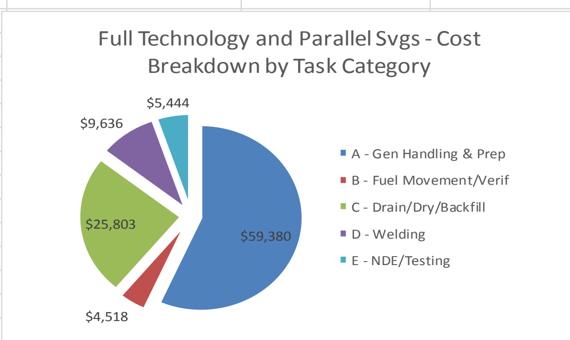
	A - Gen Handling & Prep	B - Fuel Movement/Verif	C - Drain/Dry/Backfill	D - Welding	E - NDE/Testing
Parallel Operations Time Savings	$12,277	$4,518	$0	$0	$0
Technology Time Savings	$0	$0	$4,471	$0	$0
Full Technology and Parallel Svgs	$59,380	$4,518	$25,803	$9,636	$5,444

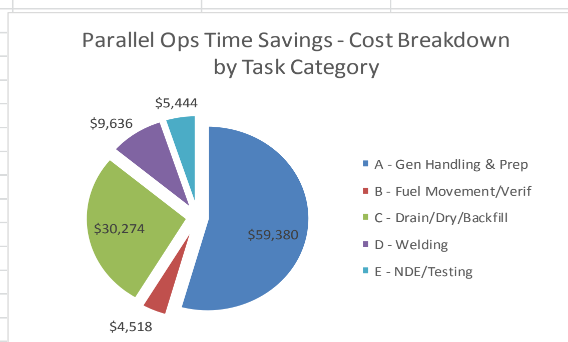




Total Estimated Cost Baseline = $126046 per STAD

Total Estimated Technology Cost Savings = $4471 per STAD





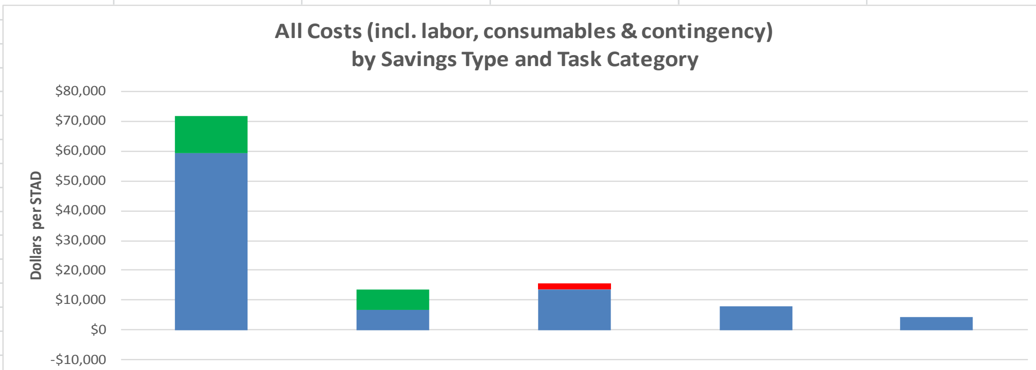
Total Estimated Technology and Parallel Cost Savings = $104780 per STAD

Total Estimated Parallel Cost Savings = $16795 per STAD

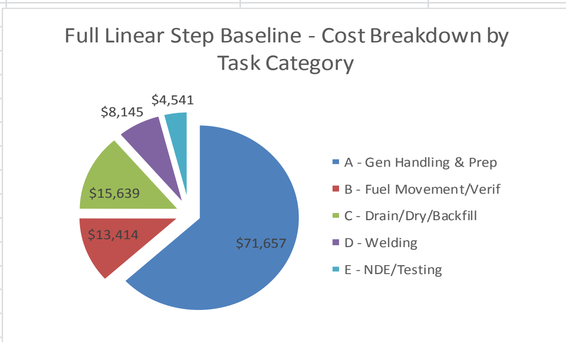
Figure 7-4. Cost Allocations for Large PWR STADs

7.4.3 Cost Allocations for Medium BWR STADs

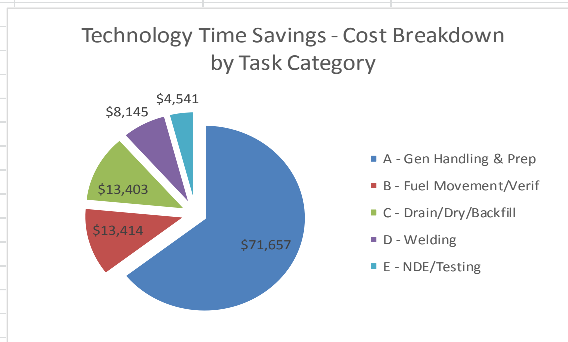
Figure 7-5 includes cost allocations for Medium BWR STADs (reference Figure 5-7).



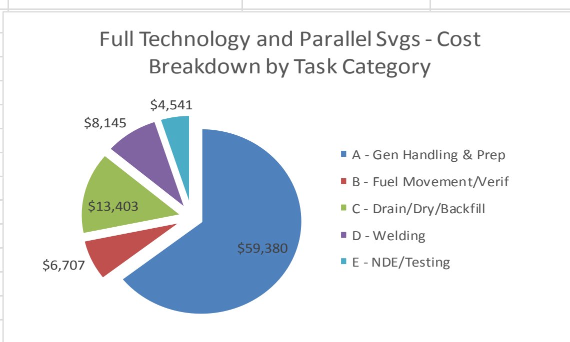
	A - Gen Handling & Prep	B - Fuel Movement/Verif	C - Drain/Dry/Backfill	D - Welding	E - NDE/Testing
Parallel Operations Time Savings	$12,277	$6,707	$0	$0	$0
Technology Time Savings	$0	$0	$2,236	$0	$0
Full Technology and Parallel Svgs	$59,380	$6,707	$13,403	$8,145	$4,541



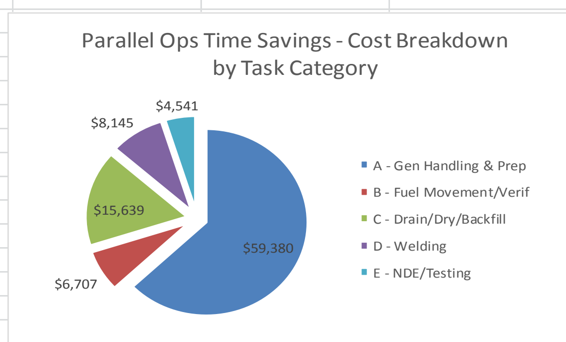
Total Estimated Cost Baseline = $113395 per STAD



Total Estimated Technology Cost Savings = $2236 per STAD



Total Estimated Technology and Parallel Cost Savings = $92176 per STAD

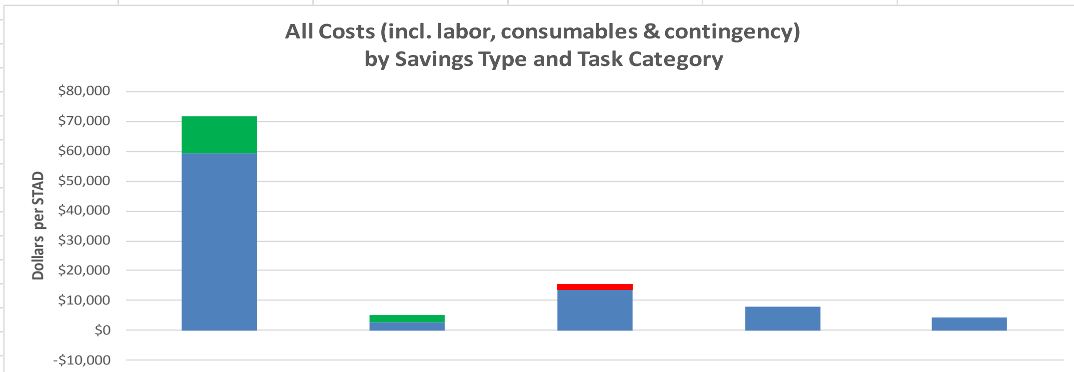


Total Estimated Parallel Cost Savings = $18984 per STAD

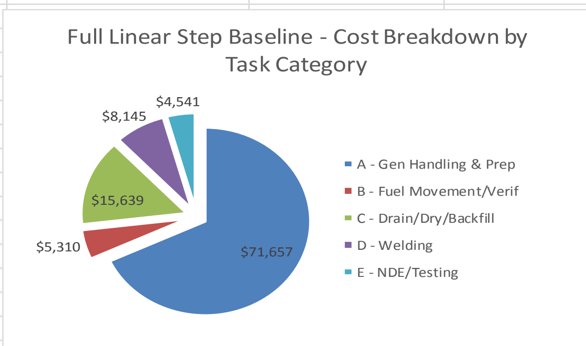
Figure 7-5. Cost Allocations for Medium BWR STADs

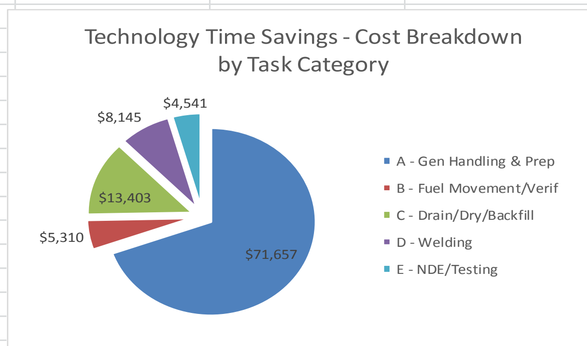
7.4.4 Cost Allocations for Medium PWR STADs

Figure 7-6 includes cost allocations for Medium PWR STADs (reference Figure 5-8).



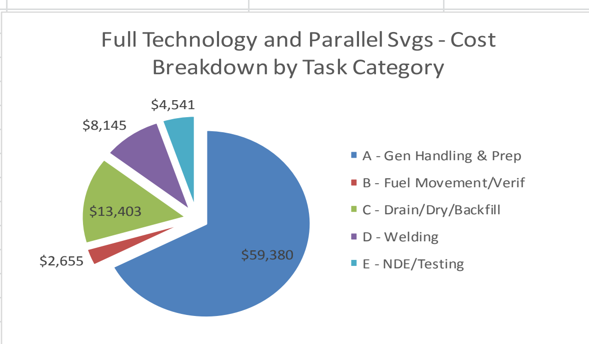
	A - Gen Handling & Prep	B - Fuel Movement/Verif	C - Drain/Dry/Backfill	D - Welding	E - NDE/Testing
Parallel Operations Time Savings	$12,277	$2,655	$0	$0	$0
Technology Time Savings	$0	$0	$2,236	$0	$0
Full Technology and Parallel Svgs	$59,380	$2,655	$13,403	$8,145	$4,541

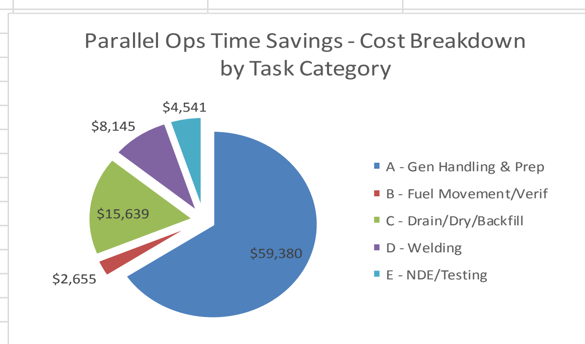




Total Estimated Cost Baseline = $105291 per STAD

Total Estimated Technology Cost Savings = $2236 per STAD





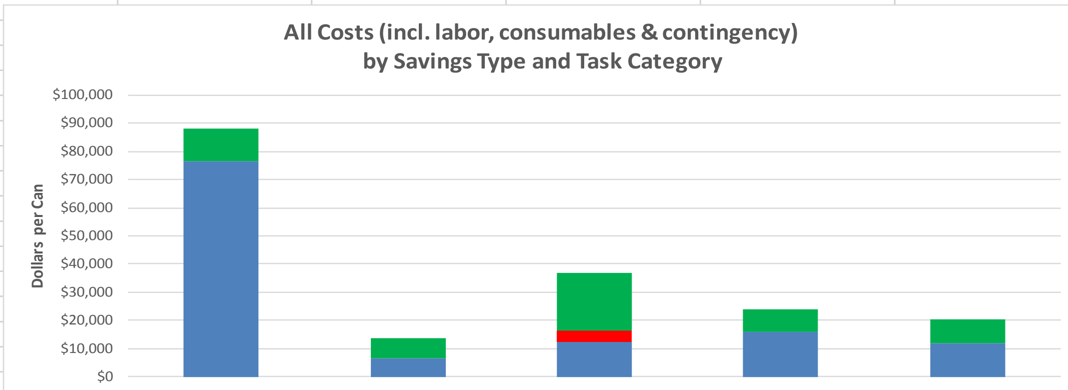
Total Estimated Technology and Parallel Cost Savings = $88124 per STAD

Total Estimated Parallel Cost Savings = $14932 per STAD

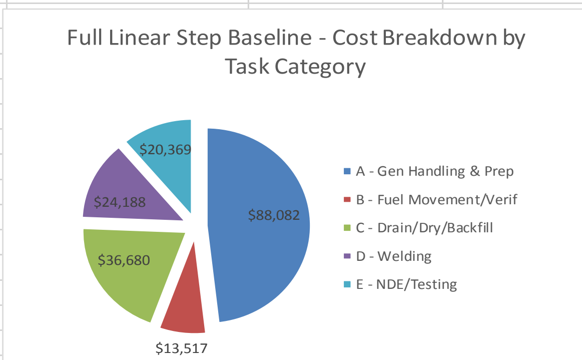
Figure 7-6. Cost Allocations for Medium PWR STADs

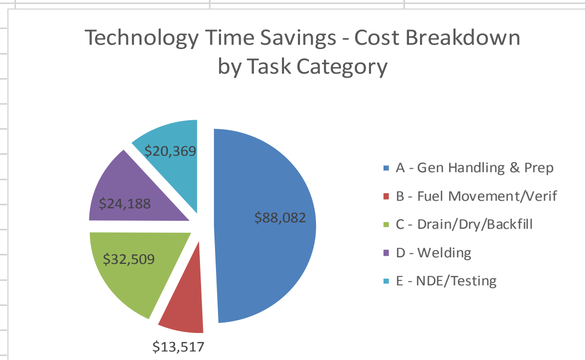
7.4.5 Cost Allocations for Small BWR STADs-in-Can

Figure 7-7 includes cost allocations for Small BWR STADs-in-Can (reference Figure 5-9).



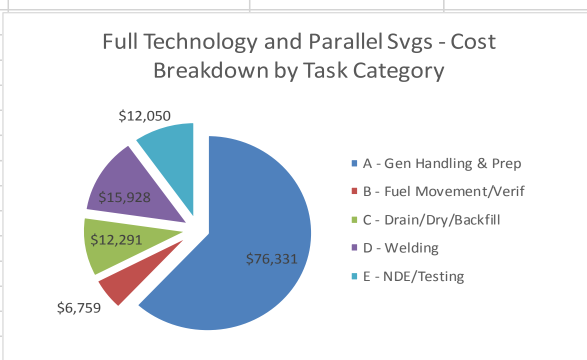
	A - Gen Handling & Prep	B - Fuel Movement/Verif	C - Drain/Dry/Backfill	D - Welding	E - NDE/Testing
Parallel Operations Time Savings	$11,751	$6,759	$20,219	$8,260	$8,319
Technology Time Savings	$0	$0	$4,171	$0	$0
Full Technology and Parallel Svgs	$76,331	$6,759	$12,291	$15,928	$12,050

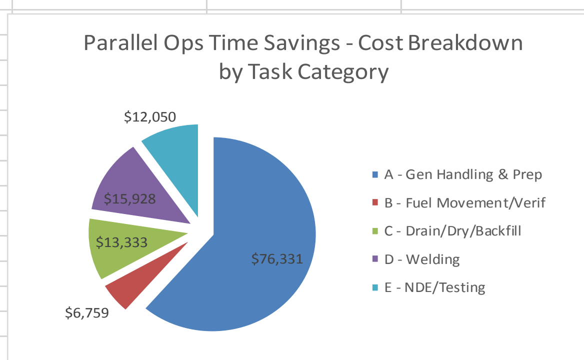




Total Estimated Cost Baseline = $182836 per Can

Total Estimated Technology Cost Savings = $4171 per Can





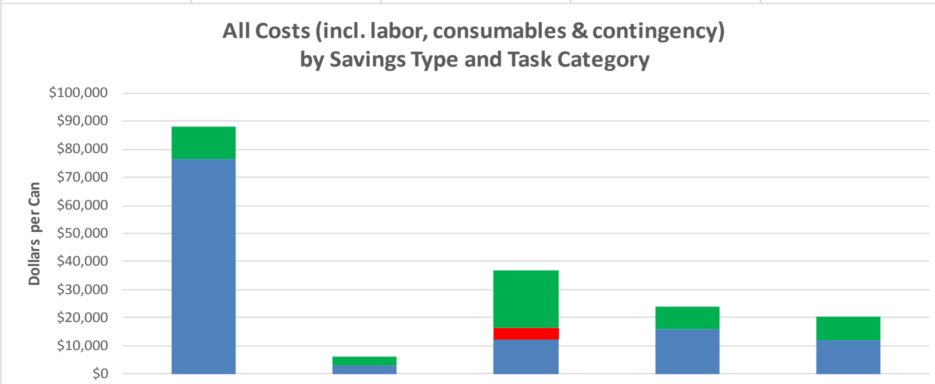
Total Estimated Technology and Parallel Cost Savings = $123359 per Can

Total Estimated Parallel Cost Savings = $58435 per Can

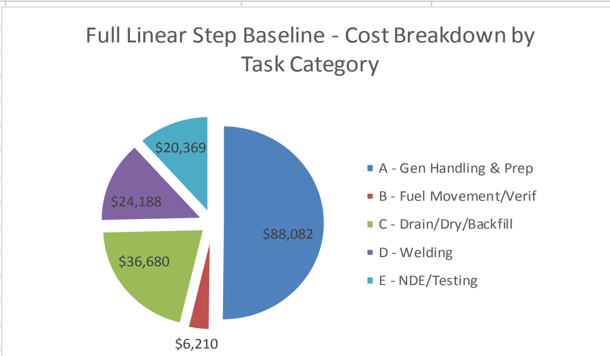
Figure 7-7. Cost Allocation for Small BWR STADs-in-Can

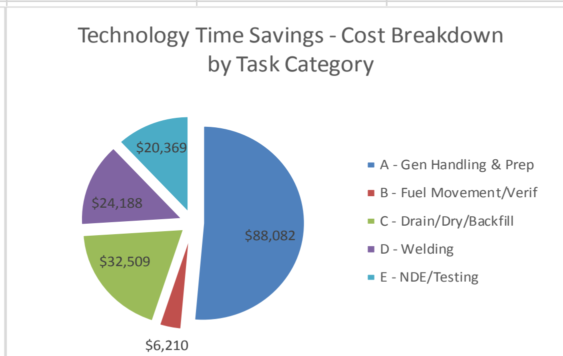
7.4.6 Cost Allocations for Small PWR STADs-in-Can

Figure 7-8 includes cost allocations for Small PWR STADs-in-Can (reference Figure 5-10).



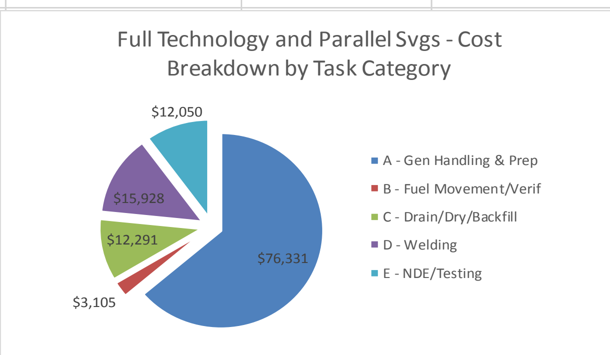
	A - Gen Handling & Prep	B - Fuel Movement/Verif	C - Drain/Dry/Backfill	D - Welding	E - NDE/Testing
Parallel Operations Time Savings	$11,751	$3,105	$20,219	$8,260	$8,319
Technology Time Savings	$0	$0	$4,171	$0	$0
Full Technology and Parallel Svgs	$76,331	$3,105	$12,291	$15,928	$12,050

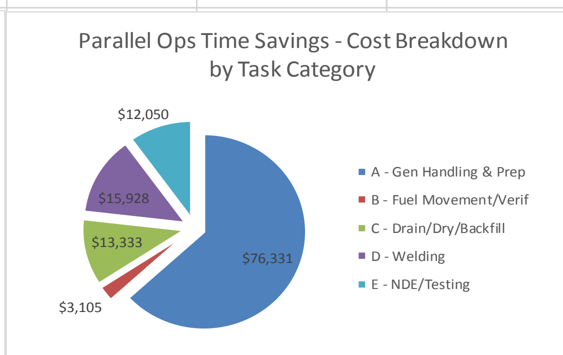




Total Estimated Cost Baseline = $175529 per Can

Total Estimated Technology Cost Savings = $4171 per Can





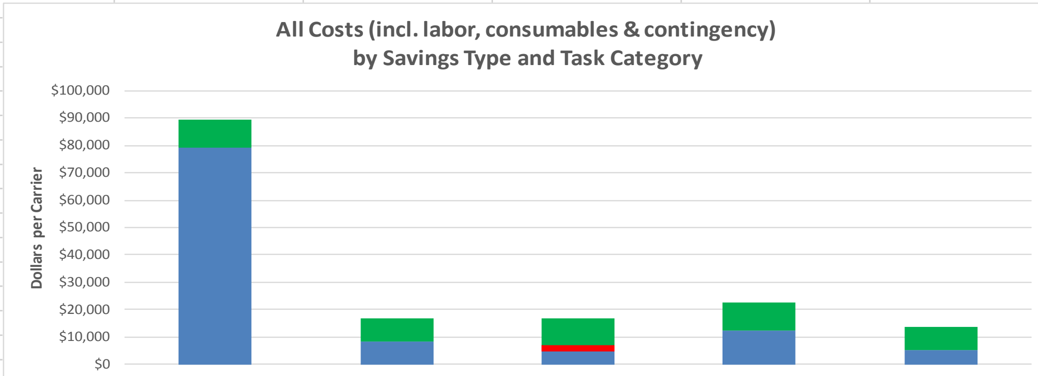
Total Estimated Technology and Parallel Cost Savings = $119705 per Can

Total Estimated Parallel Cost Savings = $54781 per Can

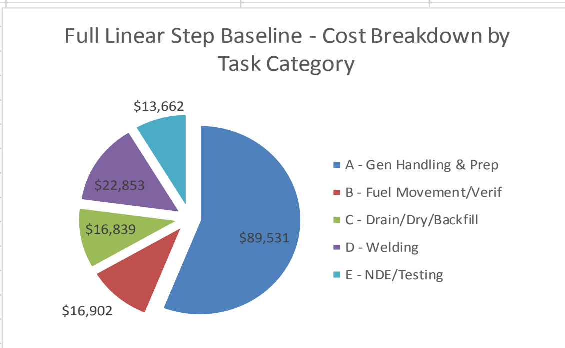
Figure 7-8. Cost Allocations for Small PWR STADs-in-Can

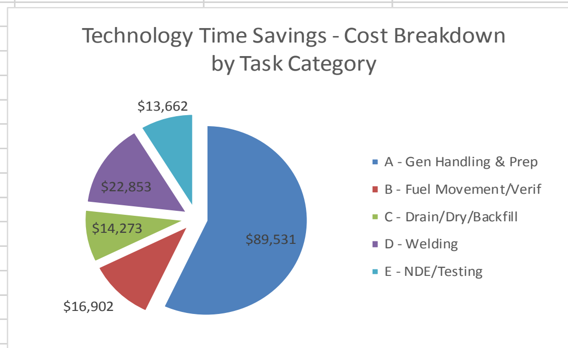
7.4.7 Cost Allocations for Small BWR STADs-in-Carrier

Figure 7-9 includes cost allocations for Small BWR STADs-in-Carrier (reference Figure 5-11).



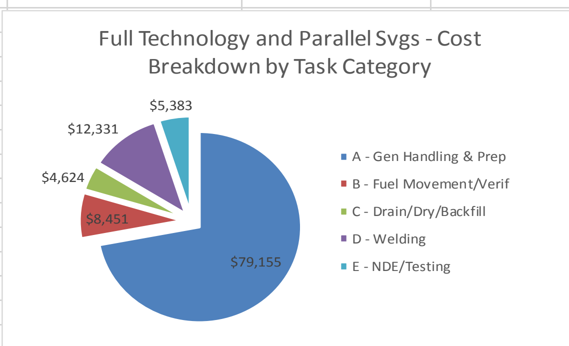
	A - Gen Handling & Prep	B - Fuel Movement/Verif	C - Drain/Dry/Backfill	D - Welding	E - NDE/Testing
Parallel Operations Time Savings	$10,376	$8,451	$9,649	$10,522	$8,279
Technology Time Savings	$0	$0	$2,567	$0	$0
Full Technology and Parallel Svgs	$79,155	$8,451	$4,624	$12,331	$5,383

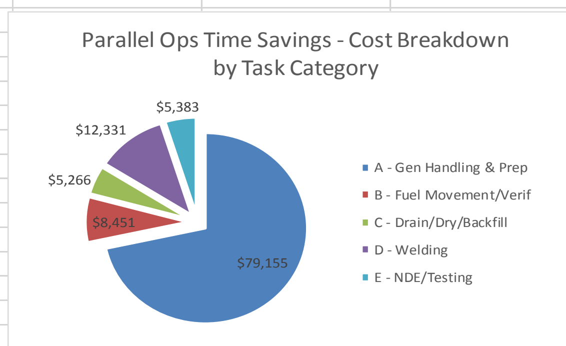




Total Estimated Cost Baseline = $159787 per Carrier

Total Estimated Technology Cost Savings = $2567 per Carrier





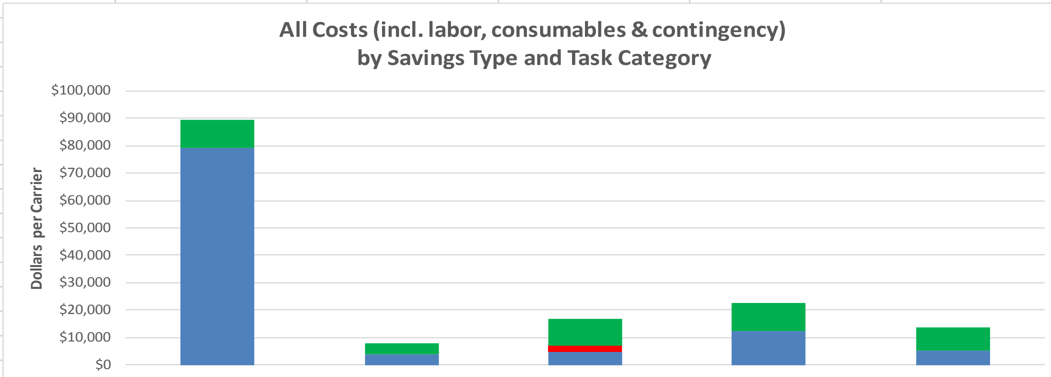
Total Estimated Technology and Parallel Cost Savings = $109943 per Carrier

Total Estimated Parallel Cost Savings = $49202 per Carrier

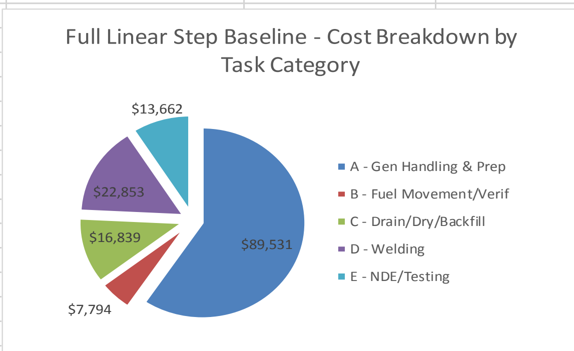
Figure 7-9. Cost Allocations for Small BWR STADs-in-Carrier

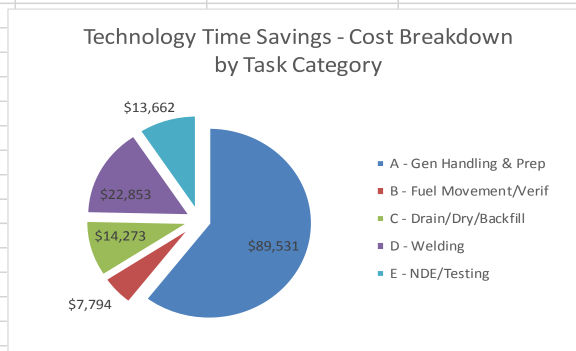
7.4.8 Cost Allocations for Small PWR STADs-in-Carrier

Figure 7-10 includes cost allocations for Small PWR STADs-in-Carrier (reference Figure 5-12).



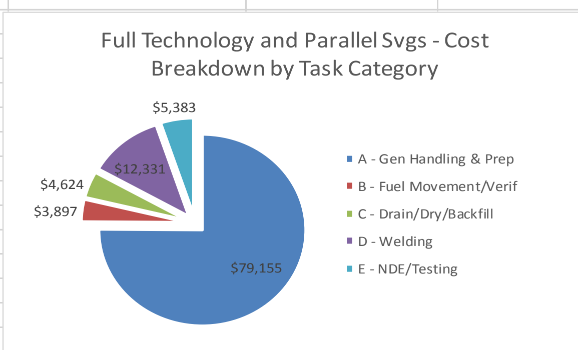
	A - Gen Handling & Prep	B - Fuel Movement/Verif	C - Drain/Dry/Backfill	D - Welding	E - NDE/Testing
Parallel Operations Time Savings	$10,376	$3,897	$9,649	$10,522	$8,279
Technology Time Savings	$0	$0	$2,567	$0	$0
Full Technology and Parallel Svgs	$79,155	$3,897	$4,624	$12,331	$5,383

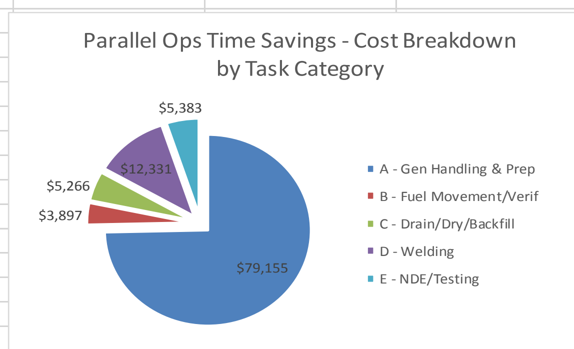




Total Estimated Cost Baseline = $150679 per Carrier

Total Estimated Technology Cost Savings = $2567 per Carrier





Total Estimated Technology and Parallel Cost Savings = $105389 per Carrier

Total Estimated Parallel Cost Savings = $44648 per Carrier

Figure 7-10. Cost Allocations for Small PWR STADs-in-Carrier

Some additional explanation on the detailed costs relates to the welders. For the small STADs, up to four welders have been estimated for each of the processes. This can be seen by referring to Appendix D tables 15-7 through 15-10. In tables 15-7 and 15-8 (STADs-in-Can), four welders are required to complete the following steps: B4 - Perform welding of 4 STAD inner lids (all passes), and B14 -Weld Can lid. In Tables 15-9 and 15-10 (STADs-in-Carrier), four welders are required to complete the following steps: B6 - Perform welding of 4 STAD inner lids (all passes), B9 - Perform welding of 4 STAD outer lids (all passes), and B14 - Weld & Test STAD inner siphon and vent port covers (all 8).

7.5 CASK SYSTEMS AND OTHER CAPITAL COSTS

This section provides STAD cask systems and other capital costs. Table 7-9 depicts cask system costs for STADs as well as for the benchmark DPC casks.

Table 7-9. Comparative Cask System Costs

COST ELEMENT (current year 2015 $; includes contingency at 20%)	BWR				PWR				Benchmark (87 BWR-DPC)	Benchmark (37 PWR DPC)
	Large STAD (44B)	Medium STAD (32B)	Small STADs-in-Can (9B)	Small STADs-in-Carrier (9B)	Large STAD (21P)	Medium STAD (12P)	Small STADs-in-Can (4P)	Small STADs-in-Carrier (4P)		
Canister(s)	$684,740	$497,993	$560,242	$560,242	$575,020	$328,583	$438,110	$438,110	$835,055	$835,055
Can/Carrier (as applicable)	na	na	$173,719	$429,188	na	na	$173,719	$429,188	na	na
Storage Overpack	$347,413	$317,203	$360,000	$360,000	$347,413	$317,203	$360,000	$360,000	$548,005	$548,005
Transfer Cask	$795,757	$726,560	$824,588	$824,588	$795,757	$726,560	$824,588	$824,588	$1,539,632	$1,539,632

Costs in the above table are derived as follows:

1. Canister(s) – Costs for the small STADs are derived from the Energy*Solutions* team Task Order 18 estimates of $116,717 and $91,273 for the 9B and 4P, respectively. In Table 7-9, each estimate is multiplied by 4 to arrive at a total sub-system cost for the four canisters. Costs for the medium and large STAD canisters are each scaled up from the 9B or 4P single canister estimates based on per assembly prices of $12,969 and $22,818 for the 9B and 4P, respectively. This line of reasoning was based on discussions with cask designers on the Energy*Solutions* Task Order 21 team, and the specific calculations are as follows

Per Assembly Price for 9B = $116,717 / 9 assemblies = $12,968.56 per assembly

*32B Canister Price = $12,968.56 * 32 * (1+20% contingency) = $497,993*

*44B Canister Price = $12,968.56 * 44 * (1+20% contingency) = $684,740*

Per Assembly Price for 4P = $91,273 / 4 assemblies = $22,818.25 per assembly

*12P Canister Price = $22,818.25 * 12 * (1+20% contingency) = $328,583*

*21P Canister Price = $22,818.25 * 21 * (1+20% contingency) = $575,020*

Finally, the canister costs for the 87 BWR and 37 PWR DPCs are derived from average costs from DOE's 2005 *Cask Capability Assessment Report*, increased by 3 percent per year for inflation. A contingency of 20% has been added to all canister estimates.

2. Can/Carrier – The estimates for the 9B/4P carrier are derived from the Energy*Solutions* team Task Order 18 estimate of $357.657. Based on discussions within the Energy*Solutions* Task Order 21 team, the cost of the can was adjusted from that of the carrier based on their relative weights (17,000 lbs for the can versus 42,000 lbs for the carrier). This adjustment reflects fewer materials and components as well as corresponding reductions in labor required to develop and assemble these materials and components. A contingency of 20% has been added to all can/carrier estimates.

3. Storage Overpack – The estimates for the 9B/4P storage overpacks are derived from the Energy*Solutions* team Task Order 18 estimate of $300,000. Costs for the medium and large STAD transfer casks are each scaled from the 9B/4P transfer cask estimate based on the storage overpack outside diameters found in the Energy*Solutions* Task Order 12 report for the small, medium, and large (typical TAD) diameters of 143 in., 126 in., and 138 in., respectively. Based on discussions with members of the Energy*Solutions* team, outside diameter was deemed to be a reasonable scaling factor that would reflect proportionate scaling and also take into account the incorporation of additional shielding for the larger casks (if needed). The storage overpack cost for the 87 BWR and 37 PWR DPCs is derived from average costs in DOE's 2005 *Cask Capability Assessment Report,* increased by 3 percent per year for inflation. A contingency of 20% has been added to all storage overpack estimates.

4. Transfer Cask – The estimate for the 9B/4P transfer cask is derived from the Energy*Solutions* team Task Order 18 estimate of $687,157. Costs for the medium and large STAD transfer casks are each scaled from the 9B/4P transfer cask estimate based on the storage overpack outside diameters. Whereas the transfer cask diameter is less

than that for the storage overpack, proportionately the deltas from one size to the next are about the same. The transfer cask cost for the 87 BWR and 37 PWR DPCs is derived from average costs in DOE's 2005 *Cask Capability Assessment Report*, increased by 3 percent per year for inflation. A contingency of 20% has been added to all transfer cask estimates.

5. Contingency –A contingency of 20 percent applied to the individual elements is consistent with DOE guidance of 10 percent to 40 percent for budget or preliminary estimates (i.e., from DOE G 413.3-21, *Cost Estimating Guide*).

Table 7-10 provides other capital costs including selected equipment and facilities.

Table 7-10. Other Costs

COST ELEMENT (current year 2015 $; includes contingency at 20%)	**Cost**
Welding Equipment	$90,000
Welding Equip. (parallel)	$360,000
Vacuum Drying Equipment	$112,210
Vacuum Drying Equip. (Smart)	$510,000
Canister Transfer Facility (CTF)	$2,760,000
Crawler for CTF	$3,900,000

Specific estimates in the above table are derived as follows:

1. Welding equipment – This estimate is a per canister price, e.g., for one DPC. A contingency of 20% has been added. The estimate was obtained from engineering analysts at Exelon.
2. Welding equipment for parallel processing – This estimate represents the welding equipment price multiplied by 4, corresponding to the number of welders operating at the same time for a small STAD system. A contingency of 20% has been added.
3. Vacuum Drying Equipment – The vacuum drying equipment cost for all casks is derived from average costs in DOE's 2005 *Cask Capability Assessment Report*, Table 3, increased by 3 percent per year for inflation and by 20% for contingency.
4. Vacuum Drying Equipment (smart drying technology) – This estimate includes the vacuum drying equipment, plant modifications and ancillary activities (Testing & Qualification, procedures, dry runs). A contingency of 20% has been added. The estimate was obtained from engineering analysts at Exelon, who checked with a vendor.

5. Canister Transfer Facility (CTF) – This is a conceptual estimate for a CTF on or near an existing pad. The estimate includes $500,000 for design plus up to $1,000,000 for construction, plus $300,000 for a steel shell for the CTF, plus $ 500,000 for project management and a design change package. A contingency of 20% has been added. It is possible that the initial $500,000 design fee could be waived as part of a cask order contract. The estimate was obtained from engineering analysts at Exelon.
6. Crawler for the CTF –This is a conceptual estimate for the crawler for the CTF, if needed. A contingency of 20% has been added. The estimate was obtained from engineering analysts at Exelon.
7. Contingency –A contingency of 20 percent applied to the individual elements is consistent with DOE guidance of 10 percent to 40 percent for budget or preliminary estimates.

7.6 COMPARISON OF OPERATIONAL COSTS FOR THE ENTIRE SIX YEARS UNDER THE RECOMMENDED APPROACH

This section compares operational costs for the entire six years under the recommended approach, i.e., process time margins at maximum campaign intervals. Table 7-11 shows operations costs for the DPCs and the four types of STADs for all nine operational cases. This table provides cost information corresponding to Table 6-1 from the timing study.

As the table shows, all STAD types would cost more than DPCs on a per assembly and total cost basis. For the STADs themselves, the Large STAD shows the lowest cost. Overall percentage cost increases for STADs over DPCs range from the 25% (BWR) to 35% (PWR) range for the Large STAD, to the 55% - 85% range for the Small STADs-in-Carrier, to higher percentage increases for the Medium STAD and the Small STADs-in-Can. Having said this, these extra costs would likely be offset by avoiding the need to repackage a portion of the SNF before it can be consigned to a geologic repository. In addition, as with previous operational estimates in this section, mobilization and demobilization costs are not included in the operational estimates.

Table 7-11. Process Costs at Recommended Campaign Intervals

Table 7-11. Process Costs at Recommended Campaign Intervals (reference Tables 6-1 & 5-14 to 5-21)

Operational Case Number	Fuel Type	Number of Reactors On Site	Operating cycle length (months)	DPC (Reference) Interval (months)	Campaigns/6 yrs	Assembly Throughput Requirements (6 years)	Required DPCs/6 years	Assemblies Per DPC	Cost Per Assembly (reference)	Total Cost (6 years)
1	BWR	1	18	72	1	900	11	87	$1,851	$1,771,734
2		1	24	72	1	900	11			$1,771,734
3		2	24	36	2	1800	21			$3,382,401
4		3	24	36	2	2700	32			$5,154,134
5	PWR	1	18	72	1	370	10	37	$3,539	$1,309,534
6		1	24	72	1	370	10			$1,309,534
7		2	18	36	2	740	20			$2,619,068
8		2	24	36	2	740	20			$2,619,068
9		3	18	36	2	1110	30			$3,928,601

Operational Case Number	Large STAD Interval (months)	Campaigns/6 yrs	Assembly Throughput Requirements (6 years)	Required STADs/6 years	Assemblies Per STAD	Cost Per Assembly (optimized)	Total Cost (6 years)	Medium STAD Interval (months)	Campaigns/6 yrs	Assembly Throughput Requirements (6 years)	Required STADs/6 years	Assemblies Per STAD	Cost Per Assembly (optimized)	Total Cost (6 years)
1	36	2	900	21	44	$2,484	$2,295,470	36	2	900	29	32	$2,880	$2,673,096
2	36	2	900	21			$2,295,470	36	2	900	29			$2,673,096
3	24	3	1800	41			$4,481,631	24	3	1800	57			$5,254,016
4	18	4	2700	62			$6,777,101	18	4	2700	85			$7,834,936
5	72	1	370	18	21	$4,990	$1,886,039	36	2	370	31	12	$7,344	$2,731,835
6	72	1	370	18			$1,886,039	36	2	370	31			$2,731,835
7	36	2	740	36			$3,772,078	24	3	740	62			$5,463,669
8	36	2	740	36			$3,772,078	24	3	740	62			$5,463,669
9	24	3	1110	53			$5,553,337	18	4	1110	93			$8,195,504

Operational Case Number	Small STADs-in-Can Interval (months)	Campaigns/6 yrs	Assembly Throughput Requirements (6 years)	Required STADs/6 years	Assemblies Per STAD	Cost Per Assembly (optimized)	Total Cost (6 years)	Small STADs-in-Carrier Interval (months)	Campaigns/6 yrs	Assembly Throughput Requirements (6 years)	Required STADs/6 years	Assemblies Per STAD	Cost Per Assembly (optimized)	Total Cost (6 years)
1	36	2	900	100	9	$3,427	$3,083,969	36	2	900	100	9	$3,054	$2,748,586
2	36	2	900	100			$3,083,969	36	2	900	100			$2,748,586
3	24	3	1800	200			$6,167,938	24	3	1800	200			$5,497,171
4	18	4	2700	300			$9,251,906	18	4	2700	300			$8,245,757
5	36	2	370	93	4	$7,482	$2,783,146	72	1	370	93	4	$6,587	$2,450,304
6	36	2	370	93			$2,783,146	72	1	370	93			$2,450,304
7	24	3	740	185			$5,536,366	36	2	740	185			$4,874,261
8	24	3	740	185			$5,536,366	36	2	740	185			$4,874,261
9	18	4	1110	278			$8,319,512	24	3	1110	278			$7,324,565

8 RESEARCH AND DEVELOPMENT RECOMMENDATIONS

The following Research and Development (R&D) activities are recommended.

8.1 RESIDUAL MOISTURE REMOVAL USING ULTRA-DRY NITROGEN

From the Team's review of options for drying the internals of the STADs, many commercial drying options were identified, but most of those processes are incompatible with drying SNF. Some of the processes used industrially, like use of triethylene glycol (TEG) as a desiccant, involve chemicals that could cause complicated interactions with the fuel cladding. Others, like use of supercritical nitrous oxide, are highly oxidizing and would potentially have very deleterious effects on SNF fuel. Still others rely on mechanical processes involving substantial gas flows through the cavity to be dried and these are incompatible with the small orifices penetrating the STAD containments.

There was one option that did not involve any chemical or mechanical attributes that otherwise would automatically preclude its use in drying the interior of the STADs. This is the drying process used in manufacture of lasers and other electro-optical equipment used at high altitudes by the air and space industries. Drying of these highly specialized systems is critical to avoid the negative impacts of condensation at the very low temperatures experienced at high altitudes and in space. For these applications, ultra-dry nitrogen with a dew point of -94°F is introduced under pressure into an enclosure or cavity where it is allowed to reach moisture equilibrium with internal components. The extremely dry nitrogen not only removes moisture from the atmosphere in the enclosure, but also removes moisture entrained in hygroscopic materials within the enclosure. The process involves introduction of the extraordinarily dry nitrogen under pressure, allowing it to absorb moisture from the cavity and then exhausting it from the cavity. This process is repeated until the humidity of the exhausted nitroge n reaches the desired level. This process creates a much drier internal environment than can be achieved by the use of standard desiccants. Nitrogen purging is normally accomplished through commercially available purging systems like those provided by AGM Container Controls of Arizona.

Background information this team found on the industrial use of ultra-dry nitrogen for moisture removal was focused on drying small cavities. It is a common process for removing moisture in aviation instruments and small electro-optical devices (rangefinders, thermal imagers, long range surveillance systems, etc.). In these applications, use of enhanced nitrogen drying systems reduces drying time substantially over traditional moisture purging systems. In addition, the pressurized dry nitrogen process was more effective at removing moisture entrained in hygroscopic materials than traditional dry, hot purge systems. How well this process would work with the much larger cavities involved with SNF storage is unknown. The time required to achieve a comparable level of internal dryness provided by vacuum systems is also unknown. The benign nature of ultra-dry nitrogen moisture removal and the effectiveness of the process in aerospace applications would suggest it is worth investigating for SNF canister drying applications. Given the uncertain availability of helium and price fluctuations driven by helium supply uncertainty, there are many reasons to pursue R&D on the effectiveness of this process both as a drying process and as a permanent fill for SNF storage applications.

8.2 DEVELOPMENT OF A MULTIPLE SMALL STAD CANISTER WELDING MACHINE

As described in Appendix J of this report, discussions with Liburdi Automation indicated that welding up to four small STAD canisters in parallel (on the basis of using remote controlled welders and a welding technician assigned to each small STAD canister) is achievable, subject to the completion of a welding development program. The time and motion studies completed for the small STAD canisters have assumed that four canisters, loaded in a carrier, will be welded in parallel and thus, completing the above welding development program is necessary to underpin the STAD-in-carrier operational approach. Budgetary information received from Liburdi Automation is provided below and forms the basis of the estimate detailed in Appendix J.

- Total budgetary cost for the welding development program for the remote welding of four small STAD canisters in parallel is $232,940 (without any contingency applied).
- Estimated scheduled for the welding development program is four months (without any contingency applied).

8.3 DEVELOPMENT OF A STANDARDIZED AND OPTIMIZED DRYING SYSTEM FOR USE WITH STAD CANISTER SYSTEM

In concert with a recommendation (see Section 9) that dedicated and experienced nuclear work loading teams be used in conjunction with a standard set of procedures that can be tailored to site specific conditions, the following R&D activity is recommended in order to avoid start-up problems during a loading campaign using STAD canisters. To ensure that the drying system used with the STAD canisters is optimized for use with the canister design it is recommended that a standardized and automated drying system be developed. As described in this report (see Appendix G), automated drying systems have been shown to reduce drying times. Developing such a system that is specifically designed for the STAD canister system and utilizes standard operating procedures would provide the option for multiple units to be produced and deployed to utilities ahead of loading campaigns. A unit could also be utilized in a central training facility, where fuel transfer operations personnel can be trained on using the STAD canister system, including the standardized drying system and any welding systems that is specifically designed for the STAD canisters, i.e., four small STAD welding system.

9 CONCLUSIONS AND RECOMMENDATIONS

Timing studies have been performed using process inputs from the Zion dry fuel storage loading campaign as baseline data to determine whether STADs, which are inherently less efficient due to their smaller capacities than the large DPC technology typically used at operating nuclear power plant facilities, can nevertheless be used effectively for loading SNF into dry storage at these facilities. Because of the size of the Zion campaign, and its completion date, the Zion data provides the best source currently available for both dry fuel storage technology and fuel loading process practices.

The baseline data were adapted to each of the eight STAD configurations analyzed (Large, Medium, and Small STADs-in-Can and STADs-in-Carrier for both BWR and PWR fuel types) using scaling assumptions for size-dependent process steps such as welding, vacuum drying, etc. In order to be a viable technology, STADs must be capable of reaching sufficient loading throughput to meet plant operational needs. Several technology improvements were identified that could be applied to STAD loading to lessen the throughput gap between the various STAD system options and the large DPC system throughput performance. The improvements included "smart" vacuum drying technology, and employing two transfer casks to minimize unnecessary down time. The Small STAD system is at the greatest relative throughput disadvantage; and so additional time-saving measures were considered including two concepts for handling Small STADs four at a time, and also for performing parallel draining, drying, and sealing operations. Overall, the various improvements promise to accelerate STAD loading times by 16-40%.

The throughput results for the various STAD systems (see Table 5-14 through Table 5-19) were compared against nine plant operating scenarios to determine whether the STAD systems had the potential to meet plant throughput requirements, recommend appropriate fuel loading campaign frequencies, and quantify the estimated margin by which the systems could meet plant needs. Table 6-1 shows the results of the evaluation.

In general, the Large and Small STADs are capable of providing the required loading throughput requirements at all NPPs. The Medium STAD systems also met required loading throughputs but had the smallest margins and lowest overall performance and so would not be recommended for the NPP scenarios with higher throughput requirements. Nevertheless, all STAD system options appear to be capable of working at most, if not all, sites, depending on the loading campaign frequency.

All STAD canister types would cost more than DPCs on a per assembly and total cost basis. For the STADs themselves, the Large STAD shows the lowest cost. Overall percentage cost increases for STADs over DPCs range from the 25% (BWR) to 35% (PWR) range for the Large

STAD, to the 55% to 85% range for the Small STADs-in-Carrier, to higher percentage increases for the Medium STAD and the Small STADs-in-Can. Having said this, these extra costs would likely be offset by avoiding the need to repackage a portion of the SNF before it can be consigned to a geologic repository. Mobilization and demobilization costs are not included in the operational cost estimates.

A number of recommendations have also been identified during the course of the work on Task Order 21.

1. To be able to achieve optimum drying times for future STAD canister systems and validate the assumptions made in this study, noting that fuel assembly age and condition can also be significant factors in canister vacuum drying durations, two recommendations of this study are:

    a. The STAD canisters need to incorporate materials (e.g., metal matrix composite neutron absorber plates, rather than borated aluminum) and design features that minimize the amount of residual water retained after canister blow-down.

    b. A standardized and automated drying system should be developed, which is optimized for use with the STAD canister design and loading configuration.

2. It has been assumed that the four small STAD canisters loaded in a carrier (or overpack can) will be welded in parallel using independent remote controlled welding machines. In order to validate this assumption, it is necessary to complete the welding development program described in Section 8.2.

3. There are real advantages to using more than one transfer cask, so that loaded STAD canisters (medium, large, or small STADs in a can or a carrier) can be transferred to the storage overpacks outside of the fuel handling building, while STAD loading into the second transfer cask is taking place in parallel in the fuel handling building. The impact of using dual transfer casks was assessed as part of this study.

    It should be noted that the above discussion addresses a PWR Light Water Reactor (LWR) design with a Fuel Handling Building. However, a similar configuration could be established for BWR LWRs; most of which do not have a separate Fuel Handling Building.

4. In order to avoid startup problems due to personnel lacking experience in fuel transfer operations and working in a nuclear safety work environment, it would be advantageous to have dedicated, experienced, STAD canister loading crews, in addition to a set of standard procedures, which can be easily adapted for site specific conditions.

These crews could either be internal to utilities or provided by a third party and thus move between NPPs as required. These crews could also use automated canister drying and welding systems, which are designed and optimized for the STAD canister system in use and for which offsite training and familiarization of the equipment could be provided prior to a loading campaign.

As a final point, Appendix F provides a database of the key characteristics relative to the use of dry storage systems at operational nuclear power plants, e.g., dual units that share a single spent fuel pool, dual units with separate pools, but only one decontamination pit, etc. This emphasizes the importance of completing, prior to a dry storage loading campaign, an analysis of the choreography regarding the handling and staging of storage overpacks, transfer casks, and moving components through hatches. Integrated dry-runs should also be performed prior to loading campaigns. The bottom line is that fully optimized STAD canister dry storage loading processes and drying/welding equipment can be fully in place but, as detailed in Sections 5.2.3 through 5.2.10, if attention is not paid to optimizing and choreographing the general handling and preparation activities, which account for around 50% of the total duration, then the benefits of the optimized loading process and equipment will be diminished.

10 REFERENCES

10 CFR 50, Appendix A, "General Design Criteria for Nuclear Power Plants", *Code of Federal Regulations*, as amended.

10 CFR 71, "Packaging and Transportation of Radioactive Material", *Code of Federal Regulations*, as amended.

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11 APPENDICES

12 APPENDIX A - RESULTS FROM FACILITATED WORKSHOP, COLUMBIA, MD - NOVEMBER 4 - 5, 2014

The workshop was held from –November 4 - 5, 2014, at Energy*Solution*s offices in Columbia, Maryland, and was attended by representatives from all of the companies comprising the team. The workshop was facilitated by the Task Order 21 Project Manager and followed the agenda below:

- Day 1
  - Review scope of work and required delivery schedule
  - Review and Finalize Workshop Objectives
  - Phase 1 Presentations
  - Review Generic Work Process Diagram
  - Options Identification
- Day 2
  - Options Down-Select
  - Options Confirmation
  - Planning for Subsequent Phases
  - Closeout

DAY 1

Following introductions, the Task Order 21 scope of work and the required schedule for completing it were reviewed. Key dates are, as follows:

- Initial Progress Review Meeting – January 6, 2015
- Submit Preliminary Report - February 4, 2015 (Note. Subsequently revised to February 12, 2015)
- Second Progress Review Meeting – February 18, 2015 (Note. Subsequently revised to February 26, 2015)
- Submit Draft Final Report – April 15, 2015
- Final Progress Review Meeting – April 29, 2015
- Submit Final Report – May 20, 2015
- Submit Closeout Report – May 27, 2015

The following objective for the workshop was reviewed and agreed to:

<u>Workshop Objective</u>

1. To gather and share experience, knowledge, lessons learned, ideas, and recommendations pertinent to the scope of work.
2. Utilizing a generic work process flow diagram, brainstorm options, ideas and recommendations and identify candidate operational approaches, including generally

categorizing plants by their capabilities and constraints and how they might match up with loading smaller capacity STAD canisters.

3. The output from this workshop will be a set of innovative operational approaches, which are considered to be the most promising technically feasible ones. These approaches will be addressed with further scrutiny in preparation for the Initial Progress Review Meeting where progress is expected to be around 30%. Work to be completed will include:

    - Draft task descriptions;
    - Work process flow diagrams and analysis;
    - Critical sequence task analysis, e.g., canister closure, vacuum drying, handling, etc.
    - List of assumptions (including assumed facility constraints) and uncertainties for each approach;
    - Conceptual engineering to develop draft sketches and outline specifications for the STAD canister sizes considered and the storage cask concepts, transfer cask concepts and transport cask concepts plus associated ancillary equipment necessary to optimizing loading operations;
    - Initial assessment of the design concepts to meet storage and transport licensing requirements;
    - Identification of opportunities for improvement;
    - Identification of automation approaches;
    - Initial assessments of the task durations and worker dose for each of the operation approaches for reactor site operating scenarios Cases 1 and 5;
    - Preparation and delivery of a briefing to the DOE on January 6.th

Brian Gutherman and Jack Wheeler provided some context on the reasons for Task Order 21.

- Jack advised that the data collected from this task order will support work being led by ORNL for DOE to assess standardization as part of an integrated waste management system, including supporting systems analysis being conducted by ANL. Task Order 21 will provide better data on how operating plants could process smaller canisters.
- Brian mentioned that cost and personnel requirements are not drivers for this particular workshop since we are developing a range of options for DOE to consider further. Right now the desire is for a range of options that could be considered for future use, and focus should be placed on developing initial operational approaches capable of satisfying the throughput requirements specified in the statement of work. [Note: Cost estimates can be developed later after operational approaches are identified].
- Brian referenced the fact that some large Dual Purpose Canisters (DPCs) may not be disposable; smaller canisters using current designs and handling processes currently present

challenges for moving the desired amount of fuel to dry storage at operating nuclear plants because of schedule and cost considerations.

- Brian said recommendations should only include a high level assessment of licensing challenges, but to not eliminate ideas simply because of licensing concerns. We should also look at recommendations for equipment and processes that need more of an R&D effort to become viable. We just need to caveat the recommendations with the challenges they present.

Discussion on the Results from Information Gathering

The team then reviewed, via a mixture of discussions and presentations, the results of the information gathering activities performed prior to the workshop. The key points were, as follows:

1. Brian Wood provided a presentation on Zion*Solutions* experience
    a. The scope of the Zion Dry Storage project is to package 2226 assemblies for dry storage. 1665 already packaged into the Magnastor system (37 PWR DPC). 45 of 61 cask systems are loaded on the pad; with some canisters short loaded
    b. 3 fabricators used to diversify the supplier chain and reduce schedule risk.
    c. Brian provided a loading process flowchart.
    d. 75% of the fuel assemblies had to be sipped (non-destructive method used to test for failed fuel elements by investigating the fission product released in a fixed volume of spent fuel pool water) to check for cladding leaks.
    e. One big hurdle was the fact that the agreement for this decommissioning project should have exempted the fuel transfer operations from the local labor agreement because normal union laborers required considerable time to gain experience as nuclear radiation workers. Using a dedicated and experienced nuclear work team from outside of the area would have streamlined the process.
    f. Drying times for canisters are driven by the poison that is used. Boral™ poison takes up to 40 hours to dry. The metal matrix poison systems only take 10-12 hours to dry. Boral™ is cheaper to buy, but it takes more operational time on the plant floor. The engineering economic analysis performed when making material selections needs to cover more than just the fabrication of the canisters, it needs to include operational costs as part of the cost/benefit analysis. The vacuum drying process was not optimized and there is definitely an art to vacuum drying.
    g. Most of the areas for improvement were management processes, not mechanical process issues. Things like the need for standardized shift turnover briefings, the need for additional first line supervisors, the need for redundant supply chain options for supply, etc.
    h. Due to an issue with the top nozzle cracking, an instrument tube tie rod was added to allow the fuel assemblies to be handled, noting that there have been

issues where assemblies have been dropped at other sites. Once this tie rod was added the fuel was no longer considered to be damaged fuel.

i. 95 assemblies are in DFCs, including 45 high burnup assemblies.

j. Now processing 2 canisters every 9 days, but it took about 20 canisters before this processing rate was obtained. The clock starts when the DPC enters the building.

k. A fully loaded Zion Vertical Concrete Cask weighs about 314,000 lbs. The weight of a fully loaded Zion dual purpose canister is about 101,000 lbs.

l. They have redundant processing equipment and essential spares (2 chillers, 2 vacuum drying systems, 2 welders, etc.).

m. Integrated dry-runs were performed prior to operations.

n. A weld technician was added to the crew to attend to the welding machine.

o. Need to have a pre-scripted briefing - rather than craft a new one for each briefing.

2. Brian Wood and Bruce Holmgren (Zion*Solutions*) discussed damaged fuel determinations at the Yankees. Some of the determinations were made to mitigate off site transport risk. This was the case for high burnup (45 assemblies) and some other fuel for a total of 95 assemblies characterized as damaged even though not all were actually physically damaged fuel.

3. Gary Lanthrum (NAC) mentioned exploring alternate closure designs like the autoclave locking lid used for chemical weapons disposal or the twist lock lid used for sealed source canisters. He also advocated for a phased approach that uses different hardware and processes as the waste handling system changes. The status quo may be used while interim storage at utility sites is still the norm. A change may be logical when a centralized storage facility is available and another change may be useful once a repository is up and running. The regulations call for "redundant closures seals" but do not explicitly require two welded seals. It might be possible to design a single mechanical closure that does not require multiple closure bolts or expensive soft metal seal rings like the system used in autoclave furnaces. It might also be possible to design a closure that uses mechanical connections for strength and a simple seal weld for leak tightness. This would be applicable to STAD-in-Can arrangements where small spent fuel canisters might have a single welded closure and then be contained in a larger can with a mechanical closure and a simple seal weld.

4. Ray Termini (Exelon) mentioned that we should avoid focusing too closely on the current regulations and anything should be on the table at this stage. Reclamation of emptied DPCs may also be a future possibility.

5. Greg Lane (Energy*Solutions*) advised that work on pulling together information on operating facilities, e.g., facility constraints, shared pools, operating cycles, etc., is ongoing.

6. Stewart Beckwith (BAH) highlighted some of the elements, which will be important for deriving cost information for the parametric studies, e.g., training, dry-runs, spares, learning curve, upset conditions, and off normal conditions, etc.

Generic Work Process Diagram

The team then reviewed a pre-prepared generic process flow diagram for STAD canisters and a set of generic mechanical flow diagrams for packaging and storing SNF in STAD canisters. Key points from the discussion were:

1. Would having more than one transfer cask be helpful? That might depend on the floor space available so one design approach may not work at all plants.
2. Need to be careful with lifting operations moved away from the main building crane. A jib crane or auxiliary hook won't be single failure proof and may not have the lifting capacity required. This may reduce the number of options available for removing use of the main hook as a schedule constraint. You can't hoist with the auxiliary hoist and main crane hoist at the same time because they use the same trolley. It would be beneficial to do as many of the lifting and transfer operations outside of the aux. building as possible. The lid could be removed from an empty storage cask outside the fuel building with a portable crane since no nuclear material is involved. A review of the lifts that could be performed outside is worth considering.
3. Need to add the chemical analysis of boron concentrations in the water at PWR plants within 4 hours of the fuel transfer. Getting the cask vendors to use burnup credit rather than soluble boron for criticality control could be a benefit. This does not need to be investigated but should be noted in the report as a potential time saver.
4. Eliminating the step for contamination removal for the outside surface of the canister might save time at the utility, but would add time at the follow-on facility. This idea did not receive a lot of support from the DOE team.
5. An analysis of the choreography needs to be done regarding the handling of storage overpacks, transfer casks, and moving components through hatches. Assumptions need to be made regarding how components will be staged.
6. Welding – Jay Wellwood (DOE) mentioned that a lid welding machine, which is suspended above the canister, rather than placed onto the canister, is being evaluated on another project. An automated welder that uses multiple welding points should be a goal. The most conservative approach is to assume that the welding machine has to be removed and replaced. Need to look at repeated repositioning of the welding machine.
7. For the medium and large STAD canisters a transporter could be used instead of a crawler.

Options Identification

After lunch, the team brainstormed options, ideas and recommendations, including consideration of the following items:

- Candidate innovative operational approaches

- Options to perform critical functions, e.g. canister closure, drying, welding
- Options to automate
- Past endeavors that are worth a second look
- Use of alternate materials or resources
- Special features on the canister systems to optimize process
- Modification of existing systems, structures and components

For specific stages in the process the following lists were developed.

- **STAD/Loading**
  - Loading 4-PWR/9-BWR STADs in a serial process is not to be considered.
  - 4-PWR/9-BWR STADs would be gang loaded and welded/dried as a group.
  - 12-PWR and 21-PWR canisters (and their BWR counterparts) would be processed individually.
  - Look at trying to get 5 small STADs into a single storage can by using something other than right circular cylinders for the small canister design. Criticality may be as much a problem as space limitations. Heat transfer may also be a problem. Suggested looking at super poison (hafnium) materials as a way of dealing with criticality challenges. ES/Campbell will look at this.
  - Look at closure options. One mechanical and one welded closure? Two mechanical screw-top lids versus autoclave type locking lid closures. Exhaust the range of closure combinations that meet 10 CFR 72 redundant closure requirements to find the best options to present to DOE.
  - The use of duplex stainless steel might simplify the welding process, improve heat transfer and could have other benefits.
- **Transfer**
  - Choreography of the loading process becomes important:
    - Plant specific
    - Door sizes
    - Number of crane picks
    - Indoor versus outdoor location of loaded and empty canister transfers between casks
  - The plumbing for drying STADs within a can, i.e., STAD-in-Can, could become complicated. This could eliminate an extra transfer operation so careful analysis of the mechanical steps involved in the full transfer process would be useful in order to produce an apples-to-apples comparison of all of the tasks involved in preparing canisters for storage.

  - Maybe a test tube type carrier could be used to move individual small STADs as a group into a larger storage overpack.
  - Designing the transporter so that it can get into a building with minimal vertical and horizontal clearances would be helpful.
  - Could use multiple transfer casks.
- **Welding & Drying**
  - Look at underwater welding;
  - NDE
    - Remote NDE – Zion tried this
    - Different NDE process
    - Integrate with welder
    - Automatic
  - Plan for bulk gas delivery;
  - For the drying part of the equation, we might want to look at the definition of "dry". That is a licensing issue that might be worth exploring;
  - Combine blowdown, drying, backfilling and hydrostatic testing. EMS system is a good process.
  - Why hydro test canisters after welding? Why not a simpler pressure test? There are differences from vendor to vendor. Can the post closure integrity tests be streamlined and made routine across all of the storage canister designs?
  - Improve the vent and siphon connections to reduce leaks and maximize drying air flow.
  - Improve leak detection capability and reduce uncertainty.
- **Storage**
  - Load multiple small STADs into an over pack can. All subsequent handling would he based on the overpack, not the individual smaller canisters. This would integrate handling in the plant for drying and welding with handling for storage and transport and possibly disposal.
- **Transport**
  - DOE would like to see 20 assemblies in a transport cask. Can we squeeze 5 small STAD canisters; each with 4 PWR assemblies, into a transportation cask without exceeding Plate B dimensional limitations during transport? Could alternative impact limiter materials shrink the overall outside diameter? How about depleted uranium for body shielding to shrink the body diameter? Maybe 5 PWR assemblies in an octagonal STAD canister. Then 4 of the octagonal STADs would then be loaded into a storage cask and a transport cask.

<u>Operational Approaches for Small STAD Canisters</u>
Considering the idea of processing multiple small STAD canisters via a "STAD-in-Can" approach, which is akin to the design concept developed by ORNL, the team derived the following process.

1. Receive Storage Overpack with can (with lid) containing 4 or 5 STADs (with lids {1 lid per STAD})
2. Remove Storage Overpack lid
3. Remove Can lid
4. Lift can with STADs (with lids)
5. Place can into the Transfer Cask
6. Remove STAD lids (need to keep lids matched to STADs)
7. Fill with deionized water the following areas:
    a. Annulus between the Transfer Cask and the Can
    b. Area between STADs and the Can
    c. Each STAD
8. Install an inflatable annulus seal between the Can and the Transfer Cask.

    Note. A shielding disk will be preinstalled in the can, which incorporates openings for each of the STADs; each of which will have wiper seals between the shielding disk and the STAD. The shielding disk will have vent and siphon ports for the purpose of filling the area between the STADs and the can with water, and later removing all of the water in the can and drying the internal surfaces of the can. The shielding disk will be thick enough to provide shielding during later STAD lid welding operations and would help guide the STADs into the can so that they don't become canted.
9. Check water chemistry (boron) - for PWR pools.
10. Place transfer cask into the pool.
11. Load STADs.
12. Install inner lids on each of the STADs.
13. Lift Transfer Cask with loaded STADs from the pool.
14. Deflate the annulus seal between the Can and the Transfer Cask and lower the water level.
15. Lower the water level in each of the STADs.
16. Perform Welding and NDE for the inner lids on each of the STADs.
17. Hydrostatic/pressure test as required.
18. Blowdown all water in each of the STADs using an octopus and bulk gas

19. Dry STADs and backfill them with helium (simple pressure) each of the STADs and perform a pressure test.
20. Install the syphon and vent port covers for each of the STADs and perform helium leak tests.
21. Blowdown or siphon water out of the can below the shielding disk with ports on the disk. Establish the level of drying needed for the can. You can't vacuum dry the can because the wiper seals around the STADs will not maintain a differential pressure.
22. Install the Can lid [Note. This step could be switched with Step # 23 and depends on how the void spaces below and above the shielding disk will be dried].
23. Dry and backfill can void spaces. [Note. This step could be switched with Step # 22 and depends on how the void spaces below and above the shielding disk will be dried and decontaminated.]
24. Drain the annulus between the Can and the Transfer cask.
25. Prepare for the transfer of the Can to a Storage Overpack.
26. Transfer the Can into the Storage Overpack.
27. Install the lid on the Storage Overpack.
28. Transport Storage Overpack to the pad.

The team also concurred that the above process also needs to be evaluated using a transfer carrier instead of the can and the carrier going into the storage and transportation overpacks.

DAY 2

Day 2 began with the team looking at operational approaches for the 12-PWR/32-BWR and 21-PWR/44-BWR sized STADs. These really can't be handled in groups, so each STAD would be processed individually. Key points noted during the discussion on the medium and large STAD sizes and the results from the options identification work on Day 1 were:

- Ray Termini suggested that transferring a medium or large STAD into the storage cask outside of the fuel building (like at a cask transfer facility) would provide real schedule advantages. The stack up height can be problematic at some plants and competing for overhead crane time is a challenge at all plants. Moving the transfer operation outside of the fuel building, combined with having 2 transfer casks, would allow bringing a second STAD into the fuel building truck bay and staging it for insertion into the pool in parallel with the recently loaded one being removed for drying and welding. This only works at plants where there is sufficient operating space, and where an external facility could support these operations
- Brian Gutherman asked about an animation or graphic that shows the whole loading process using different approaches for comparison. Both NAC and ES offered to look at other graphics that might convey this information. Perhaps a resource loaded Gantt chart

complied at a high level would be useful to show cycle times for the current process compared to the other options we propose.

- Gary Lanthrum brought up the idea of a composite closure with the structural closure being done with a mechanical system then a light metal seal weld over the crack to possibly eliminate the need for leak monitoring. This would require a thicker lid system to allow the mechanical closure connections (bolts or lugs or threads) to be offset from the seal crack.
- Ivan Thomas asked if laser welding makes sense to pursue actively, or if it should be placed on the back burner. The decision was to leave it on the back burner because it does not appear to offer time savings. The same number of weld passes will be required and the same number of NDE reviews will be necessary.
- Looking at multiple welding bays, multiple function heads (welding and NDE), and better robotic welding systems seem to offer more significant throughput benefits.
- We shifted to a discussion of hydro test requirements. There was some hope that the hydro could be eliminated since the weld NDE assures there is no leak path, and the leak test of the seal weld shows that boundary is secure.
- We looked at innovative means of leak detection. Ultrasonic leak test equipment can be used during vacuum drying to find the source of vacuum leaks. That can speed the start of the drying equipment, but doesn't speed the actual time required to get dry.

The team agreed that, based on the results of the brainstorming and subsequent discussion, that the following items shall be considered during subsequent work assignments:

1. Minimize ancillary systems
2. Licensing and operational risks for closure options (e.g., autoclave, other mechanical closures)
3. Welding
    a. Suspended (from a frame) welder (for multiple small STADs – 4 is a better configuration than 5)
    b. NDE
        i. Remote NDE – Zion tried this
        ii. Different NDE process
        iii. Integrate with welder
        iv. Automatic
    c. Multi-function (NDE and welding) head
    d. Multi-point weld head
    e. Optimized weld sizes
    f. Minimize number of welds

   g. Minimize need for shims
   h. Optimized gas delivery (bulk supply)
   i. Port covers – why weld?
   j. STAD-in-Can lid – combined mechanical closure followed by a seal weld – autoclave?
4. Drying (need redundant systems, i.e., like Zion*Solutions*)
   a. Leak detection (ultrasonic)
   b. Types
      i. Combined vacuum drying and forced He (E1000 system)
      ii. Vacuum drying
   c. Multi-canister drying in parallel
   d. Improve connections + bigger connections
   e. Automated equipment
5. Hydro testing of welded inner lid
   a. Required by Section 3, Div.3 of the B&PV code
   b. Do we have to hydro? Code states that hydro or pneumatic testing is required
6. Operations
   a. Systems need to be simple to operate (some loading crews may be very experienced in canister loading and others may not)
   b. Have standard procedures for the systems, which can then be modified, as needed, to reflect site-specific conditions
   c. Focus on task efficiency
   d. Focus on parallel activities
   e. The process of getting into and out of the building is arduous, with the Truck Bay being a bottleneck.
   f. Use non-crawlers for the medium and large STADs
7. Develop and evaluate "STAD-in-Can" approach for small STADs
8. Develop and evaluate carrier approach for small STADs

<u>Work Assignments</u>

The workshop concluded with the team deriving the following list of work assignments and planned the work to be performed through completion of the Draft Final Report.

1. **Produce flowcharts, storyboard, pictures, and steps for each of the approaches**

   [ES Richland (with support from BAH)]

   a. DPC approach to processing STADs
   b. Multiple STADs using STAD-in-Can
   c. Multiple STADs using a carrier
   d. Medium and large STADs

2. **Time and Motion Study**

   [ES Campbell (with support from BAH)]

   a. Task Durations
   b. Critical paths
   c. Human resources
   d. Equipment requirements
   e. Building entry/exits
   f. Crane picks

3. **Produce design concept for the "STAD-in-Can" operational approach**

   [NAC]

4. **Welding**

   [ES Richland and ES Campbell (with support from NAC)]

5. **Drying**

   [ZionSolutions (with support from Exelon)]

6. **STAD Design Concepts**

   [ES Campbell and ES Richland]

   a. Design concepts for STADs (small, medium and large)
   b. Non right circular cylinder for small STADs?
   c. Lift lug design
   d. Mixed metal matrix poisons, instead of Boral™
   e. 316L for the material of construction
   f. Produce a design concept for the small STAD "carrier" system utilizing input from Task Order 18.
   g. Design for two lids to be installed (would install only one for "STAD-in-Can")

7. **Storage Overpacks Design Concepts**

   [NAC]

   a. Assume above ground storage overpack (either free standing or bolted to the pad like Diablo Canyon and new Vogtle)
   b. Look to perform transfer to the storage cask external to the spent fuel pool building

c. Multiple small STADs loaded either via a "can" or a "carrier"
d. Store 3 medium STADs in an overpack

8. Transportation Casks Design Concepts

[ES Campbell and ES Richland]

a. Can we fit 5 small STADs in a transport cask?

9. Dose Estimates

[ES Campbell and ES Richland]

a. Worker dose
b. SNF assumptions

10. Operating Plant Knowledge

[ES Columbia, SC]

a. Facility constraints
b. Plant configurations
c. Operating cycles
d. Loading approaches
e. Plants that might be the best candidates for loading the small, medium and large STADs, e.g.,

- Pool cask loading pits with size, weight or seismic constraints
- Plants with crane and/or headroom constraints
- Plants with floor loading and heavy loads constraints
- Plants with cask decon. pit constraints for canister welding and vacuum drying
- Other plant-specific conditions that limit cask loading

13 APPENDIX B - CROSS-REFERENCE BETWEEN TASK ORDER 21 SCOPE OF WORK AND THE OPERATIONAL REQUIREMENTS FOR STANDARDIZED DRY FUEL CANISTER SYSTEMS REPORT

Statement of Work Section	Statement of Work Requirement	Operational Requirements for Standardized Dry Fuel Canister Systems Report, Section No.
Scope of Work		
2	Using experience designing, licensing, and supplying SNF cask systems to commercial utilities in the U.S., operational experience in loading such casks, and the assumptions and requirements identified in this task order, the contractor shall develop standardized canister design concepts and perform operational studies of innovative approaches, as described below, that will increase DOE's understanding of potential alternatives to using DPCs with the goal of maximizing waste management system flexibility and ease of disposal, while minimizing the utility impacts, potential re-packaging needs, and overall system costs.	**Section 3**
2	1. The Contractor shall outline operational approaches for, and assess the associated impacts of, moving the required SNF throughput quantities identified below in a standardized canister to an on-site dry storage facility. An emphasis shall be placed on identifying innovative operational approaches that minimize impacts in terms of avoiding or minimizing any impacts to other utility operations as well as minimizing impacts directly attributable to performing the effort (e.g., duration, cost, dose, etc.). Three different capacity standardized canisters for each SNF assembly type (PWR or BWR) shall be considered: • 4-, 12-, and 21-PWR assembly capacity canisters; and • 9-, 32-, and 44-BWR assembly capacity canisters. For each canister size (i.e., 4-PWR/9-BWR, 12-PWR/32-BWR, and 21-PWR/44-BWR), the exterior dimensions for the PWR and BWR canisters must be the same.	**Section 4** **Section 5** **Appendix C** **Appendix E** **Appendix L**

Statement of Work Section	Statement of Work Requirement	Operational Requirements for Standardized Dry Fuel Canister Systems Report, Section No.
2	For the 4- and 9-assembly capacity canisters, a "canister-in-canister" approach shall be assessed to reduce in-plant cask handing operations, e.g., using an outer canister containing multiple 4-PWR or 9-BWR canisters. The Contractor shall also make a determination on the number of inner canisters that will minimize impacts to utility operations and implementation.	**Section 4.1.5** **Appendix L**
2	The operational approach outlined for each canister option shall include:	
2	a description of the standardized canister concept and associated storage system;	**Section 4.1** **Section 4.3** **Appendix C**
2	a description of the set of tasks required to load canisters with SNF and move the required SNF throughput to dry-storage, including a work process flow diagram;	**Section 5** **Appendix E** **Appendix H**
2	the estimated durations for the tasks and worker dose incurred in performing those tasks;	**Section 5**
2	a listing of the major equipment items that would be required,	**Section 4**
2	and the estimated total cost and cost break-down for moving the required SNF throughput. Cost estimates shall be based on techniques such as material takeoffs, vendor quotations, recent nuclear facility costs, past operational experience, and/or engineering judgment (i.e., for envisioned new equipment or processes). The cost estimates and the associated justification must be sufficiently detailed to allow external review and reproduction. The detailed cost estimates should be included as an appendix in the final report.	**Section 7** **Appendix D**
2	For comparison purposes, the operational approaches outlined for the different capacities of standardized canisters shall be compared with the same set of information (described in the paragraph above) for DPCs at or close to the largest capacities being used in industry today. Comparisons should be based on packaging an equivalent amount of spent nuclear fuel with like characteristics.	**Section 5**

Statement of Work Section	Statement of Work Requirement	Operational Requirements for Standardized Dry Fuel Canister Systems Report, Section No.

2	2. In performing the work under this task order, the Contractor shall take into account two primary constraints: 1) the minimum number of SNF assemblies to be moved (i.e., the required SNF throughput); and 2) the maximum amount of calendar time available between refueling outages for dry cask storage activities as indicated below:
	
	• Required SNF throughputs values are as follows for each reactor type:
	  ○ Each BWR reactor must move at least 900 SNF assemblies to dry storage over a recurring six-year period.
	  ○ Each PWR reactor must move at least 370 SNF assemblies to dry storage over a recurring six-year period.
	
	• A maximum of 12 continuous weeks should be assumed to mobilize, perform a cask loading campaign, and demobilize. Mobilization and demobilization that occurs outside of the power plant (even if elsewhere on site) does not need to fit into the 12-week window. A maximum frequency of one campaign per calendar year should be assumed.
	
	From projected domestic operating nuclear power plant spent fuel discharges, bounding values of 900 BWR and 370 PWR SNF assemblies were chosen as the amount of SNF that must be moved from wet to dry storage at each reactor over recurring six year periods to maintain the status quo in the spent fuel pool. A six-year recurring period is chosen because it is a common whole-number multiple for 18-month and 24-month operating cycles. Some reactors permanently discharge more fuel than others each refueling outage due to cycle length or other variables. Other variables that could cause differences in actual discharges are power uprates, operating cycle length changes and capacity factor. The 900BWR/370PWR values are considered reasonable for use in this study based on actual nationwide projected discharge data at this time.
		Section 5.0

<table>
<tr><th>Statement of Work Section</th><th>Statement of Work Requirement</th><th>Operational Requirements for Standardized Dry Fuel Canister Systems Report, Section No.</th></tr>
<tr><td>2</td><td>3. The Contractor shall perform a parametric study to assess how the operational approaches identified under Item 1 above, including associated characteristics (durations, worker dose, cost, etc.), are expected to vary as a function of the number of reactors at a given site, the type of reactors at the site, and the reactor cycle length for the cases indicated in the table below. All reactors on a given site may be assumed to be of the same reactor type and have the same operating cycle length.
<table>
<tr><th>CASE</th><th>REACTOR TYPE</th><th>NUMBER OF REACTORS ON SITE</th><th>OPERATING CYCLE LENGTH (months)</th></tr>
<tr><td>1*</td><td>BWR</td><td>1</td><td>18</td></tr>
<tr><td>2</td><td>BWR</td><td>1</td><td>24</td></tr>
<tr><td>3</td><td>BWR</td><td>2</td><td>24</td></tr>
<tr><td>4</td><td>BWR</td><td>3</td><td>24</td></tr>
<tr><td>5*</td><td>PWR</td><td>1</td><td>18</td></tr>
<tr><td>6</td><td>PWR</td><td>1</td><td>24</td></tr>
<tr><td>7</td><td>PWR</td><td>2</td><td>18</td></tr>
<tr><td>8</td><td>PWR</td><td>2</td><td>24</td></tr>
<tr><td>9</td><td>PWR</td><td>3</td><td>18</td></tr>
</table>
*Case 1 and Case 5 are the two initial cases mentioned in Item 1 under this Section 2 on Scope of Work</td><td>Section 5
Section 7</td></tr>
</table>

Statement of Work Section	Statement of Work Requirement	Operational Requirements for Standardized Dry Fuel Canister Systems Report, Section No.
2	Again, innovative operational approaches for achieving the required SNF throughput and minimizing impacts shall be considered when analyzing these cases. Canister loading campaigns should only take place during times when all reactors on the site are scheduled to be operating to minimize impacts to utility operations.	**Section 5** **Section 6**
2	Typical facility constraints (e.g. shared spent fuel pools or shared lifting equipment for cases with multiple reactors at a site) should be identified by the Contractor based on experience and knowledge of typical conditions in the field. The facility constraints assumed in the development and analysis of innovative operational approaches which achieve the required SNF throughput while minimizing impacts are to be identified and justified for each case evaluated.	**Section 6** **Appendix F**
2	A recommendation for the optimum frequency for canister loading campaigns should be determined for each case identified in the table above. For example, multi-reactor sites may require annual canister loading campaigns just to keep up with the required dry storage throughput, but single-reactor sites may be able to maintain the required throughput with biennial or triennial loading campaigns to save on mobilization and demobilization costs.	**Section 6**
2	In addition to those parameters in Items 1 and 2 (e.g. canister capacity, cycle length, etc.), the Contractor shall identify and assess the influence of any other parameters or constraints the Contractor believes to have an important influence on the operational approach proposed for achieving the required SNF throughput.	**Section 4** **Section 5**
2	4. In considering innovative approaches, the Contractor shall assess potential benefits and issues of using canister concepts in which welding can be avoided or deferred until later when it is not on critical path, e.g. some time prior to downstream transport or disposal. As part of this assessment, the Contractor shall consider canister-in-canister systems for which the inner and/or outer canisters may be non-welded concepts, at least initially. For welded canister concepts, the Contractor shall also consider available automatic (robotic) or semiautomatic equipment. Other innovative canister design features may be considered, however there should be	**Section 4.1.5**

Statement of Work Section	Statement of Work Requirement	Operational Requirements for Standardized Dry Fuel Canister Systems Report, Section No.
	reasonable assurance that each design concept has the capability to meet fundamental licensing requirements for both storage under 10 CFR 72 and transportation under 10 CFR 71. Disposal compatibility and licensing requirements related to disposal may be ignored for this task order.	
2	5. The focus of this task order is on the operational requirements involved in loading standardized canisters and moving the required SNF throughput into dry storage in a manner that minimizes impacts to utilities. In developing outlines for innovative operational approaches, some conceptual engineering effort will be required. Engineering sketches, and outline specifications shall be developed, as required, to depict structures, systems, and components which support the proposed innovative operational approaches. Although this effort is not focused on standardized canister design details, key assumptions regarding the canister design and configuration made to support the study shall be provided. Sketches shall also be provided to visualize the general designs/outlines for the following: • Standardized canisters for those capacities and configurations assessed in the study as described in Item 1 above, including the canister-in-canister configurations assessed. • Associated ancillary equipment to support throughput objectives • Associated storage cask concepts • Associated transfer cask concepts to move canisters to their storage location • Associated transportation cask concepts to move canisters off-site.	**Appendix C**

Statement of Work Section	Statement of Work Requirement	Operational Requirements for Standardized Dry Fuel Canister Systems Report, Section No.
2	**6** Assumptions: This task order is intended to encourage the successful bidder(s) to think innovatively in terms of canister design and configuration, processes, equipment, and use of personnel to achieve the goal of meeting the required SNF throughput while minimizing impacts to utility operations and required resources. It is recognized that using smaller-capacity and smaller-sized standardized canisters to move fuel into dry storage will likely be more expensive on a per-assembly basis for the storage portion of the integrated waste management system as compared to use of conventional DPCs and canister loading processes. To achieve the required SNF throughput and/or allow innovation subject to certain constraints, the following assumptions should be used in performing the scope of work as described in this section: • There is no limit on the number of personnel available, loading operations may run up to 24 hours per day, seven days per week. This includes loading personnel and all support services such as health physics, security, chemistry, etc. Relative cost estimates developed under this task order for the different cases examined should take into account personnel costs, including those which may be incurred in complying with the fatigue rule, though operational approaches identified should seek to minimize these costs and other impacts. • Nuclear power plants have a cask crane capacity of 125 tons and a standard crane sister hook. The crane and all load lifting attachments and below-the-hook lifting devices may be assumed to meet the requirements of NUREG 0612, Section 5.1.6 for single-failure-proof lifting systems. The number of crane picks is a key area of utility concern. Crane and truck or rail bay time is at a premium. Due consideration should be given to minimizing additional crane picks, but the number of crane picks should not be considered a constraint to standardized canister design concepts. • Higher relative worker dose on a per assembly basis incurred in using standardized canisters having smaller capacities compared to DPCs should not	**Section 5**

Statement of Work Section	Statement of Work Requirement	Operational Requirements for Standardized Dry Fuel Canister Systems Report, Section No.
	be considered a limitation in developing innovative operational approaches and design concepts because worker dose avoided by not having to re-package DPCs later may more than balance this out. Standardized canister design and processing concepts must, however, keep the concept of ALARA in mind and provide reasonable assurance that users will be able to comply with the personnel dose limits in 10 CFR Part 20. • Although a detailed analysis supporting canister design concepts is not required for this task order, the Contractor should document and justify key supporting assumptions used in their evaluation of innovative operational approaches including those assumptions used in developing estimates of worker dose rates.	
Applicable Codes, Standards, and Standards		
3	The Contractor shall prepare the deliverables of a technical nature under Quality Rigor Level 3 guidelines. (Reference: Fuel Cycle Technologies Quality Assurance Program Document (FCT QAPD), Revision 2.)	**Technical Review performed and documented via FCT Document Cover Sheet.**

14 APPENDIX C – ENGINEERING SKETCHES AND OUTLINE SPECIFICATIONS FOR STANDARDIZED CANISTER DESIGN CONCEPTS

Utilizing design work from Task Order 18, the conceptual designs for the small STAD canisters (4-PWR and 9-BWR) are shown below in Figures 14-1, 14-2 and 14-3:

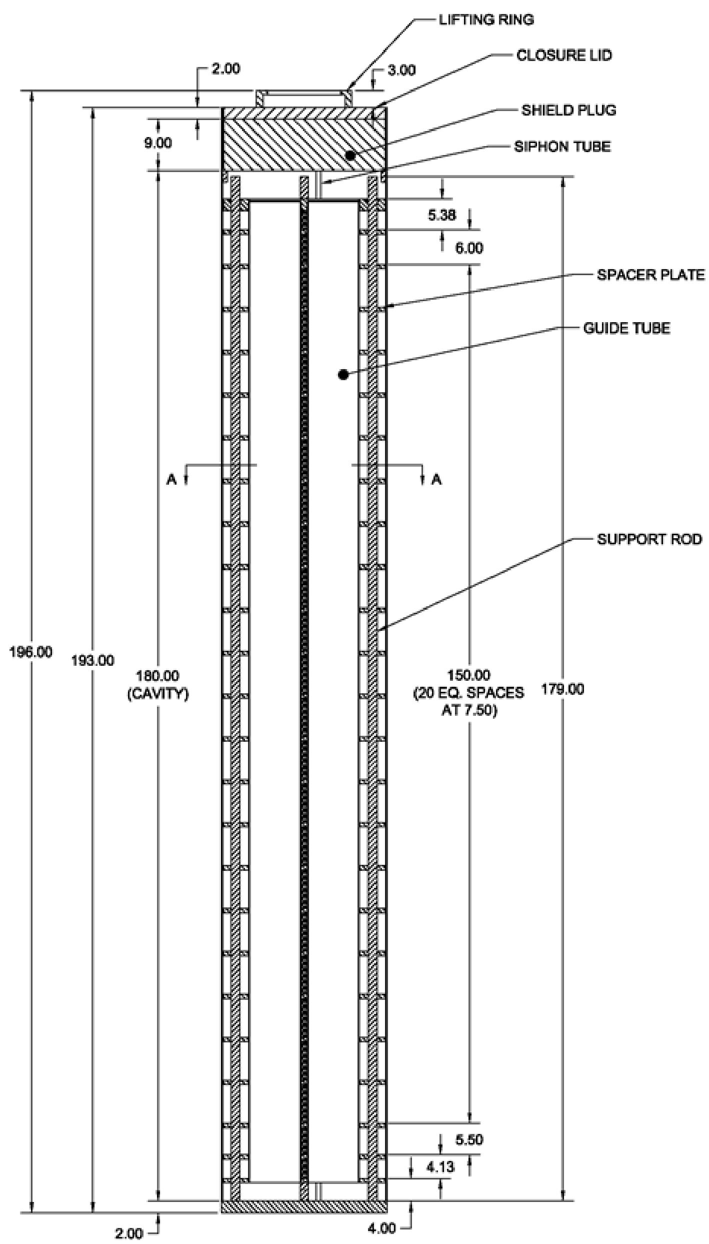


Figure 14-1. Conceptual Design for Small STAD Canister

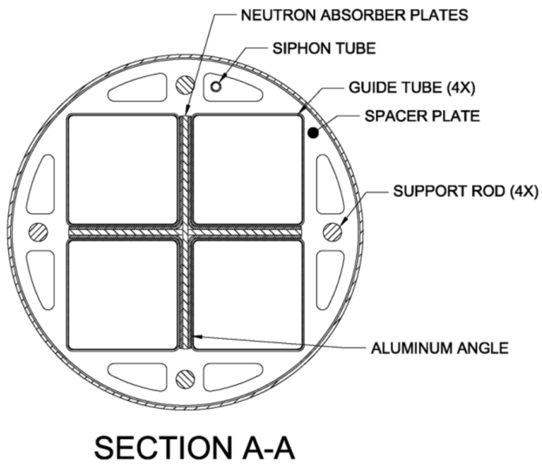


Figure 14-2. Cross-Section Showing Basket Arrangement for the 4-PWR STAD Canister

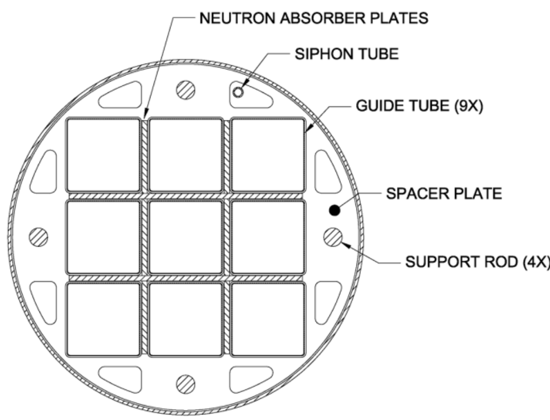
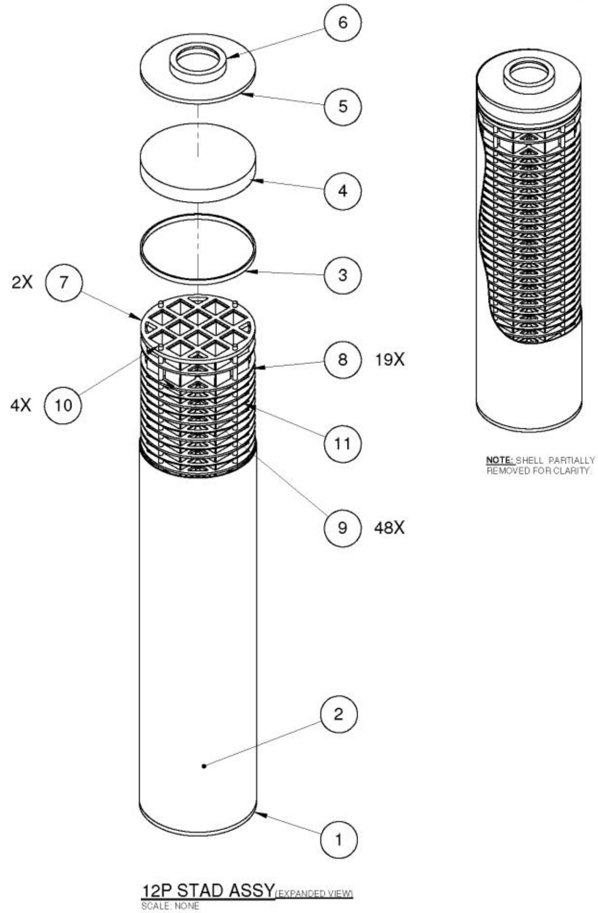


Figure 14-3. Cross-Section Showing Basket Arrangement for the 9-BWR STAD Canister

Utilizing past work under Task Order 12, the design concepts for the Medium STAD Canisters (12-PWR or 32-BWR), are shown in Figures 14-4 and 14-5 below:

Utilizing past work on the TAD canisters (21-PWR or 44-BWR), which were designed by industry for the DOE in 2008 and which have equivalent capacities to the SOW-required large STAD canisters, a drawing of the 21-PWR TAD canister designed by NAC International is shown in Figure 14-6 below.



QTY.	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	ITEM NO.
1	BOTTOM PLATE, 2" PL.	ASME SA-240, TYPE 316L	1
1	SHELL, 1/2" PL.	ASME SA-240, TYPE 316L	2
1	SUPPORT RING, 3/4" PL.	ASME SA-240, TYPE 316L	3
1	SHIELD PLUG, 7" THK	ASME SA-240, TYPE 304	4
1	TOP PLATE, 2" PL.	ASME SA-240, TYPE 316L	5
1	GRAPPLE RING	ASME SA-240, TYPE 316L	6
2	END SPACER PLATE, 2" PL.	ASME SA-240, TYPE 316L	7
19	SPACER PLATE, 1" PL.	ASME SA-240, TYPE 316L	8
48	GUIDE TUBE PLATE, 7/16" PL.	ASTM A887-89, GRADE A	9
4	SUPPORT ROD, 2" DIA	ASME SA-479, TYPE 316L	10
16	THERMAL SHUNT, 1/2" PL.	ASME SB-209, 6061 T651	11

GENERAL NOTES: (UNLESS OTHERWISE SPECIFIED)

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED.
2. CONCEPTUAL DESIGN SHOWN IS NOT FOR FABRICATION.

REV	DESCRIPTION	DRWN	ENG	CHK	APVD	IDV	DATE
A	PRELIMINARY DESIGN ISSUE	FC	SS	N/A	N/A	N/A	3/25/13

REVISIONS

N/A

PROPRIETARY
☒ NON-PROPRIETARY

	BY	DATE
DRAWN BY	F. CHAVEZ	3/25/13
ENGINEER	S. SISLEY	3/25/13
CHECKER	N/A	
APPROVED	N/A	
IDV	N/A	N/A

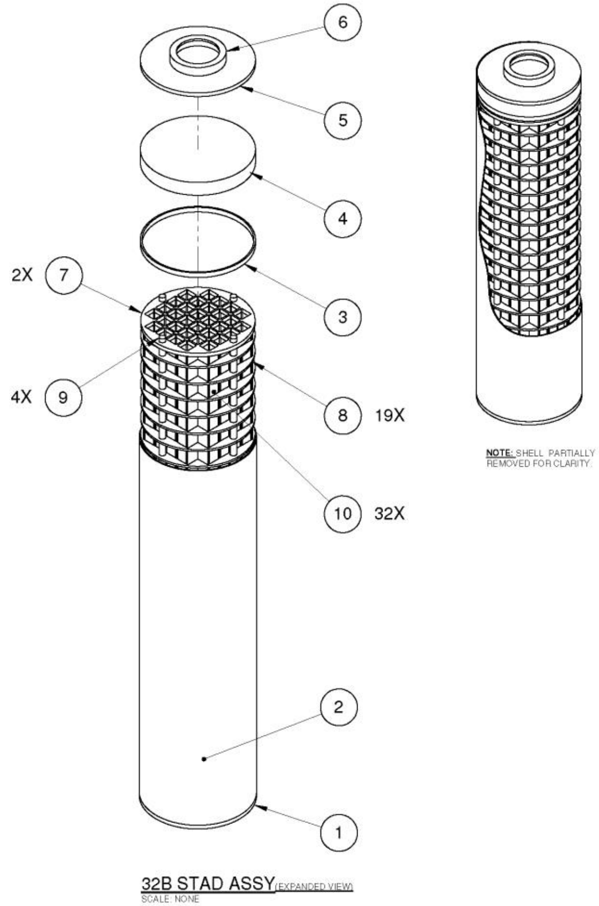
ENERGYSOLUTIONS

STANDARDIZED TRANSPORT AGING & DISPOSAL (STAD)
12P CANISTER ASSEMBLY & DETAILS

SIZE B | SKETCH NUMBER DWG-205577-ME-0010 | REV A

SCALE N/A | SHEET 1 OF 7

Figure 14-4. Conceptual Design for Medium (12-PWR) STAD Canister



QTY.	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	ITEM NO.
1	BOTTOM PLATE, 2" PL.	ASME SA-240, TYPE 316L	1
1	SHELL, 1/2" PL.	ASME SA-240, TYPE 316L	2
1	SUPPORT RING, 3/4" PL.	ASME SA-240, TYPE 316L	3
1	SHIELD PLUG, 7" THK	ASME SA-240, TYPE 304	4
1	TOP PLATE, 2" PL.	ASME SA-240, TYPE 316L	5
1	GRAPPLE RING	ASME SA-240, TYPE 316L	6
2	END SPACER PLATE, 2" PL.	ASME SA-240, TYPE 316L	7
19	SPACER PLATE, 1" PL.	ASME SA-240, TYPE 316L	8
4	SUPPORT ROD, 3" DIA	ASME SA-479, TYPE 316L	9
32	GUIDE TUBE, 16 GA.	ASME SA-240, TYPE 316L	10
180	NEUTRON ABSORBER PLATE, 7/16" PLATE	ASTM A887-89, GRADE A	11
20	NEUTRON ABSORBER PLATE, 7/16" PLATE	ASTM A887-89, GRADE A	12

GENERAL NOTES: (UNLESS OTHERWISE SPECIFIED)

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED.
2. CONCEPTUAL DESIGN SHOWN IS NOT FOR FABRICATION.

REV	DESCRIPTION	DRWN	ENG	CHK	APVD	IDV	DATE
A	PRELIMINARY DESIGN ISSUE	FC	SS	N/A	N/A	N/A	3/26/13

REVISIONS

N/A

PROPRIETARY
☒ NON-PROPRIETARY

ENERGYSOLUTIONS

	BY	DATE
DRAWN BY	F. CHAVEZ	3/26/13
ENGINEER	S. SISLEY	3/26/13
CHECKER	N/A	
APPROVED	N/A	
IDV	N/A	N/A

STANDARDIZED TRANSPORT AGING & DISPOSAL (STAD)
32B CANISTER ASSEMBLY & DETAILS

SIZE: B | SKETCH NUMBER: DWG-205577-ME-0015 | REV: A

SCALE: N/A | SHEET 1 OF 5

Figure 14-5. Conceptual Design for Medium (32-BWR) STAD Canister

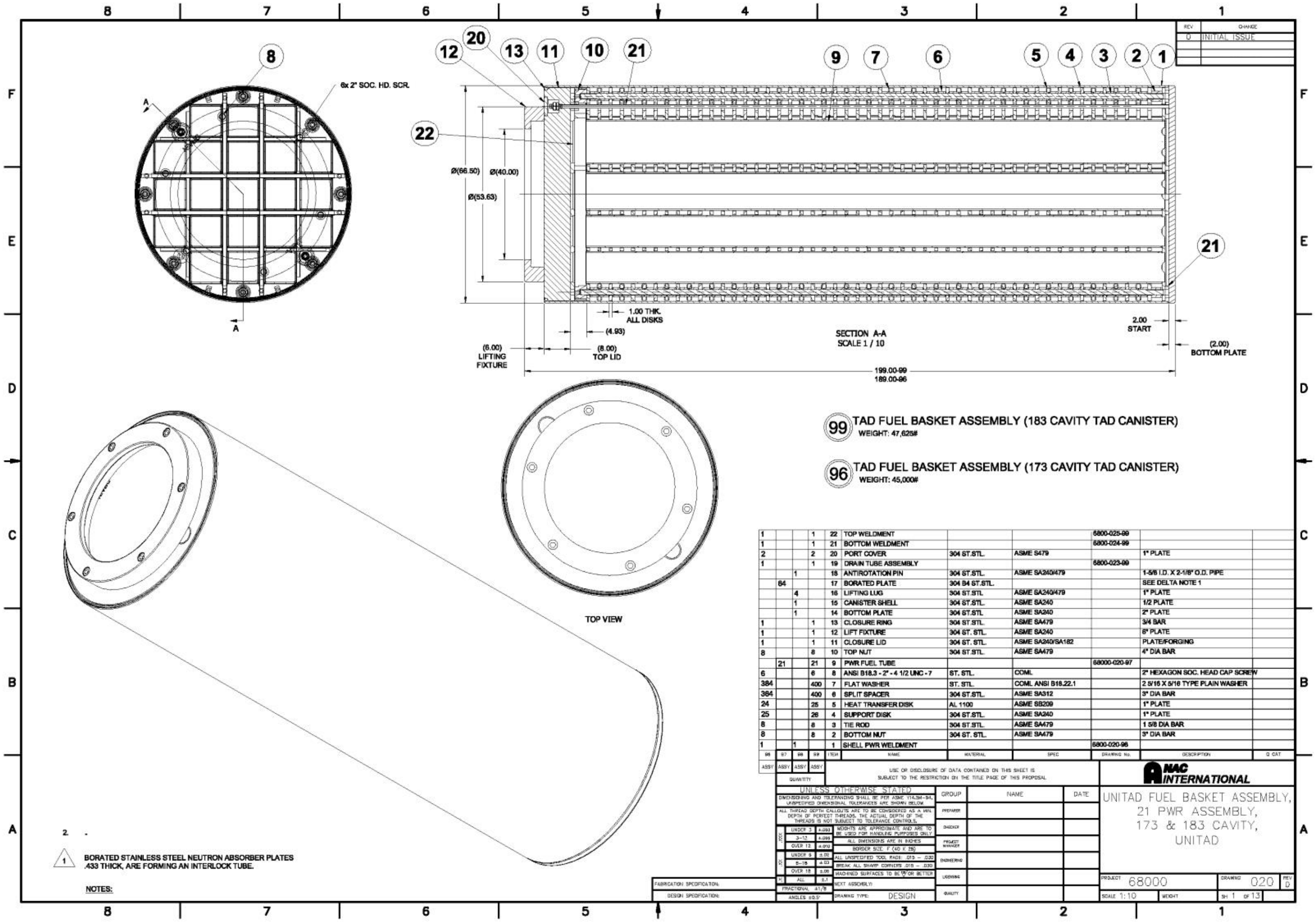


Figure 14-6. Drawing Showing 21-PWR TAD Canister Designed by NAC International

15 APPENDIX D – DETAILED COST ESTIMATES

This appendix includes detailed cost estimates for the operational costs for the two benchmark cases and the eight STAD cases. These cases include the following:

1. Table 15-1 Operations Approaches – Zion Benchmark Loading Times and Estimated Costs – 87 BWR DPC Reference Case - Basis of Estimate
2. Table 15-2 Operations Approaches – Zion Benchmark Loading Times and Estimated Costs – 37 PWR DPC - Basis of Estimate
3. Table 15-3 Operations Approaches – Large BWR STAD Canisters - Basis of Estimate
4. Table 15-4 Operations Approaches – Large PWR STAD Canisters - Basis of Estimate
5. Table 15-5 Operations Approaches – Medium BWR STAD Canisters - Basis of Estimate
6. Table 15-6 Operations Approaches – Medium PWR STAD Canisters - Basis of Estimate
7. Table 15-7 Operations Approaches – Small BWR STADs-in-Can - Basis of Estimate
8. Table 15-8 Operations Approaches – Small PWR STADs-in-Can - Basis of Estimate
9. Table 15-9 Operations Approaches – Small PWR STADs-in-Carrier - Basis of Estimate
10. Table 15-10 Operations Approaches – Small BWR STADs-in-Carrier - Basis of Estimate

Each estimate has been developed using labor categories and associated full-time equivalent (FTE) levels and costs based on the prior operational experience of analysts at Exelon. Each estimate is then aggregated according to effort (in hours) by activity for a based case as well as cases that include technology improvements and parallel processing improvements. The final baseline and optimized estimates are then aggregated to include percentages for consumables and contingency, with the final results being shown in terms of cost per STAD and cost per assembly.

Table 15-1. Operations Approaches – Zion Benchmark Loading Times and Estimated Costs – 87 BWR DPC Reference Case – Basis of Estimate

Task Location Legend: FHB Prep Area; Fuel Pool; Cask Decon Pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step #	Step Description	Task Category Code	Crane Operators		Other Heavy Eq. Operators		Mechanics		Riggers		Welders		Other Operations Staff		Supervisors/ Foremen		Deconners		Radiation Protection		Techs		QA/QC		HP		Security		Planners		Trainers		Procedure Writers		Management		Total Personnel	Linear Step Time Baseline	Staff Cost by Activity Baseline
			#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	hrs	$
1	Move Transporter & SC into FHB	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	11	0.5	$450
2	Move SC to under seismic restraint	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	0.5	$413
3	Remove the SC lid and install adapter	A	1	$75	0	$75	5	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	1.5	$1,575
4	Load spacers	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.8	$540
5	Move DPC into FHB	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	0.5	$413
6	TC Preparation	A	0	$75	0	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	2.0	$1,500
7	Move TC into decon pit	A	1	$75	0	$75	4	$75	3	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525
8	TC Preparation	A	1	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.4	$3,300
9	Place DPC into TC	A	1	$75	0	$75	3	$75	3	$75	0	$75	0	$75	1	$100	0	$75	1	$75	2	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.0	$1,125
10	Place TC/DPC into SFP	A	1	$75	0	$75	3	$75	3	$75	0	$75	2	$75	1	$100	0	$75	2	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	19	2.6	$3,965
11	Start fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	2	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	0.5	$413
12	Fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	2	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	33.4	$22,545
13	Fuel verification	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.4	$3,300
14	Install DFC lids/spacers	A	1	$75	0	$75	2	$75	2	$75	0	$75	1	$75	1	$100	0	$75	2	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	16	3.0	$3,900
15	Install DPC lid	A	1	$75	0	$75	2	$75	2	$75	0	$75	1	$75	1	$100	0	$75	2	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	16	0.5	$650
16	Remove TC/DPC from SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	3	$75	2	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	22	2.6	$4,550
17	Place TC/DPC into the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	3	$75	3	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	18	0.5	$725
18	Decon TC/DPC	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.1	$3,178
19	Remove 70 gallons water	C	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.8	$600
20	Test for hydrogen	E	0	$75	0	$75	2	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	0.5	$413
21	Perform lid fit up	A	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	4.0	$2,700
22	Weld DPC inner plate (all passes)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	4.5	$3,713
23	NDE DPC inner plate (all passes)	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	3.0	$1,575
24	Hydro pressure test DPC inner plate	E	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	1.0	$750
25	Blowdown DPC	C	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	1.0	$750
26	Set up the VDS	C	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675
27	Vacuum dry DPC	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	27.0	$18,225
28	Helium Backfill DPC	C	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	2.0	$1,500
29	Weld and test inner port covers	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.0	$3,000
30	Helium leak test port covers	E	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.2	$810
31	Weld DPC outer plate	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.5	$1,238
32	NDE DPC outer plate	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.0	$525
33	Install TC retaining lugs	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.5	$900
34	Prep TC/DPC for stack-up	A	0	$75	0	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	2.0	$1,500
35	Remove TC/DPC from the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	0.5	$575
36	Place TC/DPC in stack-up	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.5	$1,725
37	Engage TC seismic restraint	A	0	$75	0	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.0	$825
38	Remove yoke from FHB hook	A	1	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375
39	Rig DPC to FHB hook	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	12	1.8	$1,755
40	Transfer DPC to SC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.0	$1,150
41	Remove rigging	A	1	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	1.5	$1,350
42	Close transfer adapter	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375
43	Install yoke	A	0	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	0.5	$413
44	Disengage TC seismic restraint	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675
45	Move TC to decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	12	0.5	$488
46	Remove rigging from DPC	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	1.0	$900
47	Remove transfer adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	12	1.5	$1,463
48	Set SC lid	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	2.0	$1,350
49	Check SC vents	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.5	$338
50	Perform the hazards walkdown	A	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	5	1.0	$450
51	Move SC to transporter	A	0	$75	1	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	14	0.5	$563
52	Perform SC dose rates	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$625
53	Move support equipment to ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375
54	Move transporter to haul road	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	4	$75	1	$75	0	$75	1	$75	1	$125	16	1.3	$1,690
55	Replace security barriers	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.3	$203
56	Move transporter/SC/DPC to ISFSI pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	5	$75	1	$75	0	$75	1	$75	1	$125	17	3.0	$4,125
57	Tie security barrier at ISFSI and open gate	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	5	$75	1	$75	0	$75	1	$75	1	$125	17	0.3	$413
58	Move transporter into position at ISFSI	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	5	$75	1	$75	0	$75	1	$75	1	$125	17	0.5	$688
59	Position SC on pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	1	$75	1	$100	5	$75	1	$75	0	$75	1	$75	1	$125	18	0.5	$725
60	Install vent screens	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$388
61	Move equipment from ISFSI	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	12	0.5	$488
62	Replace security barriers	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	12	0.3	$293
	Total Time per STAD (hours)																																					144.8	
	Total Time per STAD (days)																																					6d	
	Subtotal Labor Costs																																						**$116,715**
	Other Costs (consumables) 15%																																						$17,507
	Subtotal Costs w/o Contingency																																						**$134,222**
	Contingency 20%																																						$26,844
	Total Cost per DPC																																						**$161,067**
	# of Assemblies per DPC 87																																						87
	Subtotal Cost per Assembly w/o Contingency																																						**$1,543**
	Contingency 20%																																						**$309**
	Total Hours/Cost per Assembly																																					1.66	**$1,851**

Table 15-2. Operations Approaches – Zion Benchmark Loading Times and Estimated Costs – 37 PWR DPC Reference Case – Basis of Estimate

Task Location Legend: FHB Prep Area; Fuel Pool; Cask Decon Pit; ISFSI; Outside Prot Area

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step #	Step Description :	Task Category Code	Crane Operators		Other Heavy Eq. Operators		Mechanics		Riggers		Welders		Other Operations Staff		Supervisors/ Foremen		Deconners		Radiation Protection		Techs		QA/QC		HP		Security		Planners		Trainers		Procedure Writers		Management		Total Personnel	Linear Step Time Baseline	Staff Cost by Activity	On-clock?	Off-clock Time	Staff Cost by Actibity Off-clock time	Clock Toime	Staff Cost by Activity Baseline
			#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	hrs	$	hrs	hrs	$	hrs	$
1	VCT pre-use inspection		0	$75	1	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	5	1.0	$450		1.0	$450	0.0	$0
2	VCC pre-use inspection		0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	9	1.0	$750		1.0	$750	0.0	$0
3	Load VCC onto VCT		0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.8	$506		0.8	$506	0.0	$0
4	Move VCC to security protected area		0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375		0.5	$375	0.0	$0
5	Move VCT & VCC into FHB	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	x	0.0	$0	0.5	$375
6	Move VCC to under seismic restraint	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.5	$338	x	0.0	$0	0.5	$338
7	Remove the VCC lid and install adapter	A	1	$75	0	$75	2	$75	1	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.5	$1,013	x	0.0	$0	1.5	$1,013
8	Load spacers	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.8	$480	x	0.0	$0	0.8	$480
9	Move TSC into FHB	A	0	$75	1	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	12	0.5	$488	x	0.0	$0	0.5	$488
10	MTC preparation	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	2.0	$1,200	x	0.0	$0	2.0	$1,200
11	Move MTC into decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	0.5	$450	x	0.0	$0	0.5	$450
12	MTC preparation	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	4.4	$2,652	x	0.0	$0	4.4	$2,652
13	Place TSC into MTC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	1.0	$900	x	0.0	$0	1.0	$900
14	Place MTC/TSC into SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	2	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	16	2.6	$3,367	x	0.0	$0	2.6	$3,367
15	Start fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.5	$338	x	0.0	$0	0.5	$338
16	Fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	14.0	$9,450	x	0.0	$0	14.0	$9,450
17	Fuel verification	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	3	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.6	$1,087	x	0.0	$0	1.6	$1,087
18	Install DFC lids/spacers	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	3	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	3.0	$2,025	x	0.0	$0	3.0	$2,025
19	Install TSC lid	A	1	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	0.5	$413	x	0.0	$0	0.5	$413
20	Remove MTC/TSC from SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	3	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	18	2.6	$3,770	x	0.0	$0	2.6	$3,770
21	Place MTC/TSC into the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	0.5	$575	x	0.0	$0	0.5	$575
22	Decon MTC/TSC	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	3	$75	3	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	4.1	$3,774	x	0.0	$0	4.1	$3,774
23	Remove 70 gallons water	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.8	$450	x	0.0	$0	0.8	$450
24	Test for hydrogen	A	0	$75	0	$75	0	$75	0	$75	2	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	x	0.0	$0	0.5	$300
25	Perform lid fit up, welder setup	A	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	4.0	$2,700	x	0.0	$0	4.0	$2,700
26	Weld TSC lid root weld start	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.7	$466	x	0.0	$0	0.7	$466
27	Weld TSC lid root weld finish	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.5	$1,013	x	0.0	$0	1.5	$1,013
28	NDE TSC lid root weld	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	x	0.0	$0	1.0	$600
29	Weld TSC lid intermediate weld	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.5	$1,013	x	0.0	$0	1.5	$1,013
30	NDE TSC lid intermediate weld	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	x	0.0	$0	1.0	$600
31	Weld TSC lid final weld	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.5	$1,013	x	0.0	$0	1.5	$1,013
32	NDE TSC lid final weld	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	x	0.0	$0	1.0	$600
33	Hydro pressure test TSC lid	E	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	1.0	$750	x	0.0	$0	1.0	$750
34	Weld closure ring	D	0	$75	0	$75	0	$75	0	$75	2	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.5	$900	x	0.0	$0	1.5	$900
35	NDE closure ring	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	x	0.0	$0	1.0	$600
36	Blowdown TSC	C	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675	x	0.0	$0	1.0	$675
37	Set up to the VDS	C	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$662	x	0.0	$0	1.0	$662
38	Vacuum dry TSC	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	30.0	$20,250	x	0.0	$0	30.0	$20,250
39	Helium backfill TSC	C	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	2.0	$1,500	x	0.0	$0	2.0	$1,500
40	Weld and test inner port covers	D	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	5	4.0	$1,800	x	0.0	$0	4.0	$1,800
41	Helium leak test port covers	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.2	$641	x	0.0	$0	1.2	$641
42	Weld and test and outer port covers	D	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	4.0	$2,100	x	0.0	$0	4.0	$2,100
43	Install MTC retaining lugs	A	0	$75	0	$75	2	$75	1	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.5	$924	x	0.0	$0	1.5	$924
44	Prep MTC/TSC for stack up	A	0	$75	0	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	2.0	$1,500	x	0.0	$0	2.0	$1,500
45	Remove NTC/TSC from the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	x	0.0	$0	0.5	$525
46	Place NTC/TSC in stack up	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.5	$1,725	x	0.0	$0	1.5	$1,725
47	Engage MTC seismic restraint	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	x	0.0	$0	1.0	$600
48	Remove yoke from FHB hook	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	x	0.0	$0	0.5	$375
49	Rig TSC to FHB hook	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	1.8	$1,575	x	0.0	$0	1.8	$1,575
50	Transfer TSC to VCC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.0	$1,150	x	0.0	$0	1.0	$1,150
51	Remove rigging	A	0	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	1.5	$1,125	x	0.0	$0	1.5	$1,125
52	Close transfer adapter	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	x	0.0	$0	0.5	$300
53	Install yoke	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	x	0.0	$0	0.5	$375
54	Disengage MTC seismic restraint	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.0	$525	x	0.0	$0	1.0	$525
55	Move MTC to decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	12	0.5	$488	x	0.0	$0	0.5	$488
56	Remove rigging from TSC	A	1	$75	0	$75	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675	x	0.0	$0	1.0	$675
57	Remove transfer adapter	A	1	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	1.5	$1,350	x	0.0	$0	1.5	$1,350
58	Set VCC lid	A	1	$75	0	$75	2	$75	1	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	2.0	$1,500	x	0.0	$0	2.0	$1,500
59	Check VCC vents	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	x	0.0	$0	0.5	$300
60	Perform fire hazards walkdown	A	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	5	1.0	$450	x	0.0	$0	1.0	$450
61	Move VCC to VCT	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	x	0.0	$0	0.5	$375
62	Perform VCC dose rates	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.0	$525	x	0.0	$0	1.0	$525
63	Move support equipment to ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	x	0.0	$0	0.5	$375
64	Move VCT to haul road	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	3	$75	1	$75	0	$75	1	$75	1	$125	12	1.3	$1,229	x	0.0	$0	1.3	$1,229
65	Replace security barriers	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	8	0.3	$169	x	0.0	$0	0.3	$169
66	Move VCT/VCC/TSC to ISFSI pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	3	$75	1	$75	0	$75	1	$75	1	$125	14	3.0	$3,375	x	0.0	$0	3.0	$3,375
67	The security barrier at ISFSI and open gate	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$188	x	0.0	$0	0.3	$188
68	Move VCT into position at ISFSI	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	x	0.0	$0	0.5	$525
69	Position VCC on pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	12	0.5	$488	x	0.0	$0	0.5	$488
70	Install vent screens	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	x	0.0	$0	0.5	$300
71	Move equipment from ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	x	0.0	$0	0.5	$375
72	Replace security barriers	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$188	x	0.0	$0	0.3	$188
	Total Time per STAD (hours)																																					133.3		0.0	3.3		130.0	
	Total Time per STAD (days)																																					5.6d		0d	0.1d		5.4d	
	Subtotal Labor Costs																																						$96,975			$2,081		$94,894
	Other Costs (consumables) 15%																																						$14,546			$312		$14,234
	Subtotal Costs w/o Contingency																																						$111,521			$2,393		$109,128
	Contingency 20%																																						$22,304			$479		$21,826
	Total Cost per DPC																																						$133,826			$2,872		$130,953
	# of Assemblies per DPC 37																																						37			37		37
	Subtotal Cost per Assembly w/o Contingency																																						$3,014			$65		$2,949
	Contingency 20%																																						$603			$13		$590
	Total Hours/Cost per Assembly																																						$3,617			$78	3.51	$3,539

Table 15-3. Operations Approaches – Large BWR STAD Canisters – Basis of Estimate

TABLE 15-3. Operations Approaches - Large BWR STAD Canisters Detailed Costs [ref. Table 19-3]

Task Location Legend: FHB Prep Area; Fuel Pool; Cask Decon Pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step #	Step Description :	Task Category Code	Crane Operators #	Crane Operators $	Other Heavy Eq. Operators #	Other Heavy Eq. Operators $	Mechanics #	Mechanics $	Riggers #	Riggers $	Welders #	Welders $	Other Operations Staff #	Other Operations Staff $	Supervisors/ Foremen #	Supervisors/ Foremen $	Deconners #	Deconners $	Radiation Protection #	Radiation Protection $	RXS Techs #	RXS Techs $	QA/QC #	QA/QC $	HP #	HP $	Security #	Security $	Planners #	Planners $	Trainers #	Trainers $	Procedure Writers #	Procedure Writers $	Management #	Management $	Total Personnel (#)	Linear Step Time Baseline (hrs)	Staff Cost by Activity ($)	Technology Improvement (hours saved) (hrs)	Step Time with Tech Savings Alone (hrs)	Staff Cost by Activity with Tech Savings Alone ($)	Percent on Clock (parallel savings) (%)	Time Saved per STAD by Parallel Ops (hrs)	Step Time with Parallel Svgs Alone (hrs)	Staff Cost by Activity with Parallel Savings Alone ($)	Step Time with Tech & Parallel Svgs (hrs)	Staff Cost by Activity with Tech & Parallel Savings ($)
1	Move Transporter & SC into FHB	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	10	0.5	$413	0.0	0.5	$413	100%	0.0	0.5	$413	0.5	$413
2	Move SC to under seismic restraint	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	100%	0.0	0.5	$375	0.5	$375
3	Remove the SC lid and install adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	1.5	$1,350	0.0	1.5	$1,350	100%	0.0	1.5	$1,350	1.5	$1,350
4	Load spacers	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.8	$540	0.0	0.8	$540	100%	0.0	0.8	$540	0.8	$540
5	Move STAD into FHB	A	0	$75	1	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	100%	0.0	0.5	$525	0.5	$525
6	TC Preparation	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	2.0	$1,200	0.0	2.0	$1,200	100%	0.0	2.0	$1,200	2.0	$1,200
7	Move TC into decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	0.5	$450	0.0	0.5	$450	100%	0.0	0.5	$450	0.5	$450
8	TC Preparation	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	4.4	$2,640	0.0	4.4	$2,640	100%	0.0	4.4	$2,640	4.4	$2,640
9	Place STAD into TC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	2	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	1.0	$1,050	0.0	1.0	$1,050	100%	0.0	1.0	$1,050	1.0	$1,050
10	Place TC/STAD into SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	2	$75	2	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	18	2.6	$3,770	0.0	2.6	$3,770	100%	0.0	2.6	$3,770	2.6	$3,770
11	Start fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.5	$338	0.0	0.5	$338	50%	0.3	0.3	$169	0.3	$169
12	Fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	16.9	$11,408	0.0	16.9	$11,408	50%	8.5	8.5	$5,704	8.5	$5,704
13	Fuel verification	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	3	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	2.2	$1,485	0.0	2.2	$1,485	50%	1.1	1.1	$743	1.1	$743
14	Install DFC Lids/Spacers	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	2	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	3.0	$2,475	0.0	3.0	$2,475	100%	0.0	3.0	$2,475	3.0	$2,475
15	Install STAD lid	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	16	0.5	$638	0.0	0.5	$638	100%	0.0	0.5	$638	0.5	$638
16	Remove TC/STAD from SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	3	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	20	2.6	$4,160	0.0	2.6	$4,160	100%	0.0	2.6	$4,160	2.6	$4,160
17	Place TC/STAD into the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	3	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	0.5	$563	0.0	0.5	$563	100%	0.0	0.5	$563	0.5	$563
18	Decon TC/STAD	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	3	$75	3	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	4.1	$3,793	0.0	4.1	$3,793	100%	0.0	4.1	$3,793	4.1	$3,793
19	Remove 70 gallons water	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.7	$420	0.0	0.7	$420	100%	0.0	0.7	$420	0.7	$420
20	Test for hydrogen	E	0	$75	0	$75	0	$75	0	$75	2	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	100%	0.0	0.5	$300	0.5	$300
21	Perform lid fit up	A	1	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.0	$3,000	0.0	4.0	$3,000	100%	0.0	4.0	$3,000	4.0	$3,000
22	Weld STAD inner plate (all passes)	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	4.4	$2,970	0.0	4.4	$2,970	100%	0.0	4.4	$2,970	4.4	$2,970
23	NDE STAD inner plate (all passes)	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	2.9	$1,740	0.0	2.9	$1,740	100%	0.0	2.9	$1,740	2.9	$1,740
24	Hydro pressure test STAD inner plate	E	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675	0.0	1.0	$675	100%	0.0	1.0	$675	1.0	$675
25	Blowdown STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.9	$540	0.0	0.9	$540	100%	0.0	0.9	$540	0.9	$540
26	Set up the VDS	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
27	Vacuum dry STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	28.0	$18,900	4.8	23.2	$15,660	100%	0.0	28.0	$18,900	23.2	$15,660
28	Helium Backfill STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	2.1	$1,418	0.0	2.1	$1,418	100%	0.0	2.1	$1,418	2.1	$1,418
29	Weld and test inner port covers	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.0	$3,000	0.0	4.0	$3,000	100%	0.0	4.0	$3,000	4.0	$3,000
30	Helium leak test port covers	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.2	$630	0.0	1.2	$630	100%	0.0	1.2	$630	1.2	$630
31	Weld STAD outer plate	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.5	$1,013	0.0	1.5	$1,013	100%	0.0	1.5	$1,013	1.5	$1,013
32	NDE STAD outer plate	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
33	Install TC retaining lugs	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.5	$1,013	0.0	1.5	$1,013	100%	0.0	1.5	$1,013	1.5	$1,013
34	Prep TC/STAD for stack-up	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	2.0	$1,500	0.0	2.0	$1,500	100%	0.0	2.0	$1,500	2.0	$1,500
35	Remove TC/STAD from the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	100%	0.0	0.5	$525	0.5	$525
36	Place TC/STAD in stack-up	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.5	$1,725	0.0	1.5	$1,725	100%	0.0	1.5	$1,725	1.5	$1,725
37	Engage TC seismic restraint	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
38	Remove yoke from FHB hook	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	100%	0.0	0.5	$300	0.5	$300
39	Rig STAD to FHB hook	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.8	$1,530	0.0	1.8	$1,530	100%	0.0	1.8	$1,530	1.8	$1,530
40	Transfer STAD to SC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.0	$1,150	0.0	1.0	$1,150	50%	0.5	0.5	$575	0.5	$575
41	Remove rigging	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.5	$1,238	0.0	1.5	$1,238	50%	0.8	0.8	$619	0.8	$619
42	Close transfer adapter	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
43	Install yoke	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
44	Disengage TC seismic restraint	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675	0.0	1.0	$675	50%	0.5	0.5	$338	0.5	$338
45	Move TC to decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	50%	0.3	0.3	$263	0.3	$263
46	Remove rigging from STAD	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.0	$825	0.0	1.0	$825	50%	0.5	0.5	$413	0.5	$413
47	Remove transfer adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	1.5	$1,575	0.0	1.5	$1,575	50%	0.8	0.8	$788	0.8	$788
48	Set SC lid	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	2.0	$1,650	0.0	2.0	$1,650	50%	1.0	1.0	$825	1.0	$825
49	Check SC vents	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
50	Perform the hazards walkdown	A	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	5	1.0	$450	0.0	1.0	$450	50%	0.5	0.5	$225	0.5	$225
51	Move SC to transporter	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
52	Perform SC dose rates	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.0	$525	0.0	1.0	$525	50%	0.5	0.5	$263	0.5	$263
53	Move support equipment to ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
54	Move transporter to haul road	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	12	1.3	$1,268	0.0	1.3	$1,268	50%	0.7	0.7	$634	0.7	$634
55	Replace security barriers	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
56	Move transporter/SC/STAD to ISFSI pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	15	3.0	$3,600	0.0	3.0	$3,600	50%	1.5	1.5	$1,800	1.5	$1,800
57	Tie security barrier at ISFSI and open gate	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
58	Move transporter into position at ISFSI	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	15	0.5	$600	0.0	0.5	$600	50%	0.3	0.3	$300	0.3	$300
59	Position SC on pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	1	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	16	0.5	$638	0.0	0.5	$638	50%	0.3	0.3	$319	0.3	$319
60	Install vent screens	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
61	Move equipment from ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
62	Replace security barriers	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
	Total Time per STAD (hours)																																					126.8		4.8	122.0			19.9	106.9		102.1	
	Total Time per STAD (days)																																					5.3d		0.2d	5.1d			0.8d	4.5d		4.3d	
	Subtotal Labor Costs																																						$97,960			$94,720				$82,449		$79,209
	Other Costs (consumables) 15%																																						$14,694			$14,208				$12,367		$11,881
	Subtotal Costs w/o Contingency																																						$112,654			$108,928				$94,816		$91,090
	Contingency 20%																																						$22,531			$21,786				$18,963		$18,218
	Total Cost per STAD																																						$135,185			$130,714				$113,779		$109,308
	# of Assemblies per STAD 44																																						44			44				44		44
	Subtotal Cost per Assembly w/o Contingency																																						$2,560			$2,476				$2,155		$2,070
	Contingency 20%																																						$512			$495				$431		$414
	Total Hours/Cost per Assembly																																					2.88	$3,072		2.77	$2,971			2.43	$2,586	2.32	$2,484

Note: FTE counts apply to both the baseline and optimized cases.

Table 15-4. Operations Approaches – Large PWR STAD Canisters – Basis of Estimate

TABLE 15-4. Operations Approaches - Large PWR STAD Canisters Detailed Costs [ref. Table 19-4]

Task Location Legend: FHB Prep Area; Fuel Pool; Cask Decon Pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step #	Step Description	Task Category Code	Crane Operators		Other Heavy Eq. Operators		Mechanics		Riggers		Welders		Other Operations Staff		Supervisors/ Foremen		Deconners		Radiation Protection		RXS Techs		QA/QC		HP		Security		Planners		Trainers		Procedure Writers		Management		Total Personnel	Linear Step Time Baseline	Staff Cost by Activity	Technology Improvement (hours saved)	Step Time with Tech Savings Alone	Staff Cost by Activity with Tech Savings Alone	Percent on Clock (parallel savings)	Time Saved per STAD by Parallel Ops	Step Time with Parallel Svgs Alone	Staff Cost by Activity with Parallel Savings Alone	Step Time with Tech & Parallel Svgs	Staff Cost by Activity with Tech & Parallel Savings
	Step Description :		#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	hrs	$	hrs	hrs	$	%	hrs	hrs	$	hrs	$
1	Move Transporter & SC into FHB	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	10	0.5	$413	0.0	0.5	$413	100%	0.0	0.5	$413	0.5	$413
2	Move SC to under seismic restraint	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	100%	0.0	0.5	$375	0.5	$375
3	Remove the SC lid and install adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	1.5	$1,350	0.0	1.5	$1,350	100%	0.0	1.5	$1,350	1.5	$1,350
4	Load spacers	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.8	$540	0.0	0.8	$540	100%	0.0	0.8	$540	0.8	$540
5	Move STAD into FHB	A	0	$75	1	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	100%	0.0	0.5	$525	0.5	$525
6	TC Preparation	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	2.0	$1,200	0.0	2.0	$1,200	100%	0.0	2.0	$1,200	2.0	$1,200
7	Move TC into decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	0.5	$450	0.0	0.5	$450	100%	0.0	0.5	$450	0.5	$450
8	TC Preparation	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	4.4	$2,640	0.0	4.4	$2,640	100%	0.0	4.4	$2,640	4.4	$2,640
9	Place STAD into TC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	2	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	1.0	$1,050	0.0	1.0	$1,050	100%	0.0	1.0	$1,050	1.0	$1,050
10	Place TC/STAD into SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	2	$75	2	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	18	2.6	$3,770	0.0	2.6	$3,770	100%	0.0	2.6	$3,770	2.6	$3,770
11	Start fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.5	$338	0.0	0.5	$338	50%	0.3	0.3	$169	0.3	$169
12	Fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	8.1	$5,468	0.0	8.1	$5,468	50%	4.1	4.1	$2,734	4.1	$2,734
13	Fuel verification	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	3	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.1	$743	0.0	1.1	$743	50%	0.6	0.6	$371	0.6	$371
14	Install DFC Lids/Spacers	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	2	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	3.0	$2,475	0.0	3.0	$2,475	100%	0.0	3.0	$2,475	3.0	$2,475
15	Install STAD lid	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	16	0.5	$638	0.0	0.5	$638	100%	0.0	0.5	$638	0.5	$638
16	Remove TC/STAD from SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	3	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	20	2.6	$4,160	0.0	2.6	$4,160	100%	0.0	2.6	$4,160	2.6	$4,160
17	Place TC/STAD into the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	3	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	0.5	$563	0.0	0.5	$563	100%	0.0	0.5	$563	0.5	$563
18	Decon TC/STAD	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	3	$75	3	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	4.1	$3,793	0.0	4.1	$3,793	100%	0.0	4.1	$3,793	4.1	$3,793
19	Remove 70 gallons water	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.7	$420	0.0	0.7	$420	100%	0.0	0.7	$420	0.7	$420
20	Test for hydrogen	E	0	$75	0	$75	0	$75	0	$75	2	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	100%	0.0	0.5	$300	0.5	$300
21	Perform lid fit up	A	1	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.0	$3,000	0.0	4.0	$3,000	100%	0.0	4.0	$3,000	4.0	$3,000
22	Weld STAD inner plate (all passes)	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	4.4	$2,970	0.0	4.4	$2,970	100%	0.0	4.4	$2,970	4.4	$2,970
23	NDE STAD inner plate (all passes)	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	2.9	$1,740	0.0	2.9	$1,740	100%	0.0	2.9	$1,740	2.9	$1,740
24	Hydro pressure test STAD inner plate	E	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675	0.0	1.0	$675	100%	0.0	1.0	$675	1.0	$675
25	Blowdown STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
26	Set up the VDS	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
27	Vacuum dry STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	28.0	$18,900	4.8	23.2	$15,660	100%	0.0	28.0	$18,900	23.2	$15,660
28	Helium Backfill STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	2.1	$1,418	0.0	2.1	$1,418	100%	0.0	2.1	$1,418	2.1	$1,418
29	Weld and test inner port covers	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.0	$3,000	0.0	4.0	$3,000	100%	0.0	4.0	$3,000	4.0	$3,000
30	Helium leak test port covers	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.2	$630	0.0	1.2	$630	100%	0.0	1.2	$630	1.2	$630
31	Weld STAD outer plate	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.5	$1,013	0.0	1.5	$1,013	100%	0.0	1.5	$1,013	1.5	$1,013
32	NDE STAD outer plate	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
33	Install TC retaining lugs	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.5	$1,013	0.0	1.5	$1,013	100%	0.0	1.5	$1,013	1.5	$1,013
34	Prep TC/STAD for stack-up	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	2.0	$1,500	0.0	2.0	$1,500	100%	0.0	2.0	$1,500	2.0	$1,500
35	Remove TC/STAD from the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	100%	0.0	0.5	$525	0.5	$525
36	Place TC/STAD in stack-up	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.5	$1,725	0.0	1.5	$1,725	100%	0.0	1.5	$1,725	1.5	$1,725
37	Engage TC seismic restraint	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
38	Remove yoke from FHB hook	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	100%	0.0	0.5	$300	0.5	$300
39	Rig STAD to FHB hook	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.8	$1,530	0.0	1.8	$1,530	100%	0.0	1.8	$1,530	1.8	$1,530
40	Transfer STAD to SC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.0	$1,150	0.0	1.0	$1,150	50%	0.5	0.5	$575	0.5	$575
41	Remove rigging	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.5	$1,238	0.0	1.5	$1,238	50%	0.8	0.8	$619	0.8	$619
42	Close transfer adapter	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
43	Install yoke	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
44	Disengage TC seismic restraint	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675	0.0	1.0	$675	50%	0.5	0.5	$338	0.5	$338
45	Move TC to decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	50%	0.3	0.3	$263	0.3	$263
46	Remove rigging from STAD	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.0	$825	0.0	1.0	$825	50%	0.5	0.5	$413	0.5	$413
47	Remove transfer adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	1.5	$1,575	0.0	1.5	$1,575	50%	0.8	0.8	$788	0.8	$788
48	Set SC lid	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	2.0	$1,650	0.0	2.0	$1,650	50%	1.0	1.0	$825	1.0	$825
49	Check SC vents	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
50	Perform the hazards walkdown	A	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	5	1.0	$450	0.0	1.0	$450	50%	0.5	0.5	$225	0.5	$225
51	Move SC to transporter	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
52	Perform SC dose rates	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.0	$525	0.0	1.0	$525	50%	0.5	0.5	$263	0.5	$263
53	Move support equipment to ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
54	Move transporter to haul road	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	12	1.3	$1,268	0.0	1.3	$1,268	50%	0.7	0.7	$634	0.7	$634
55	Replace security barriers	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
56	Move transporter/SC/STAD to ISFSI pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	15	3.0	$3,600	0.0	3.0	$3,600	50%	1.5	1.5	$1,800	1.5	$1,800
57	Tie security barrier at ISFSI and open gate	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
58	Move transporter into position at ISFSI	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	15	0.5	$600	0.0	0.5	$600	50%	0.3	0.3	$300	0.3	$300
59	Position SC on pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	1	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	16	0.5	$638	0.0	0.5	$638	50%	0.3	0.3	$319	0.3	$319
60	Install vent screens	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
61	Move equipment from ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
62	Replace security barriers	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
	Total Time per STAD (hours)																																					117.0		4.8	112.2			15.0	102.1		97.3	
	Total Time per STAD (days)																																					4.9d		0.2d	4.7d			0.6d	4.3d		4.1d	
	Subtotal Labor Costs																																						**$91,338**			**$88,098**				**$79,168**		**$75,928**
	Other Costs (consumables) 15%																																						$13,701			$13,215				$11,875		$11,389
	Subtotal Costs w/o Contingency																																						**$105,038**			**$101,312**				**$91,043**		**$87,317**
	Contingency 20%																																						$21,008			$20,262				$18,209		$17,463
	Total Cost per STAD																																						**$126,046**			**$121,575**				**$109,251**		**$104,780**
	# of Assemblies per STAD 21																																						21			21				21		21
	Subtotal Cost per Assembly w/o Contingency																																						**$5,002**			**$4,824**				**$4,335**		**$4,158**
	Contingency 20%																																						**$1,000**			**$965**				**$867**		**$832**
	Total Hours/Cost per Assembly																																					5.57	**$6,002**		5.34	**$5,789**			4.86	**$5,202**	4.63	**$4,990**

Note: FTE counts apply to both the baseline and optimized cases.

Table 15-5. Operational Approaches – Medium BWR STAD Canisters – Basis of Estimate

TABLE 15-5. Operations Approaches - Medium BWR STAD Canisters Detailed Costs [ref. Table 19-5]

Task Location Legend: FHB Prep Area; Fuel Pool; Cask Decon Pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step #	Step Description :	Task Category Code	Crane Operators #	Crane Operators $	Other Heavy Eq. Operators #	Other Heavy Eq. Operators $	Mechanics #	Mechanics $	Riggers #	Riggers $	Welders #	Welders $	Other Operations Staff #	Other Operations Staff $	Supervisors/ Foremen #	Supervisors/ Foremen $	Deconners #	Deconners $	Radiation Protection #	Radiation Protection $	RXS Techs #	RXS Techs $	QA/QC #	QA/QC $	HP #	HP $	Security #	Security $	Planners #	Planners $	Trainers #	Trainers $	Procedure Writers #	Procedure Writers $	Management #	Management $	Total Personnel (#)	Linear Step Time Baseline (hrs)	Staff Cost by Activity ($)	Technology Improvement (hours saved) (hrs)	Step Time with Tech Savings Alone (hrs)	Staff Cost by Activity with Tech Savings Alone ($)	Percent on Clock (parallel savings) (%)	Time Saved per STAD by Parallel Ops (hrs)	Step Time with Parallel Svgs Alone (hrs)	Staff Cost by Activity with Parallel Savings Alone ($)	Step Time with Tech & Parallel Svgs (hrs)	Staff Cost by Activity with Tech & Parallel Savings ($)
1	Move Transporter & SC into FHB	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	10	0.5	$413	0.0	0.5	$413	100%	0.0	0.5	$413	0.5	$413
2	Move SC to under seismic restraint	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	100%	0.0	0.5	$375	0.5	$375
3	Remove the SC lid and install adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	1.5	$1,350	0.0	1.5	$1,350	100%	0.0	1.5	$1,350	1.5	$1,350
4	Load spacers	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.8	$540	0.0	0.8	$540	100%	0.0	0.8	$540	0.8	$540
5	Move STAD into FHB	A	0	$75	1	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	100%	0.0	0.5	$525	0.5	$525
6	TC Preparation	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	2.0	$1,200	0.0	2.0	$1,200	100%	0.0	2.0	$1,200	2.0	$1,200
7	Move TC into decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	0.5	$450	0.0	0.5	$450	100%	0.0	0.5	$450	0.5	$450
8	TC Preparation	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	4.4	$2,640	0.0	4.4	$2,640	100%	0.0	4.4	$2,640	4.4	$2,640
9	Place STAD into TC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	2	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	1.0	$1,050	0.0	1.0	$1,050	100%	0.0	1.0	$1,050	1.0	$1,050
10	Place TC/STAD into SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	2	$75	2	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	18	2.6	$3,770	0.0	2.6	$3,770	100%	0.0	2.6	$3,770	2.6	$3,770
11	Start fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.5	$338	0.0	0.5	$338	50%	0.3	0.3	$169	0.3	$169
12	Fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	12.3	$8,303	0.0	12.3	$8,303	50%	6.2	6.2	$4,151	6.2	$4,151
13	Fuel verification	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	3	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.6	$1,080	0.0	1.6	$1,080	50%	0.8	0.8	$540	0.8	$540
14	Install DFC Lids/Spacers	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	2	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	3.0	$2,475	0.0	3.0	$2,475	100%	0.0	3.0	$2,475	3.0	$2,475
15	Install STAD lid	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	16	0.5	$638	0.0	0.5	$638	100%	0.0	0.5	$638	0.5	$638
16	Remove TC/STAD from SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	3	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	20	2.6	$4,160	0.0	2.6	$4,160	100%	0.0	2.6	$4,160	2.6	$4,160
17	Place TC/STAD into the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	3	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	0.5	$563	0.0	0.5	$563	100%	0.0	0.5	$563	0.5	$563
18	Decon TC/STAD	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	3	$75	3	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	4.1	$3,793	0.0	4.1	$3,793	100%	0.0	4.1	$3,793	4.1	$3,793
19	Remove 70 gallons water	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.4	$240	0.0	0.4	$240	100%	0.0	0.4	$240	0.4	$240
20	Test for hydrogen	E	0	$75	0	$75	0	$75	0	$75	2	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	100%	0.0	0.5	$300	0.5	$300
21	Perform lid fit up	A	1	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.0	$3,000	0.0	4.0	$3,000	100%	0.0	4.0	$3,000	4.0	$3,000
22	Weld STAD inner plate (all passes)	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	3.2	$2,160	0.0	3.2	$2,160	100%	0.0	3.2	$2,160	3.2	$2,160
23	NDE STAD inner plate (all passes)	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	2.1	$1,260	0.0	2.1	$1,260	100%	0.0	2.1	$1,260	2.1	$1,260
24	Hydro pressure test STAD inner plate	E	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675	0.0	1.0	$675	100%	0.0	1.0	$675	1.0	$675
25	Blowdown STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	100%	0.0	0.5	$300	0.5	$300
26	Set up the VDS	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
27	Vacuum dry STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	14.0	$9,450	2.4	11.6	$7,830	100%	0.0	14.0	$9,450	11.6	$7,830
28	Helium Backfill STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.1	$743	0.0	1.1	$743	100%	0.0	1.1	$743	1.1	$743
29	Weld and test inner port covers	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.0	$3,000	0.0	4.0	$3,000	100%	0.0	4.0	$3,000	4.0	$3,000
30	Helium leak test port covers	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.2	$635	0.0	1.2	$635	100%	0.0	1.2	$635	1.2	$635
31	Weld STAD outer plate	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.1	$743	0.0	1.1	$743	100%	0.0	1.1	$743	1.1	$743
32	NDE STAD outer plate	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.7	$420	0.0	0.7	$420	100%	0.0	0.7	$420	0.7	$420
33	Install TC retaining lugs	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.5	$1,013	0.0	1.5	$1,013	100%	0.0	1.5	$1,013	1.5	$1,013
34	Prep TC/STAD for stack-up	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	2.0	$1,500	0.0	2.0	$1,500	100%	0.0	2.0	$1,500	2.0	$1,500
35	Remove TC/STAD from the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	100%	0.0	0.5	$525	0.5	$525
36	Place TC/STAD in stack-up	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.5	$1,725	0.0	1.5	$1,725	100%	0.0	1.5	$1,725	1.5	$1,725
37	Engage TC seismic restraint	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
38	Remove yoke from FHB hook	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	100%	0.0	0.5	$300	0.5	$300
39	Rig STAD to FHB hook	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.8	$1,530	0.0	1.8	$1,530	100%	0.0	1.8	$1,530	1.8	$1,530
40	Transfer STAD to SC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.0	$1,150	0.0	1.0	$1,150	50%	0.5	0.5	$575	0.5	$575
41	Remove rigging	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.5	$1,238	0.0	1.5	$1,238	50%	0.8	0.8	$619	0.8	$619
42	Close transfer adapter	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
43	Install yoke	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
44	Disengage TC seismic restraint	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675	0.0	1.0	$675	50%	0.5	0.5	$338	0.5	$338
45	Move TC to decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	50%	0.3	0.3	$263	0.3	$263
46	Remove rigging from STAD	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.0	$825	0.0	1.0	$825	50%	0.5	0.5	$413	0.5	$413
47	Remove transfer adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	1.5	$1,575	0.0	1.5	$1,575	50%	0.8	0.8	$788	0.8	$788
48	Set SC lid	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	2.0	$1,650	0.0	2.0	$1,650	50%	1.0	1.0	$825	1.0	$825
49	Check SC vents	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
50	Perform the hazards walkdown	A	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	5	1.0	$450	0.0	1.0	$450	50%	0.5	0.5	$225	0.5	$225
51	Move SC to transporter	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
52	Perform SC dose rates	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.0	$525	0.0	1.0	$525	50%	0.5	0.5	$263	0.5	$263
53	Move support equipment to ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
54	Move transporter to haul road	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	12	1.3	$1,268	0.0	1.3	$1,268	50%	0.7	0.7	$634	0.7	$634
55	Replace security barriers	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
56	Move transporter/SC/STAD to ISFSI pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	15	3.0	$3,600	0.0	3.0	$3,600	50%	1.5	1.5	$1,800	1.5	$1,800
57	Tie security barrier at ISFSI and open gate	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
58	Move transporter into position at ISFSI	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	15	0.5	$600	0.0	0.5	$600	50%	0.3	0.3	$300	0.3	$300
59	Position SC on pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	1	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	16	0.5	$638	0.0	0.5	$638	50%	0.3	0.3	$319	0.3	$319
60	Install vent screens	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
61	Move equipment from ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
62	Replace security barriers	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
	Total Time per STAD (hours)																																					103.2		2.4	100.8			17.3	85.9		83.5	
	Total Time per STAD (days)																																					4.3d		0.1d	4.2d			0.7d	3.6d		3.5d	
	Subtotal Labor Costs																																						**$82,170**			**$80,550**				**$68,414**		**$66,794**
	Other Costs (consumables)	15%																																					$12,326			$12,083				$10,262		$10,019
	Subtotal Costs w/o Contingency																																						**$94,496**			**$92,633**				**$78,676**		**$76,813**
	Contingency	20%																																					$18,899			$18,527				$15,735		$15,363
	Total Cost per STAD																																						**$113,395**			**$111,159**				**$94,411**		**$92,176**
	# of Assemblies per STAD	32																																					32			32				32		32
	Subtotal Cost per Assembly w/o Contingency																																						**$2,953**			**$2,895**				**$2,459**		**$2,400**
	Contingency	20%																																					**$591**			**$579**				**$492**		**$480**
	Total Hours/Cost per Assembly																																					3.23	**$3,544**		3.15	**$3,474**			2.68	**$2,950**	2.61	**$2,880**

Note: FTE counts apply to both the baseline and optimized cases.

Table 15-6. Operations Approaches – Medium PWR STAD Canisters – Basis of Estimate

TABLE 15-6. Operations Approaches - Medium PWR STAD Canisters Detailed Costs [ref. Table 19-6]

Task Location Legend: FHB Prep Area; Fuel Pool; Cask Decon Pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step #	Step Description :	Task Category Code	Crane Operators		Other Heavy Eq. Operators		Mechanics		Riggers		Welders		Other Operations Staff		Supervisors/ Foremen		Deconners		Radiation Protection	
			#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$
1	Move Transporter & SC into FHB	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
2	Move SC to under seismic restraint	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
3	Remove the SC lid and install adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75
4	Load spacers	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
5	Move STAD into FHB	A	0	$75	1	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75
6	TC Preparation	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
7	Move TC into decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75
8	TC Preparation	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
9	Place STAD into TC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75
10	Place TC/STAD into SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	2	$75
11	Start fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
12	Fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
13	Fuel verification	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
14	Install DFC Lids/Spacers	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
15	Install STAD lid	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75
16	Remove TC/STAD from SFP	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	3	$75
17	Place TC/STAD into the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	3	$75
18	Decon TC/STAD	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	3	$75	3	$75
19	Remove 70 gallons water	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
20	Test for hydrogen	E	0	$75	0	$75	0	$75	0	$75	2	$75	0	$75	1	$100	0	$75	0	$75
21	Perform lid fit up	A	1	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75
22	Weld STAD inner plate (all passes)	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75
23	NDE STAD inner plate (all passes)	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75
24	Hydro pressure test STAD inner plate	E	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
25	Blowdown STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
26	Set up the VDS	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
27	Vacuum dry STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
28	Helium Backfill STAD	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
29	Weld and test inner port covers	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75
30	Helium leak test port covers	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
31	Weld STAD outer plate	D	0	$75	0	$75	0	$75	0	$75	3	$75	0	$75	1	$100	0	$75	1	$75
32	NDE STAD outer plate	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75
33	Install TC retaining lugs	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
34	Prep TC/STAD for stack-up	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75
35	Remove TC/STAD from the decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75
36	Place TC/STAD in stack-up	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75
37	Engage TC seismic restraint	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
38	Remove yoke from FHB hook	A	1	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
39	Rig STAD to FHB hook	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75
40	Transfer STAD to SC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75
41	Remove rigging	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75
42	Close transfer adapter	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
43	Install yoke	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75
44	Disengage TC seismic restraint	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
45	Move TC to decon pit	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75
46	Remove rigging from STAD	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75
47	Remove transfer adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75
48	Set SC lid	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75
49	Check SC vents	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
50	Perform the hazards walkdown	A	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
51	Move SC to transporter	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
52	Perform SC dose rates	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75
53	Move support equipment to ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
54	Move transporter to haul road	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75
55	Replace security barriers	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
56	Move transporter/SC/STAD to ISFSI pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75
57	Tie security barrier at ISFSI and open gate	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
58	Move transporter into position at ISFSI	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75
59	Position SC on pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75
60	Install vent screens	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75
61	Move equipment from ISFSI	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75
62	Replace security barriers	A	0	$75	1	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75

Step #	RXS Techs		QA/QC		HP		Security		Planners		Trainers		Procedure Writers		Management		Total Personnel	Linear Step Time Baseline	Staff Cost by Activity	Technology Improvement (hours saved)	Step Time with Tech Savings Alone	Staff Cost by Activity with Tech Savings Alone	Percent on Clock (parallel savings)	Time Saved per STAD by Parallel Ops	Step Time with Parallel Svgs Alone	Staff Cost by Activity with Parallel Savings Alone	Step Time with Tech & Parallel Svgs	Staff Cost by Activity with Tech & Parallel Savings
	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	hrs	$	hrs	hrs	$	%	hrs	hrs	$	hrs	$
1	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	10	0.5	$413	0.0	0.5	$413	100%	0.0	0.5	$413	0.5	$413
2	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	100%	0.0	0.5	$375	0.5	$375
3	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	1.5	$1,350	0.0	1.5	$1,350	100%	0.0	1.5	$1,350	1.5	$1,350
4	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.8	$540	0.0	0.8	$540	100%	0.0	0.8	$540	0.8	$540
5	0	$75	0	$75	0	$100	1	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	100%	0.0	0.5	$525	0.5	$525
6	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	2.0	$1,200	0.0	2.0	$1,200	100%	0.0	2.0	$1,200	2.0	$1,200
7	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	0.5	$450	0.0	0.5	$450	100%	0.0	0.5	$450	0.5	$450
8	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	4.4	$2,640	0.0	4.4	$2,640	100%	0.0	4.4	$2,640	4.4	$2,640
9	2	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	1.0	$1,050	0.0	1.0	$1,050	100%	0.0	1.0	$1,050	1.0	$1,050
10	2	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	18	2.6	$3,770	0.0	2.6	$3,770	100%	0.0	2.6	$3,770	2.6	$3,770
11	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.5	$338	0.0	0.5	$338	50%	0.3	0.3	$169	0.3	$169
12	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	4.6	$3,105	0.0	4.6	$3,105	50%	2.3	2.3	$1,553	2.3	$1,553
13	3	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	0.6	$405	0.0	0.6	$405	50%	0.3	0.3	$203	0.3	$203
14	2	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	3.0	$2,475	0.0	3.0	$2,475	100%	0.0	3.0	$2,475	3.0	$2,475
15	3	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	16	0.5	$638	0.0	0.5	$638	100%	0.0	0.5	$638	0.5	$638
16	3	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	20	2.6	$4,160	0.0	2.6	$4,160	100%	0.0	2.6	$4,160	2.6	$4,160
17	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	0.5	$563	0.0	0.5	$563	100%	0.0	0.5	$563	0.5	$563
18	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	11	4.1	$3,793	0.0	4.1	$3,793	100%	0.0	4.1	$3,793	4.1	$3,793
19	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.4	$240	0.0	0.4	$240	100%	0.0	0.4	$240	0.4	$240
20	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	100%	0.0	0.5	$300	0.5	$300
21	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.0	$3,000	0.0	4.0	$3,000	100%	0.0	4.0	$3,000	4.0	$3,000
22	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	3.2	$2,160	0.0	3.2	$2,160	100%	0.0	3.2	$2,160	3.2	$2,160
23	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	2.1	$1,260	0.0	2.1	$1,260	100%	0.0	2.1	$1,260	2.1	$1,260
24	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675	0.0	1.0	$675	100%	0.0	1.0	$675	1.0	$675
25	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	100%	0.0	0.5	$300	0.5	$300
26	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
27	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	14.0	$9,450	2.4	11.6	$7,830	100%	0.0	14.0	$9,450	11.6	$7,830
28	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.1	$743	0.0	1.1	$743	100%	0.0	1.1	$743	1.1	$743
29	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	4.0	$3,000	0.0	4.0	$3,000	100%	0.0	4.0	$3,000	4.0	$3,000
30	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.2	$635	0.0	1.2	$635	100%	0.0	1.2	$635	1.2	$635
31	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.1	$743	0.0	1.1	$743	100%	0.0	1.1	$743	1.1	$743
32	0	$75	1	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.7	$420	0.0	0.7	$420	100%	0.0	0.7	$420	0.7	$420
33	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.5	$1,013	0.0	1.5	$1,013	100%	0.0	1.5	$1,013	1.5	$1,013
34	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	2.0	$1,500	0.0	2.0	$1,500	100%	0.0	2.0	$1,500	2.0	$1,500
35	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	100%	0.0	0.5	$525	0.5	$525
36	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.5	$1,725	0.0	1.5	$1,725	100%	0.0	1.5	$1,725	1.5	$1,725
37	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
38	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	100%	0.0	0.5	$300	0.5	$300
39	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.8	$1,530	0.0	1.8	$1,530	100%	0.0	1.8	$1,530	1.8	$1,530
40	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	1	$125	14	1.0	$1,150	0.0	1.0	$1,150	50%	0.5	0.5	$575	0.5	$575
41	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.5	$1,238	0.0	1.5	$1,238	50%	0.8	0.8	$619	0.8	$619
42	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
43	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
44	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	8	1.0	$675	0.0	1.0	$675	50%	0.5	0.5	$338	0.5	$338
45	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	50%	0.3	0.3	$263	0.3	$263
46	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	1.0	$825	0.0	1.0	$825	50%	0.5	0.5	$413	0.5	$413
47	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	13	1.5	$1,575	0.0	1.5	$1,575	50%	0.8	0.8	$788	0.8	$788
48	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	10	2.0	$1,650	0.0	2.0	$1,650	50%	1.0	1.0	$825	1.0	$825
49	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
50	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	5	1.0	$450	0.0	1.0	$450	50%	0.5	0.5	$225	0.5	$225
51	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
52	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	6	1.0	$525	0.0	1.0	$525	50%	0.5	0.5	$263	0.5	$263
53	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
54	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	12	1.3	$1,268	0.0	1.3	$1,268	50%	0.7	0.7	$634	0.7	$634
55	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
56	0	$75	0	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	15	3.0	$3,600	0.0	3.0	$3,600	50%	1.5	1.5	$1,800	1.5	$1,800
57	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
58	0	$75	0	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	15	0.5	$600	0.0	0.5	$600	50%	0.3	0.3	$300	0.3	$300
59	0	$75	1	$75	0	$100	4	$75	1	$75	0	$75	1	$75	1	$125	16	0.5	$638	0.0	0.5	$638	50%	0.3	0.3	$319	0.3	$319
60	0	$75	0	$75	0	$100	0	$75	1	$75	0	$75	1	$75	1	$125	7	0.5	$300	0.0	0.5	$300	50%	0.3	0.3	$150	0.3	$150
61	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	50%	0.3	0.3	$188	0.3	$188
62	0	$75	0	$75	0	$100	2	$75	1	$75	0	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	50%	0.2	0.2	$113	0.2	$113
Total Time per STAD (hours)																		94.5		2.4	92.1			13.0	81.6		79.2	
Total Time per STAD (days)																		3.9d		0.1d	3.8d			0.5d	3.4d		3.3d	
Subtotal Labor Costs																			**$76,298**			**$74,678**				**$65,478**		**$63,858**
Other Costs (consumables) 15%																			$11,445			$11,202				$9,822		$9,579
Subtotal Costs w/o Contingency																			**$87,742**			**$85,879**				**$75,299**		**$73,436**
Contingency 20%																			$17,548			$17,176				$15,060		$14,687
Total Cost per STAD																			**$105,291**			**$103,055**				**$90,359**		**$88,124**
# of Assemblies per STAD 12																			12			12				12		12
Subtotal Cost per Assembly w/o Contingency																			**$7,312**			**$7,157**				**$6,275**		**$6,120**
Contingency 20%																			**$1,462**			**$1,431**				**$1,255**		**$1,224**
Total Hours/Cost per Assembly																		7.88	**$8,774**		7.68	**$8,588**			6.80	**$7,530**	6.60	**$7,344**

Note: FTE counts apply to both the baseline and optimized cases.

Table 15-7. Operations Approaches – Small BWR STADs-in-Can – Basis of Estimate

TABLE 15-7. Operations Approaches - Small BWR STADs-in-Can Detailed Costs [ref. Table 19-7]

Task Location Legend: FHB Prep Area; Fuel Pool; Cask Decon Pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step #	Step Description :	Task Category Code	Crane Operators		Other Heavy Eq. Operators		Mechanics		Riggers		Welders		Other Opera-tions Staff		Supervisors/ Foremen		Deconners		Radiation Protection		RXS Techs	
			#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$
A5	Move VCT & SOC into PCT	A	0	$75	1	$75	4	$75	1	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
A6	Move SOC to seismic restraint	A	0	$75	1	$75	3	$75	1	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75
A7	Remove the SOC lid	A	1	$75	0	$75	3	$75	1	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75
A8	Remove Can lid	A	1	$75	0	$75	2	$75	1	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75
A9	Lift Can with STADs from SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75
A10	Place Can into Transfer Cask	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75
A11	Remove STAD lids	A	1	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75
A12	Fill Transfer Cask with de-ionized water	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75
A13	Install inflatable seal between Can and Transfer Cask	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75
A14	Verify water chemistry matches fuel pool	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75
A15	Place Transfer Cask into Fuel Pool	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	1	$75	1	$75
A16	Fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
A17	Fuel verification	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B1	Install 4 STAD lids	A	1	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B2	Lift Transfer Cask from Fuel Pool	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	2	$75	2	$75	1	$75
B3	Lower water level in 4 STADs	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	1	$75
B4	Perform welding of 4 STAD inner lids (all passes)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B5	Perform weld NDE for 4 STAD innter lids (all passes)	E	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B6	STAD hydrostatic test (all 4)	E	0	$75	0	$75	2	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B7	STAD water blowdown (all 4)	C	0	$75	0	$75	2	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B8	STAD drying and helium backfill (all 4)	C	0	$75	0	$75	3	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B9	STAD leak test (all 4)	E	0	$75	0	$75	2	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B10	Install STAD siphon and vent pool covers (all 8)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B11	Perform siphone and vent cover He leak tests (all 8)	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B12	Blowdown can water level below shielding disk	C	0	$75	0	$75	2	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B13	Install Can lid	A	1	$75	0	$75	3	$75	1	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B14	Weld Can lid	D	0	$75	0	$75	1	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B15	NDE Can lid weld	E	0	$75	0	$75	1	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B16	Dry and backfill Can with helium	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B17	Can pressure test	E	0	$75	0	$75	2	$75	0	$75	2	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B18	Install Can siphon and vent pool covers	D	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B19	Perform Can siphon and vent cover leak test	E	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B20	Deflate seal between Can and Transfer Cask	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B21	Drain water from Can/Transfer Cask annulus	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
B22	Decon Transfer Cask	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	3	$75	2	$75	1	$75
B23	Prepare for the Can to SOC transfer	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	1	$75
B24	Mover Transfer Cask to SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	1	$75
B25	Load Can into SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	1	$75
B26	Move Transfer Cask to staging area	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
C1	Install SOC lid	A	1	$75	0	$75	2	$75	1	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
C2	Load SOC onto VCT	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75
C3	Transport SOC to storage pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75

Step #	Step Description :	QA/QC		HP		Security		Planners		Trainers		Procedure Writers		Management		Total Personnel	Linear Step Time Baseline	Staff Cost by Activity	Technology Improvement (hours saved)	Step Time with Tech Savings Alone	Staff Cost by Activity with Tech Savings Alone	Percent on Clock (parallel savings)	Time Saved per STAD by Parallel Ops	Step Time with Parallel Svgs Alone	Staff Cost by Activity with Parallel Savings Alone	Step Time with Tech & Parallel Svgs	Staff Cost by Activity with Tech & Parallel Savings
		#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	hrs	$	hrs	hrs	$	%	hrs	hrs	$	hrs	$
A5	Move VCT & SOC into PCT	0	$75	0	$100	1	$75	1	$75	1	$75	1	$75	1	$125	14	0.5	$563	0.0	0.5	$563	100%	0.0	0.5	$563	0.5	$563
A6	Move SOC to seismic restraint	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	0.5	$450	0.0	0.5	$450	100%	0.0	0.5	$450	0.5	$450
A7	Remove the SOC lid	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	1.5	$1,350	0.0	1.5	$1,350	100%	0.0	1.5	$1,350	1.5	$1,350
A8	Remove Can lid	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	1.5	$1,238	0.0	1.5	$1,238	100%	0.0	1.5	$1,238	1.5	$1,238
A9	Lift Can with STADs from SOC	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	13	2.0	$2,100	0.0	2.0	$2,100	100%	0.0	2.0	$2,100	2.0	$2,100
A10	Place Can into Transfer Cask	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	13	2.0	$2,100	0.0	2.0	$2,100	100%	0.0	2.0	$2,100	2.0	$2,100
A11	Remove STAD lids	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	12	4.0	$3,900	0.0	4.0	$3,900	100%	0.0	4.0	$3,900	4.0	$3,900
A12	Fill Transfer Cask with de-ionized water	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	8	2.0	$1,350	0.0	2.0	$1,350	100%	0.0	2.0	$1,350	2.0	$1,350
A13	Install inflatable seal between Can and Transfer Cask	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	8	2.0	$1,350	0.0	2.0	$1,350	100%	0.0	2.0	$1,350	2.0	$1,350
A14	Verify water chemistry matches fuel pool	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
A15	Place Transfer Cask into Fuel Pool	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	1	$125	17	2.6	$3,575	0.0	2.6	$3,575	50%	1.3	1.3	$1,788	1.3	$1,788
A16	Fuel moves	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	14.3	$8,580	0.0	14.3	$8,580	50%	7.2	7.2	$4,290	7.2	$4,290
A17	Fuel verification	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	8	1.8	$1,215	0.0	1.8	$1,215	50%	0.9	0.9	$608	0.9	$608
B1	Install 4 STAD lids	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	13	1.0	$1,050	0.0	1.0	$1,050	100%	0.0	1.0	$1,050	1.0	$1,050
B2	Lift Transfer Cask from Fuel Pool	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	1	$125	20	2.6	$4,160	0.0	2.6	$4,160	100%	0.0	2.6	$4,160	2.6	$4,160
B3	Lower water level in 4 STADs	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	0.5	$413	0.0	0.5	$413	45%	0.3	0.2	$186	0.2	$186
B4	Perform welding of 4 STAD inner lids (all passes)	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	9.3	$6,278	0.0	9.3	$6,278	47%	5.0	4.3	$3,892	4.3	$3,892
B5	Perform weld NDE for 4 STAD innter lids (all passes)	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	12	3.2	$2,400	0.0	3.2	$2,400	33%	2.1	1.1	$1,030	1.1	$1,030
B6	STAD hydrostatic test (all 4)	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	2.0	$1,800	0.0	2.0	$1,800	25%	1.5	0.5	$450	0.5	$450
B7	STAD water blowdown (all 4)	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	0.8	$660	0.0	0.8	$660	88%	0.1	0.7	$578	0.7	$578
B8	STAD drying and helium backfill (all 4)	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	12	18.2	$17,745	3.1	15.1	$14,723	25%	13.7	4.6	$4,436	3.8	$3,681
B9	STAD leak test (all 4)	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	4.9	$4,410	0.0	4.9	$4,410	25%	3.7	1.2	$1,103	1.2	$1,103
B10	Install STAD siphon and vent pool covers (all 8)	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	8.0	$5,400	0.0	8.0	$5,400	25%	6.0	2.0	$1,800	2.0	$1,800
B11	Perform siphone and vent cover He leak tests (all 8)	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	9	2.4	$1,800	0.0	2.4	$1,800	100%	0.0	2.4	$1,800	2.4	$1,800
B12	Blowdown can water level below shielding disk	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	0.5	$413	0.0	0.5	$413	100%	0.0	0.5	$413	0.5	$413
B13	Install Can lid	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	13	4.0	$4,200	0.0	4.0	$4,200	100%	0.0	4.0	$4,200	4.0	$4,200
B14	Weld Can lid	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	9	4.6	$3,450	0.0	4.6	$3,450	100%	0.0	4.6	$3,450	4.6	$3,450
B15	NDE Can lid weld	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	3.0	$2,475	0.0	3.0	$2,475	100%	0.0	3.0	$2,475	3.0	$2,475
B16	Dry and backfill Can with helium	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	8.0	$6,600	0.0	8.0	$6,600	50%	4.0	4.0	$3,300	4.0	$3,300
B17	Can pressure test	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	12	1.0	$975	0.0	1.0	$975	100%	0.0	1.0	$975	1.0	$975
B18	Install Can siphon and vent pool covers	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	4.0	$2,400	0.0	4.0	$2,400	100%	0.0	4.0	$2,400	4.0	$2,400
B19	Perform Can siphon and vent cover leak test	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	9	1.2	$900	0.0	1.2	$900	100%	0.0	1.2	$900	1.2	$900
B20	Deflate seal between Can and Transfer Cask	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	9	0.3	$225	0.0	0.3	$225	100%	0.0	0.3	$225	0.3	$225
B21	Drain water from Can/Transfer Cask annulus	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	9	1.0	$750	0.0	1.0	$750	100%	0.0	1.0	$750	1.0	$750
B22	Decon Transfer Cask	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	4.1	$3,690	0.0	4.1	$3,690	100%	0.0	4.1	$3,690	4.1	$3,690
B23	Prepare for the Can to SOC transfer	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	2.0	$1,800	0.0	2.0	$1,800	100%	0.0	2.0	$1,800	2.0	$1,800
B24	Mover Transfer Cask to SOC	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	15	6.8	$8,160	0.0	6.8	$8,160	100%	0.0	6.8	$8,160	6.8	$8,160
B25	Load Can into SOC	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	15	1.0	$1,200	0.0	1.0	$1,200	100%	0.0	1.0	$1,200	1.0	$1,200
B26	Move Transfer Cask to staging area	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	14	6.5	$7,313	0.0	6.5	$7,313	100%	0.0	6.5	$7,313	6.5	$7,313
C1	Install SOC lid	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	2.0	$1,800	0.0	2.0	$1,800	50%	1.0	1.0	$900	1.0	$900
C2	Load SOC onto VCT	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	2.0	$1,800	0.0	2.0	$1,800	50%	1.0	1.0	$900	1.0	$900
C3	Transport SOC to storage pad	1	$75	0	$100	4	$75	1	$75	1	$75	1	$75	1	$125	17	7.3	$9,855	0.0	7.3	$9,855	50%	3.7	3.7	$4,928	3.7	$4,928
	Total Time per STADs-in-Can (hours)																147.9		3.1	144.8			51.3	96.6		95.8	
	Total Time per STADs-in-Can (days)																6.2d		0.1d	6d			2.1d	4d		4d	
	Subtotal Labor Costs																	**$132,490**			**$129,468**				**$90,146**		**$89,390**
	Other Costs (consumables) 15%																	$19,874			$19,420				$13,522		$13,409
	Subtotal Costs w/o Contingency																	**$152,364**			**$148,888**				**$103,668**		**$102,799**
	Contingency 20%																	$30,473			$29,778				$20,734		$20,560
	Total Cost per Can																	**$182,836**			**$178,665**				**$124,402**		**$123,359**
	# of STADs per Can 4																	4			4				4		4
	# of Assemblies per STAD 9																	9			9				9		9
	Subtotal Cost per Assembly w/o Contingency																	**$4,232**			**$4,136**				**$2,880**		**$2,856**
	Contingency 20%																	**$846**			**$827**				**$576**		**$571**
	Total Hours/Cost per Assembly																4.11	**$5,079**		4.02	**$4,963**			2.68	**$3,456**	2.66	**$3,427**

Note: FTE counts apply to both the baseline and optimized cases with the following exceptions - for steps B4, B5 and B10, four welders are shown for the optimized case, whereas only 1 welder has been included for the baseline case (not shown)

Table 15-8. Operations Approaches – Small PWR STADs-in-Can – Basis of Estimate

TABLE 15-8. Operations Approaches - Small PWR STADs-in-Can Detailed Costs [ref. Table 19-8]

Task Location Legend: FHB Prep Area; Fuel Pool; Cask Decon Pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step #	Step Description :	Task Category Code	Crane Operators		Other Heavy Eq. Operators		Mechanics		Riggers		Welders		Other Operations Staff		Supervisors/ Foremen		Deconners		Radiation Protection		RXS Techs		QA/QC		HP		Security		Planners		Trainers		Procedure Writers		Management	
			#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$	#	$
A5	Move VCT & SOC into PCT	A	0	$75	1	$75	4	$75	1	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	1	$75	1	$75	1	$75	1	$75	1	$125
A6	Move SOC to seismic restraint	A	0	$75	1	$75	3	$75	1	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A7	Remove the SOC lid	A	1	$75	0	$75	3	$75	1	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A8	Remove Can lid	A	1	$75	0	$75	2	$75	1	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A9	Lift Can with STADs from SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A10	Place Can into Transfer Cask	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A11	Remove STAD lids	A	1	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A12	Fill Transfer Cask with de-ionized water	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A13	Install inflatable seal between Can and Transfer Cask	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A14	Verify water chemistry matches fuel pool	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A15	Place Transfer Cask into Fuel Pool	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	1	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A16	Fuel moves	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A17	Fuel verification	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B1	Install 4 STAD lids	A	1	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B2	Lift Transfer Cask from Fuel Pool	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	2	$75	2	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B3	Lower water level in 4 STADs	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B4	Perform welding of 4 STAD inner lids (all passes)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B5	Perform weld NDE for 4 STAD innter lids (all passes)	E	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B6	STAD hydrostatic test (all 4)	E	0	$75	0	$75	2	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B7	STAD water blowdown (all 4)	C	0	$75	0	$75	2	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B8	STAD drying and helium backfill (all 4)	C	0	$75	0	$75	3	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B9	STAD leak test (all 4)	E	0	$75	0	$75	2	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B10	Install STAD siphon and vent pool covers (all 8)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B11	Perform siphone and vent cover He leak tests (all 8)	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B12	Blowdown can water level below shielding disk	C	0	$75	0	$75	2	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B13	Install Can lid	A	1	$75	0	$75	3	$75	1	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B14	Weld Can lid	D	0	$75	0	$75	1	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B15	NDE Can lid weld	E	0	$75	0	$75	1	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B16	Dry and backfill Can with helium	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B17	Can pressure test	E	0	$75	0	$75	2	$75	0	$75	2	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B18	Install Can siphon and vent pool covers	D	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B19	Perform Can siphon and vent cover leak test	E	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B20	Deflate seal between Can and Transfer Cask	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B21	Drain water from Can/Transfer Cask annulus	C	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B22	Decon Transfer Cask	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	3	$75	2	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B23	Prepare for the Can to SOC transfer	A	0	$75	0	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B24	Mover Transfer Cask to SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B25	Load Can into SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B26	Move Transfer Cask to staging area	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
C1	Install SOC lid	A	1	$75	0	$75	2	$75	1	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
C2	Load SOC onto VCT	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
C3	Transport SOC to storage pad	A	0	$75	1	$75	4	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	0	$100	4	$75	1	$75	1	$75	1	$75	1	$125

Step #	Step Description :		Total Personnel	Linear Step Time Baseline	Staff Cost by Activity	Technology Improvement (hours saved)	Step Time with Tech Savings Alone	Staff Cost by Activity with Tech Savings Alone	Percent on Clock (parallel savings)	Time Saved per STAD by Parallel Ops	Step Time with Parallel Svgs Alone	Staff Cost by Activity with Parallel Savings Alone	Step Time with Tech & Parallel Svgs	Staff Cost by Activity with Tech & Parallel Savings
			#	hrs	$	hrs	hrs	$	%	hrs	hrs	$	hrs	$
A5	Move VCT & SOC into PCT		14	0.5	$563	0.0	0.5	$563	100%	0.0	0.5	$563	0.5	$563
A6	Move SOC to seismic restraint		11	0.5	$450	0.0	0.5	$450	100%	0.0	0.5	$450	0.5	$450
A7	Remove the SOC lid		11	1.5	$1,350	0.0	1.5	$1,350	100%	0.0	1.5	$1,350	1.5	$1,350
A8	Remove Can lid		10	1.5	$1,238	0.0	1.5	$1,238	100%	0.0	1.5	$1,238	1.5	$1,238
A9	Lift Can with STADs from SOC		13	2.0	$2,100	0.0	2.0	$2,100	100%	0.0	2.0	$2,100	2.0	$2,100
A10	Place Can into Transfer Cask		13	2.0	$2,100	0.0	2.0	$2,100	100%	0.0	2.0	$2,100	2.0	$2,100
A11	Remove STAD lids		12	4.0	$3,900	0.0	4.0	$3,900	100%	0.0	4.0	$3,900	4.0	$3,900
A12	Fill Transfer Cask with de-ionized water		8	2.0	$1,350	0.0	2.0	$1,350	100%	0.0	2.0	$1,350	2.0	$1,350
A13	Install inflatable seal between Can and Transfer Cask		8	2.0	$1,350	0.0	2.0	$1,350	100%	0.0	2.0	$1,350	2.0	$1,350
A14	Verify water chemistry matches fuel pool		7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
A15	Place Transfer Cask into Fuel Pool		17	2.6	$3,575	0.0	2.6	$3,575	50%	1.3	1.3	$1,788	1.3	$1,788
A16	Fuel moves		7	6.6	$3,960	0.0	6.6	$3,960	50%	3.3	3.3	$1,980	3.3	$1,980
A17	Fuel verification		8	0.8	$540	0.0	0.8	$540	50%	0.4	0.4	$270	0.4	$270
B1	Install 4 STAD lids		13	1.0	$1,050	0.0	1.0	$1,050	100%	0.0	1.0	$1,050	1.0	$1,050
B2	Lift Transfer Cask from Fuel Pool		20	2.6	$4,160	0.0	2.6	$4,160	100%	0.0	2.6	$4,160	2.6	$4,160
B3	Lower water level in 4 STADs		10	0.5	$413	0.0	0.5	$413	45%	0.3	0.2	$186	0.2	$186
B4	Perform welding of 4 STAD inner lids (all passes)		11	9.3	$6,278	0.0	9.3	$6,278	47%	5.0	4.3	$3,892	4.3	$3,892
B5	Perform weld NDE for 4 STAD innter lids (all passes)		12	3.2	$2,400	0.0	3.2	$2,400	33%	2.1	1.1	$1,030	1.1	$1,030
B6	STAD hydrostatic test (all 4)		11	2.0	$1,800	0.0	2.0	$1,800	25%	1.5	0.5	$450	0.5	$450
B7	STAD water blowdown (all 4)		10	0.8	$660	0.0	0.8	$660	88%	0.1	0.7	$578	0.7	$578
B8	STAD drying and helium backfill (all 4)		12	18.2	$17,745	3.1	15.1	$14,723	25%	13.7	4.6	$4,436	3.8	$3,681
B9	STAD leak test (all 4)		11	4.9	$4,410	0.0	4.9	$4,410	25%	3.7	1.2	$1,103	1.2	$1,103
B10	Install STAD siphon and vent pool covers (all 8)		11	8.0	$5,400	0.0	8.0	$5,400	25%	6.0	2.0	$1,800	2.0	$1,800
B11	Perform siphone and vent cover He leak tests (all 8)		9	2.4	$1,800	0.0	2.4	$1,800	100%	0.0	2.4	$1,800	2.4	$1,800
B12	Blowdown can water level below shielding disk		10	0.5	$413	0.0	0.5	$413	100%	0.0	0.5	$413	0.5	$413
B13	Install Can lid		13	4.0	$4,200	0.0	4.0	$4,200	100%	0.0	4.0	$4,200	4.0	$4,200
B14	Weld Can lid		9	4.6	$3,450	0.0	4.6	$3,450	100%	0.0	4.6	$3,450	4.6	$3,450
B15	NDE Can lid weld		10	3.0	$2,475	0.0	3.0	$2,475	100%	0.0	3.0	$2,475	3.0	$2,475
B16	Dry and backfill Can with helium		10	8.0	$6,600	0.0	8.0	$6,600	50%	4.0	4.0	$3,300	4.0	$3,300
B17	Can pressure test		12	1.0	$975	0.0	1.0	$975	100%	0.0	1.0	$975	1.0	$975
B18	Install Can siphon and vent pool covers		7	4.0	$2,400	0.0	4.0	$2,400	100%	0.0	4.0	$2,400	4.0	$2,400
B19	Perform Can siphon and vent cover leak test		9	1.2	$900	0.0	1.2	$900	100%	0.0	1.2	$900	1.2	$900
B20	Deflate seal between Can and Transfer Cask		9	0.3	$225	0.0	0.3	$225	100%	0.0	0.3	$225	0.3	$225
B21	Drain water from Can/Transfer Cask annulus		9	1.0	$750	0.0	1.0	$750	100%	0.0	1.0	$750	1.0	$750
B22	Decon Transfer Cask		11	4.1	$3,690	0.0	4.1	$3,690	100%	0.0	4.1	$3,690	4.1	$3,690
B23	Prepare for the Can to SOC transfer		11	2.0	$1,800	0.0	2.0	$1,800	100%	0.0	2.0	$1,800	2.0	$1,800
B24	Mover Transfer Cask to SOC		15	6.8	$8,160	0.0	6.8	$8,160	100%	0.0	6.8	$8,160	6.8	$8,160
B25	Load Can into SOC		15	1.0	$1,200	0.0	1.0	$1,200	100%	0.0	1.0	$1,200	1.0	$1,200
B26	Move Transfer Cask to staging area		14	6.5	$7,313	0.0	6.5	$7,313	100%	0.0	6.5	$7,313	6.5	$7,313
C1	Install SOC lid		11	2.0	$1,800	0.0	2.0	$1,800	50%	1.0	1.0	$900	1.0	$900
C2	Load SOC onto VCT		11	2.0	$1,800	0.0	2.0	$1,800	50%	1.0	1.0	$900	1.0	$900
C3	Transport SOC to storage pad		17	7.3	$9,855	0.0	7.3	$9,855	50%	3.7	3.7	$4,928	3.7	$4,928
	Total Time per STADs-in-Can (hours)			139.2		3.1	136.1			47.0	92.2		91.5	
	Total Time per STADs-in-Can (days)			5.8d		0.1d	5.7d			2d	3.8d		3.8d	
	Subtotal Labor Costs				**$127,195**			**$124,173**				**$87,499**		**$86,743**
	Other Costs (consumables)	15%			$19,079			$18,626				$13,125		$13,011
	Subtotal Costs w/o Contingency				**$146,274**			**$142,798**				**$100,623**		**$99,754**
	Contingency	20%			$29,255			$28,560				$20,125		$19,951
	Total Cost per Can				**$175,529**			**$171,358**				**$120,748**		**$119,705**
	# of STADs per Can	4			4			4				4		4
	# of Assemblies per STAD	4			4			4				4		4
	Subtotal Cost per Assembly w/o Contingency				**$9,142**			**$8,925**				**$6,289**		**$6,235**
	Contingency	20%			**$1,828**			**$1,785**				**$1,258**		**$1,247**
	Total Hours/Cost per Assembly			8.70	**$10,971**		8.51	**$10,710**			5.76	**$7,547**	5.72	**$7,482**

Note: FTE counts apply to both the baseline and optimized cases with the following exceptions - for steps B4, B5 and B10, four welders are shown for the optimized case, whereas only 1 welder has been included for the baseline case (not shown)

Table 15-9. Operations Approaches – Small BWR STADs-in-Carrier - Basis of Estimate

TABLE 15-9. Operations Approaches - Small BWR STADs-in-Carrier Detailed Costs [ref. Table 19-9]

Task Location Legend: FHB Prep Area; Fuel Pool; Cask Decon Pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step #	Step Description :	Task Category Code	Crane Operators #	Crane Operators $	Other Heavy Eq. Operators #	Other Heavy Eq. Operators $	Mechanics #	Mechanics $	Riggers #	Riggers $	Welders #	Welders $	Other Operations Staff #	Other Operations Staff $	Supervisors/ Foremen #	Supervisors/ Foremen $
A5	Move VCT & SOC into FHB	A	0	$75	1	$75	3	$75	1	$75	0	$75	0	$75	1	$100
A6	Move SOC to seismic restraint	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100
A7	Remove the SOC lid	A	1	$75	0	$75	2	$75	1	$75	0	$75	0	$75	1	$100
A8	Move Carrier with empty STADs fro SOC to TC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100
A9	Prepare TC for SFP	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100
A10	Remove STAD lids	A	1	$75	0	$75	3	$75	1	$75	0	$75	0	$75	1	$100
A11	Fill TC & STADs with deionized water	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100
A12	Install inflatable seal between Carrier and TC	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100
A13	Verify water chemistry matches fuel pool	A	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100
A14	Place TC into Fuel Pool	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100
A15	Load Fuel into STADs	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100
A16	Fuel verification	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100
B1	Install 4 STAD inner lids	A	1	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100
B2	Lift TC from Fuel Pool	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100
B3	Move to decon pit and decon TC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100
B4	Deflate seal between Carrier and TC	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100
B5	Lower water level in 4 STADs	C	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100
B6	Perform welding of 4 STAD inner lids (all passes)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100
B7	Perform weld NDE for 4 STAD inner lids (all passes)	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100
B8	STAD hydrostatic test (all 4)	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100
B9	Perform welding of 4 STAD outer lids (all passes)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100
B10	Perform weld NDE for 4 STAD outer lids (all passes)	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100
B11	STAD water blowdown (all 4)	C	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100
B12	STAD drying and helium backfill (all 4)	C	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100
B13	STAD leak test (all 4)	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100
B14	Weld & test STAD inner siphon and vent port covers (all 8)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100
B15	Perform siphon and vent cover He leak tests (all 8)	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100
B16	Drain water from Carrier/TC annulus	C	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100
B17	Prepare for the Carrier to SOC transfer	A	0	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100
B18	Install transfer adapter on top of SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100
B19	Move TC to SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100
B20	Install Carrier lift rigging	A	1	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100
B21	Load Carrier into SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100
B22	Move TC to staging area	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100
B23	Remove transfer adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100
C1	Install SOC lid	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100
C2	Check SOC vents	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100
C3	Perform fire hazards walkdown	A	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100
C4	Load SOC onto VCT	A	0	$75	1	$75	4	$75	2	$75	0	$75	0	$75	1	$100
C5	Survey SOC dose rates	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100
C6	Transport SOC to storage pad	A	0	$75	1	$75	4	$75	2	$75	0	$75	0	$75	1	$100

Step #	Deconners #	Deconners $	Radiation Protection #	Radiation Protection $	RXS Techs #	RXS Techs $	QA/QC #	QA/QC $	HP #	HP $	Security #	Security $	Planners #	Planners $	Trainers #	Trainers $	Procedure Writers #	Procedure Writers $	Management #	Management $
A5	0	$75	1	$75	0	$75	0	$75	0	$100	1	$75	1	$75	1	$75	1	$75	1	$125
A6	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A7	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A8	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A9	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A10	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A11	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A12	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A13	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A14	0	$75	2	$75	3	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A15	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
A16	0	$75	1	$75	3	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B1	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B2	2	$75	3	$75	3	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B3	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B4	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B5	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B6	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B7	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B8	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B9	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B10	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B11	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B12	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B13	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B14	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B15	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B16	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B17	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B18	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B19	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B20	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B21	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B22	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
B23	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
C1	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
C2	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
C3	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
C4	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
C5	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125
C6	0	$75	2	$75	0	$75	1	$75	0	$100	4	$75	1	$75	1	$75	1	$75	1	$125

Step #	Step Description :	Total Personnel (#)	Linear Step Time Baseline (hrs)	Staff Cost by Activity ($)	Technology Improvement (hours saved) (hrs)	Step Time with Tech Savings Alone (hrs)	Staff Cost by Activity with Tech Savings Alone ($)	Percent on Clock (parallel savings) (%)	Time Saved per STAD by Parallel Ops (hrs)	Step Time with Parallel Svgs Alone (hrs)	Staff Cost by Activity with Parallel Savings Alone ($)	Step Time with Tech & Parallel Svgs (hrs)	Staff Cost by Activity with Tech & Parallel Savings ($)
A5	Move VCT & SOC into FHB	12	0.5	$488	0.0	0.5	$488	100%	0.0	0.5	$488	0.5	$488
A6	Move SOC to seismic restraint	9	0.5	$375	0.0	0.5	$375	100%	0.0	0.5	$375	0.5	$375
A7	Remove the SOC lid	9	1.5	$1,125	0.0	1.5	$1,125	100%	0.0	1.5	$1,125	1.5	$1,125
A8	Move Carrier with empty STADs fro SOC to TC	12	1.5	$1,463	0.0	1.5	$1,463	100%	0.0	1.5	$1,463	1.5	$1,463
A9	Prepare TC for SFP	7	2.0	$1,200	0.0	2.0	$1,200	100%	0.0	2.0	$1,200	2.0	$1,200
A10	Remove STAD lids	10	2.0	$1,650	0.0	2.0	$1,650	100%	0.0	2.0	$1,650	2.0	$1,650
A11	Fill TC & STADs with deionized water	7	2.2	$1,320	0.0	2.2	$1,320	100%	0.0	2.2	$1,320	2.2	$1,320
A12	Install inflatable seal between Carrier and TC	7	1.2	$720	0.0	1.2	$720	100%	0.0	1.2	$720	1.2	$720
A13	Verify water chemistry matches fuel pool	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
A14	Place TC into Fuel Pool	20	2.6	$4,160	0.0	2.6	$4,160	100%	0.0	2.6	$4,160	2.6	$4,160
A15	Load Fuel into STADs	9	13.8	$10,350	0.0	13.8	$10,350	50%	6.9	6.9	$5,175	6.9	$5,175
A16	Fuel verification	10	2.3	$1,898	0.0	2.3	$1,898	50%	1.2	1.2	$949	1.2	$949
B1	Install 4 STAD inner lids	15	1.0	$1,200	0.0	1.0	$1,200	50%	0.5	0.5	$600	0.5	$600
B2	Lift TC from Fuel Pool	23	5.2	$9,490	0.0	5.2	$9,490	100%	0.0	5.2	$9,490	5.2	$9,490
B3	Move to decon pit and decon TC	18	4.6	$6,670	0.0	4.6	$6,670	100%	0.0	4.6	$6,670	4.6	$6,670
B4	Deflate seal between Carrier and TC	8	0.3	$203	0.0	0.3	$203	100%	0.0	0.3	$203	0.3	$203
B5	Lower water level in 4 STADs	6	0.5	$263	0.0	0.5	$263	45%	0.3	0.2	$118	0.2	$118
B6	Perform welding of 4 STAD inner lids (all passes)	10	9.3	$5,580	0.0	9.3	$5,580	47%	5.0	4.3	$3,568	4.3	$3,568
B7	Perform weld NDE for 4 STAD inner lids (all passes)	8	3.2	$2,160	0.0	3.2	$2,160	33%	2.1	1.1	$713	1.1	$713
B8	STAD hydrostatic test (all 4)	7	2.0	$1,200	0.0	2.0	$1,200	25%	1.5	0.5	$300	0.5	$300
B9	Perform welding of 4 STAD outer lids (all passes)	10	9.3	$5,580	0.0	9.3	$5,580	47%	5.0	4.3	$3,568	4.3	$3,568
B10	Perform weld NDE for 4 STAD outer lids (all passes)	8	3.2	$2,160	0.0	3.2	$2,160	33%	2.1	1.1	$713	1.1	$713
B11	STAD water blowdown (all 4)	6	0.8	$420	0.0	0.8	$420	88%	0.1	0.7	$368	0.7	$368
B12	STAD drying and helium backfill (all 4)	7	18.2	$10,920	3.1	15.1	$9,060	25%	13.7	4.6	$2,730	3.8	$2,265
B13	STAD leak test (all 4)	7	4.9	$2,940	0.0	4.9	$2,940	25%	3.7	1.2	$735	1.2	$735
B14	Weld & test STAD inner siphon and vent port covers (all 8)	11	8.0	$5,400	0.0	8.0	$5,400	25%	6.0	2.0	$1,800	2.0	$1,800
B15	Perform siphon and vent cover He leak tests (all 8)	7	2.4	$1,440	0.0	2.4	$1,440	100%	0.0	2.4	$1,440	2.4	$1,440
B16	Drain water from Carrier/TC annulus	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
B17	Prepare for the Carrier to SOC transfer	10	2.0	$1,650	0.0	2.0	$1,650	100%	0.0	2.0	$1,650	2.0	$1,650
B18	Install transfer adapter on top of SOC	13	1.5	$1,575	0.0	1.5	$1,575	100%	0.0	1.5	$1,575	1.5	$1,575
B19	Move TC to SOC	13	5.3	$5,565	0.0	5.3	$5,565	100%	0.0	5.3	$5,565	5.3	$5,565
B20	Install Carrier lift rigging	12	1.5	$1,463	0.0	1.5	$1,463	50%	0.8	0.8	$731	0.8	$731
B21	Load Carrier into SOC	13	1.0	$1,050	0.0	1.0	$1,050	100%	0.0	1.0	$1,050	1.0	$1,050
B22	Move TC to staging area	13	6.5	$6,825	0.0	6.5	$6,825	100%	0.0	6.5	$6,825	6.5	$6,825
B23	Remove transfer adapter	13	1.0	$1,050	0.0	1.0	$1,050	100%	0.0	1.0	$1,050	1.0	$1,050
C1	Install SOC lid	11	2.0	$1,800	0.0	2.0	$1,800	100%	0.0	2.0	$1,800	2.0	$1,800
C2	Check SOC vents	8	0.5	$338	0.0	0.5	$338	100%	0.0	0.5	$338	0.5	$338
C3	Perform fire hazards walkdown	6	1.0	$525	0.0	1.0	$525	100%	0.0	1.0	$525	1.0	$525
C4	Load SOC onto VCT	13	0.5	$525	0.0	0.5	$525	50%	0.3	0.3	$263	0.3	$263
C5	Survey SOC dose rates	7	1.0	$600	0.0	1.0	$600	50%	0.5	0.5	$300	0.5	$300
C6	Transport SOC to storage pad	19	7.5	$11,250	0.0	7.5	$11,250	50%	3.8	3.8	$5,625	3.8	$5,625
	Total Time per STADs-in-Carrier (hours)		136.3		3.1	133.2			53.2	83.1		82.3	
	Total Time per STADs-in-Carrier (days)		5.7d		0.1d	5.6d			2.2d	3.5d		3.4d	
	Subtotal Labor Costs			**$115,788**			**$113,928**				**$80,134**		**$79,669**
	Other Costs (consumables) 15%			$17,368			$17,089				$12,020		$11,950
	Subtotal Costs w/o Contingency			**$133,156**			**$131,017**				**$92,154**		**$91,620**
	Contingency 20%			$26,631			$26,203				$18,431		$18,324
	Total Cost per Carrier			**$159,787**			**$157,220**				**$110,585**		**$109,943**
	# of STADs per Carrier 4			4			4				4		4
	# of Assemblies per STAD 9			9			9				9		9
	Subtotal Cost per Assembly w/o Contingency			**$3,699**			**$3,639**				**$2,560**		**$2,545**
	Contingency 20%			**$740**			**$728**				**$512**		**$509**
	Total Hours/Cost per Assembly		3.79	**$4,439**		3.70	**$4,367**			2.31	**$3,072**	2.29	**$3,054**

Note: FTE counts apply to both the baseline and optimized cases with the following exceptions - for steps B6, B9 and B14, four welders are shown for the optimized case, whereas only 1 welder has been included for the baseline case (not shown)

Table 15-10. Operations Approaches – Small PWR STADs-in-Carrier - Basis of Estimate

TABLE 15-10. Operations Approaches - Small PWR STADs-in-Carrier Detailed Costs [ref. Table 19-10]

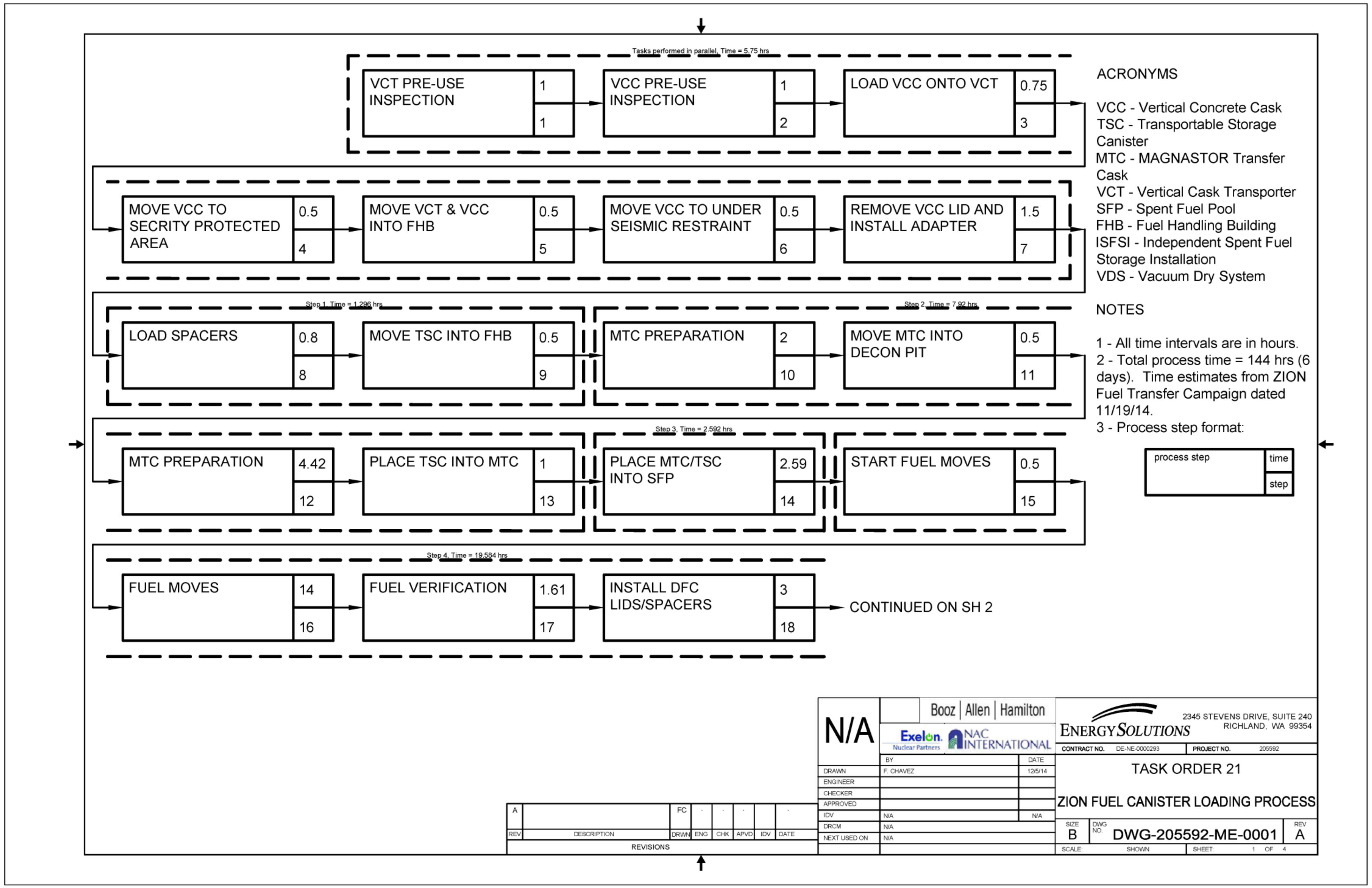
Task Location Legend: FHB Prep Area; Fuel Pool; Cask Decon Pit; ISFSI

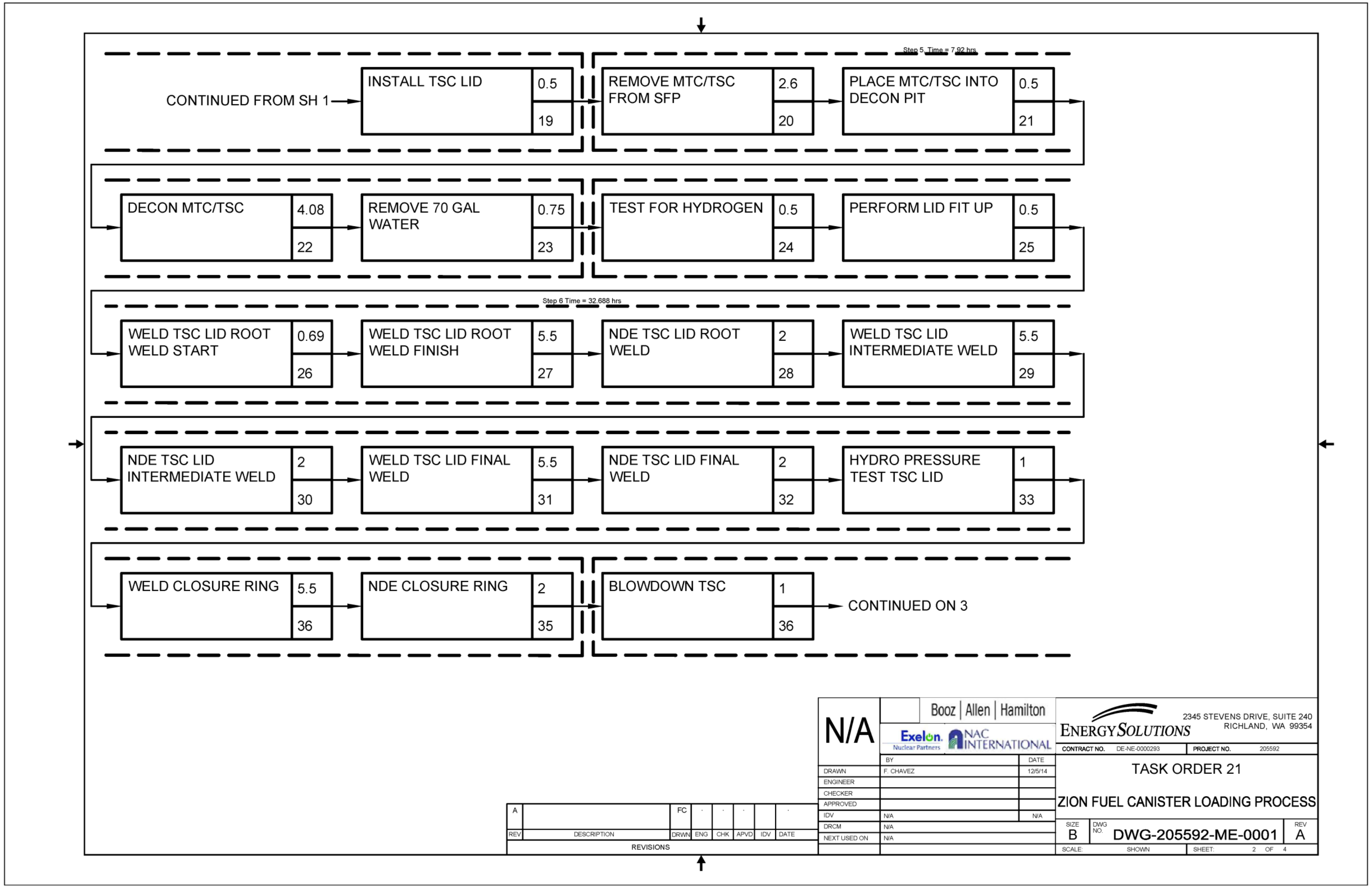
Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

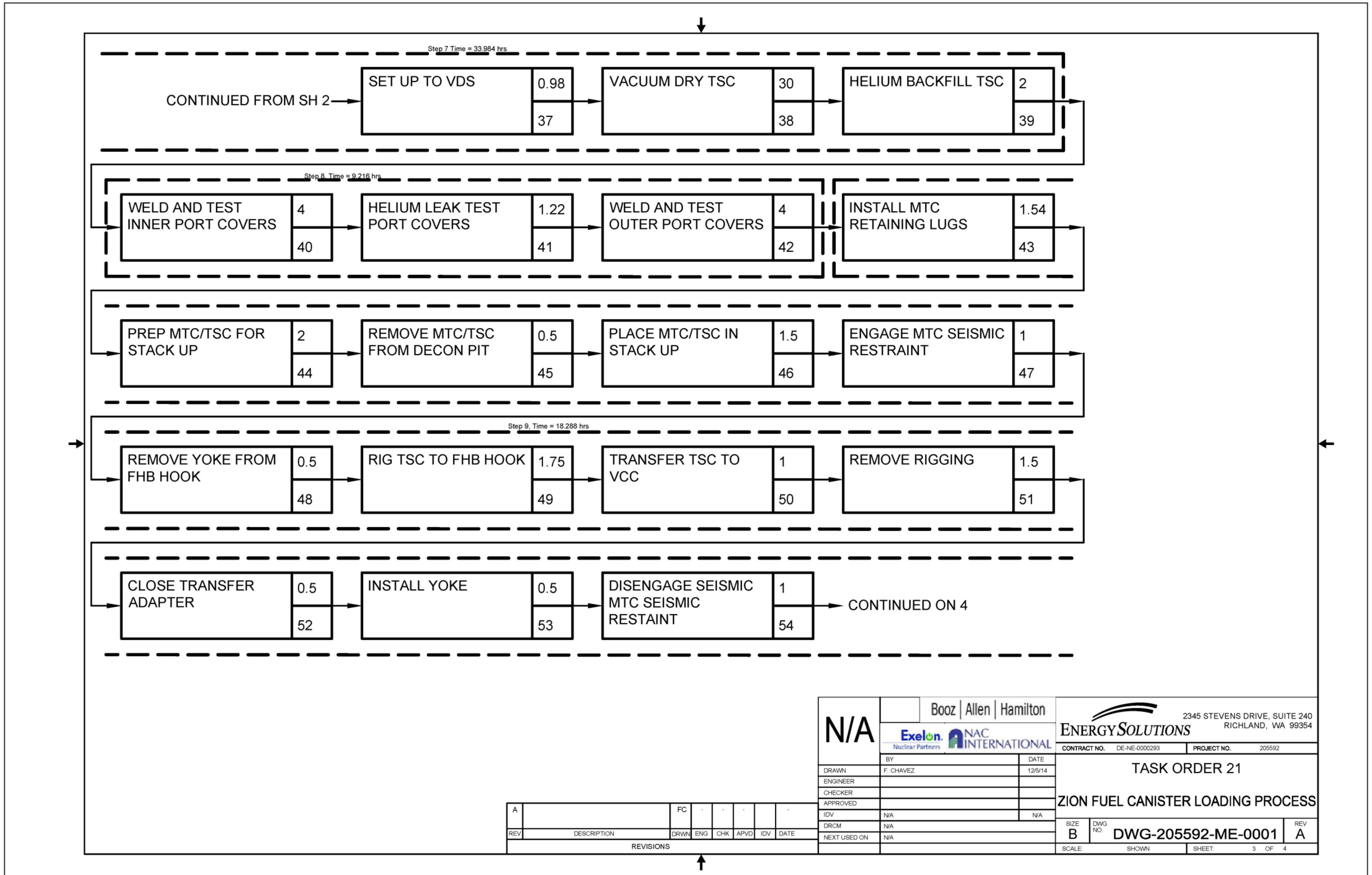
Step #	Step Description :	Task Category Code	Crane Operators #	Crane Operators $	Other Heavy Eq. Operators #	Other Heavy Eq. Operators $	Mechanics #	Mechanics $	Riggers #	Riggers $	Welders #	Welders $	Other Operations Staff #	Other Operations Staff $	Supervisors/ Foremen #	Supervisors/ Foremen $	Deconners #	Deconners $	Radiation Protection #	Radiation Protection $	RXS Techs #	RXS Techs $	QA/QC #	QA/QC $	HP #	HP $	Security #	Security $	Planners #	Planners $	Trainers #	Trainers $	Procedure Writers #	Procedure Writers $	Management #	Management $	Total Personnel #	Linear Step Time Baseline hrs	Staff Cost by Activity $	Technology Improvement (hours saved) hrs	Step Time with Tech Savings Alone hrs	Staff Cost by Activity with Tech Savings Alone $	Percent on Clock (parallel savings) %	Time Saved per STAD by Parallel Ops hrs	Step Time with Parallel Svgs Alone hrs	Staff Cost by Activity with Parallel Savings Alone $	Step Time with Tech & Parallel Svgs hrs	Staff Cost by Activity with Tech & Parallel Savings $
A5	Move VCT & SOC into FHB	A	0	$75	1	$75	3	$75	1	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	1	$75	1	$75	1	$75	1	$75	1	$125	12	0.5	$488	0.0	0.5	$488	100%	0.0	0.5	$488	0.5	$488
A6	Move SOC to seismic restraint	A	0	$75	1	$75	3	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	9	0.5	$375	0.0	0.5	$375	100%	0.0	0.5	$375	0.5	$375
A7	Remove the SOC lid	A	1	$75	0	$75	2	$75	1	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	9	1.5	$1,125	0.0	1.5	$1,125	100%	0.0	1.5	$1,125	1.5	$1,125
A8	Move Carrier with empty STADs fro SOC to TC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	12	1.5	$1,463	0.0	1.5	$1,463	100%	0.0	1.5	$1,463	1.5	$1,463
A9	Prepare TC for SFP	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	2.0	$1,200	0.0	2.0	$1,200	100%	0.0	2.0	$1,200	2.0	$1,200
A10	Remove STAD lids	A	1	$75	0	$75	3	$75	1	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	2.0	$1,650	0.0	2.0	$1,650	100%	0.0	2.0	$1,650	2.0	$1,650
A11	Fill TC & STADs with deionized water	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	2.2	$1,320	0.0	2.2	$1,320	100%	0.0	2.2	$1,320	2.2	$1,320
A12	Install inflatable seal between Carrier and TC	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	1.2	$720	0.0	1.2	$720	100%	0.0	1.2	$720	1.2	$720
A13	Verify water chemistry matches fuel pool	A	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
A14	Place TC into Fuel Pool	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	0	$75	2	$75	3	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	1	$125	20	2.6	$4,160	0.0	2.6	$4,160	100%	0.0	2.6	$4,160	2.6	$4,160
A15	Load Fuel into STADs	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	9	6.1	$4,575	0.0	6.1	$4,575	50%	3.1	3.1	$2,288	3.1	$2,288
A16	Fuel verification	B	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	1.3	$1,073	0.0	1.3	$1,073	50%	0.7	0.7	$536	0.7	$536
B1	Install 4 STAD inner lids	A	1	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	3	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	15	1.0	$1,200	0.0	1.0	$1,200	50%	0.5	0.5	$600	0.5	$600
B2	Lift TC from Fuel Pool	A	1	$75	0	$75	4	$75	2	$75	0	$75	2	$75	1	$100	2	$75	3	$75	3	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	1	$125	23	5.2	$9,490	0.0	5.2	$9,490	100%	0.0	5.2	$9,490	5.2	$9,490
B3	Move to decon pit and decon TC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	1	$75	1	$75	1	$125	18	4.6	$6,670	0.0	4.6	$6,670	100%	0.0	4.6	$6,670	4.6	$6,670
B4	Deflate seal between Carrier and TC	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	8	0.3	$203	0.0	0.3	$203	100%	0.0	0.3	$203	0.3	$203
B5	Lower water level in 4 STADs	C	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	6	0.5	$263	0.0	0.5	$263	45%	0.3	0.2	$118	0.2	$118
B6	Perform welding of 4 STAD inner lids (all passes)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	9.3	$5,580	0.0	9.3	$5,580	47%	5.0	4.3	$3,568	4.3	$3,568
B7	Perform weld NDE for 4 STAD inner lids (all passes)	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	8	3.2	$2,160	0.0	3.2	$2,160	33%	2.1	1.1	$713	1.1	$713
B8	STAD hydrostatic test (all 4)	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	2.0	$1,200	0.0	2.0	$1,200	25%	1.5	0.5	$300	0.5	$300
B9	Perform welding of 4 STAD outer lids (all passes)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	9.3	$5,580	0.0	9.3	$5,580	47%	5.0	4.3	$3,568	4.3	$3,568
B10	Perform weld NDE for 4 STAD outer lids (all passes)	E	0	$75	0	$75	0	$75	0	$75	1	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	8	3.2	$2,160	0.0	3.2	$2,160	33%	2.1	1.1	$713	1.1	$713
B11	STAD water blowdown (all 4)	C	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	6	0.8	$420	0.0	0.8	$420	88%	0.1	0.7	$368	0.7	$368
B12	STAD drying and helium backfill (all 4)	C	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	18.2	$10,920	3.1	15.1	$9,060	25%	13.7	4.6	$2,730	3.8	$2,265
B13	STAD leak test (all 4)	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	4.9	$2,940	0.0	4.9	$2,940	25%	3.7	1.2	$735	1.2	$735
B14	Weld & test STAD inner siphon and vent port covers (all 8)	D	0	$75	0	$75	0	$75	0	$75	4	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	8.0	$5,400	0.0	8.0	$5,400	25%	6.0	2.0	$1,800	2.0	$1,800
B15	Perform siphon and vent cover He leak tests (all 8)	E	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	1	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	2.4	$1,440	0.0	2.4	$1,440	100%	0.0	2.4	$1,440	2.4	$1,440
B16	Drain water from Carrier/TC annulus	C	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	100%	0.0	1.0	$600	1.0	$600
B17	Prepare for the Carrier to SOC transfer	A	0	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	10	2.0	$1,650	0.0	2.0	$1,650	100%	0.0	2.0	$1,650	2.0	$1,650
B18	Install transfer adapter on top of SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	13	1.5	$1,575	0.0	1.5	$1,575	100%	0.0	1.5	$1,575	1.5	$1,575
B19	Move TC to SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	13	5.3	$5,565	0.0	5.3	$5,565	100%	0.0	5.3	$5,565	5.3	$5,565
B20	Install Carrier lift rigging	A	1	$75	0	$75	3	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	12	1.5	$1,463	0.0	1.5	$1,463	50%	0.8	0.8	$731	0.8	$731
B21	Load Carrier into SOC	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	13	1.0	$1,050	0.0	1.0	$1,050	100%	0.0	1.0	$1,050	1.0	$1,050
B22	Move TC to staging area	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	13	6.5	$6,825	0.0	6.5	$6,825	100%	0.0	6.5	$6,825	6.5	$6,825
B23	Remove transfer adapter	A	1	$75	0	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	13	1.0	$1,050	0.0	1.0	$1,050	100%	0.0	1.0	$1,050	1.0	$1,050
C1	Install SOC lid	A	1	$75	0	$75	2	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	11	2.0	$1,800	0.0	2.0	$1,800	100%	0.0	2.0	$1,800	2.0	$1,800
C2	Check SOC vents	A	0	$75	0	$75	2	$75	0	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	8	0.5	$338	0.0	0.5	$338	100%	0.0	0.5	$338	0.5	$338
C3	Perform fire hazards walkdown	A	0	$75	0	$75	1	$75	0	$75	0	$75	0	$75	1	$100	0	$75	0	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	6	1.0	$525	0.0	1.0	$525	100%	0.0	1.0	$525	1.0	$525
C4	Load SOC onto VCT	A	0	$75	1	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	1	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	13	0.5	$525	0.0	0.5	$525	50%	0.3	0.3	$263	0.3	$263
C5	Survey SOC dose rates	A	0	$75	0	$75	0	$75	0	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	0	$75	0	$100	0	$75	1	$75	1	$75	1	$75	1	$125	7	1.0	$600	0.0	1.0	$600	50%	0.5	0.5	$300	0.5	$300
C6	Transport SOC to storage pad	A	0	$75	1	$75	4	$75	2	$75	0	$75	0	$75	1	$100	0	$75	2	$75	0	$75	1	$75	0	$100	4	$75	1	$75	1	$75	1	$75	1	$125	19	7.5	$11,250	0.0	7.5	$11,250	50%	3.8	3.8	$5,625	3.8	$5,625
	Total Time per STADs-in-Carrier (hours)																																					127.6		3.1	124.5			48.9	78.7		77.9	
	Total Time per STADs-in-Carrier (days)																																					5.3d		0.1d	5.2d			2d	3.3d		3.2d	
	Subtotal Labor Costs																																						**$109,188**			**$107,328**				**$76,834**		**$76,369**
	Other Costs (consumables)	15%																																					$16,378			$16,099				$11,525		$11,455
	Subtotal Costs w/o Contingency																																						**$125,566**			**$123,427**				**$88,359**		**$87,825**
	Contingency	20%																																					$25,113			$24,685				$17,672		$17,565
	Total Cost per Carrier																																						**$150,679**			**$148,112**				**$106,031**		**$105,389**
	# of STADs per Carrier	4																																					4			4				4		4
	# of Assemblies per STAD	4																																					4			4				4		4
	Subtotal Cost per Assembly w/o Contingency																																						**$7,848**			**$7,714**				**$5,522**		**$5,489**
	Contingency	20%																																					**$1,570**			**$1,543**				**$1,104**		**$1,098**
	Total Hours/Cost per Assembly																																					7.98	**$9,417**		7.78	**$9,257**			4.92	**$6,627**	4.87	**$6,587**

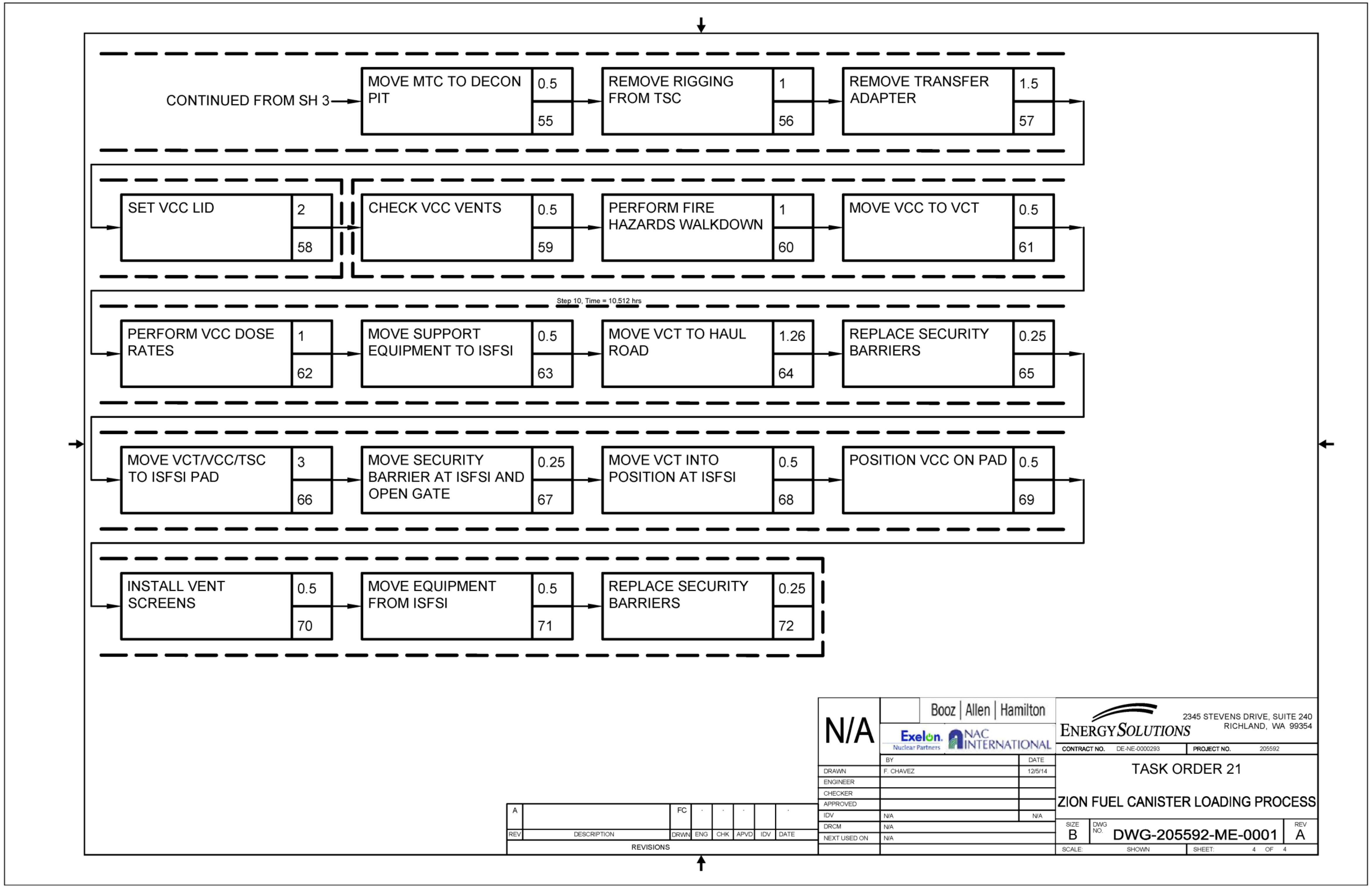
Note: FTE counts apply to both the baseline and optimized cases with the following exceptions - for steps B6, B9 and B14, four welders are shown for the optimized case, whereas only 1 welder has been included for the baseline case (not shown)

16 APPENDIX E – LOADING PROCESS FLOWSHEETS

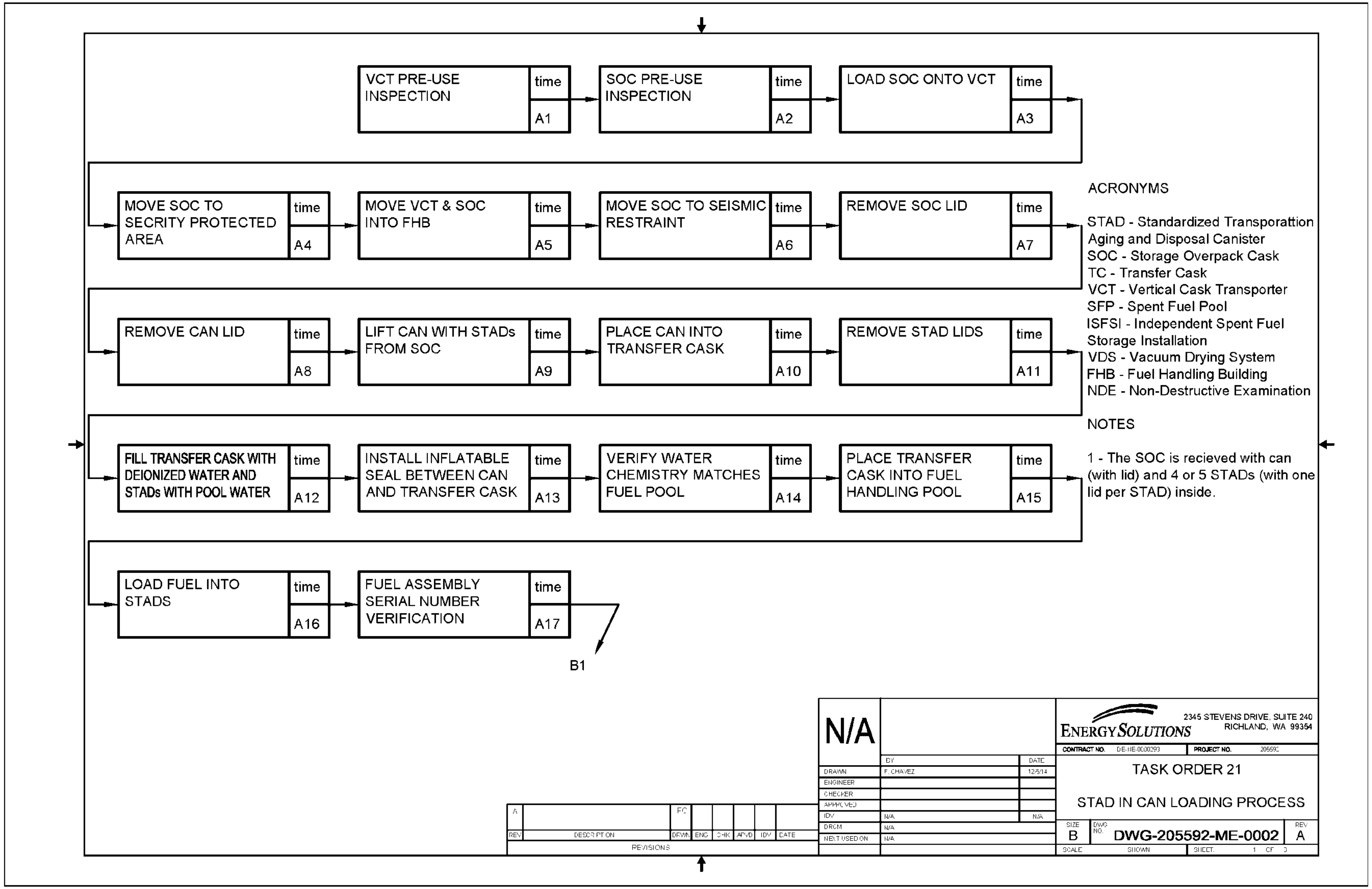


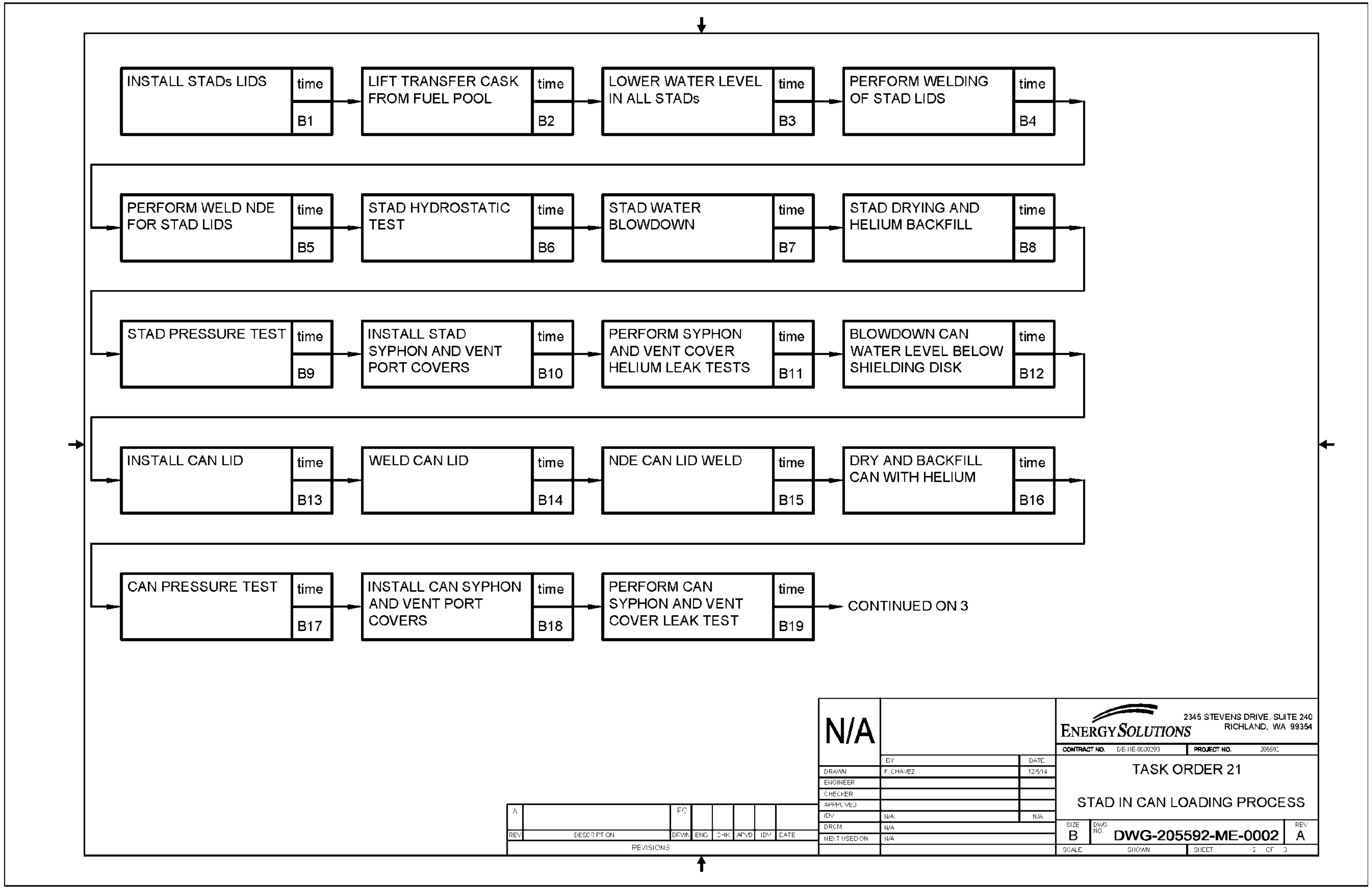

Step 5 Time = 7.92 hrs
CONTINUED FROM SH 1
INSTALL TSC LID 0.5 19
REMOVE MTC/TSC FROM SFP 2.6 20
PLACE MTC/TSC INTO DECON PIT 0.5 21
DECON MTC/TSC 4.08 22
REMOVE 70 GAL WATER 0.75 23
TEST FOR HYDROGEN 0.5 24
PERFORM LID FIT UP 0.5 25
Step 6 Time = 32.688 hrs
WELD TSC LID ROOT WELD START 0.69 26
WELD TSC LID ROOT WELD FINISH 5.5 27
NDE TSC LID ROOT WELD 2 28
WELD TSC LID INTERMEDIATE WELD 5.5 29
NDE TSC LID INTERMEDIATE WELD 2 30
WELD TSC LID FINAL WELD 5.5 31
NDE TSC LID FINAL WELD 2 32
HYDRO PRESSURE TEST TSC LID 1 33
WELD CLOSURE RING 5.5 36
NDE CLOSURE RING 2 35
BLOWDOWN TSC 1 36
CONTINUED ON 3
N/A
Booz | Allen | Hamilton
Exelon. Nuclear Partners
NAC INTERNATIONAL
ENERGYSOLUTIONS
2345 STEVENS DRIVE, SUITE 240
RICHLAND, WA 99354
CONTRACT NO. DE-NE-0000293
PROJECT NO. 205592
DRAWN F. CHAVEZ 12/5/14
ENGINEER
CHECKER
APPROVED
IDV N/A N/A
DRCM N/A
NEXT USED ON N/A
TASK ORDER 21
ZION FUEL CANISTER LOADING PROCESS
SIZE B
DWG NO. DWG-205592-ME-0001
REV A
SCALE SHOWN
SHEET 2 OF 4
A FC
REV DESCRIPTION DRWN ENG CHK APVD IDV DATE
REVISIONS

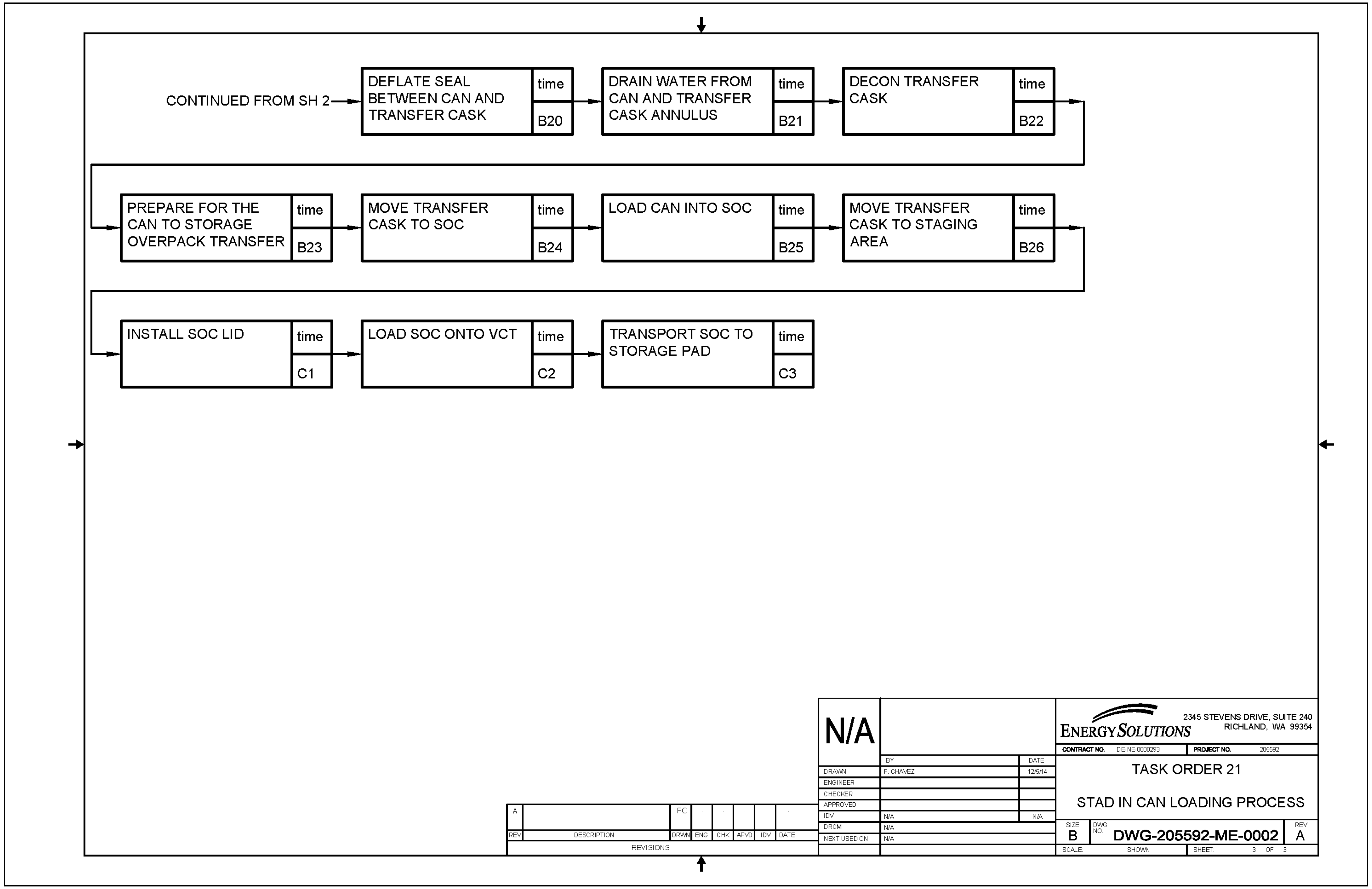

Step 7 Time = 33.984 hrs
CONTINUED FROM SH 2
SET UP TO VDS
0.98
37
VACUUM DRY TSC
30
38
HELIUM BACKFILL TSC
2
39
Step 8, Time = 9.216 hrs
WELD AND TEST INNER PORT COVERS
4
40
HELIUM LEAK TEST PORT COVERS
1.22
41
WELD AND TEST OUTER PORT COVERS
4
42
INSTALL MTC RETAINING LUGS
1.54
43
PREP MTC/TSC FOR STACK UP
2
44
REMOVE MTC/TSC FROM DECON PIT
0.5
45
PLACE MTC/TSC IN STACK UP
1.5
46
ENGAGE MTC SEISMIC RESTRAINT
1
47
Step 9, Time = 18.288 hrs
REMOVE YOKE FROM FHB HOOK
0.5
48
RIG TSC TO FHB HOOK
1.75
49
TRANSFER TSC TO VCC
1
50
REMOVE RIGGING
1.5
51
CLOSE TRANSFER ADAPTER
0.5
52
INSTALL YOKE
0.5
53
DISENGAGE SEISMIC MTC SEISMIC RESTAINT
1
54
CONTINUED ON 4
A
FC
REV
DESCRIPTION
DRWN
ENG
CHK
APVD
IDV
DATE
REVISIONS
N/A
Booz | Allen | Hamilton
Exelon. Nuclear Partners
NAC INTERNATIONAL
ENERGYSOLUTIONS
2345 STEVENS DRIVE, SUITE 240
RICHLAND, WA 99354
CONTRACT NO. DE-NE-0000293
PROJECT NO. 205592
BY
DATE
DRAWN
F. CHAVEZ
12/5/14
ENGINEER
CHECKER
APPROVED
IDV
N/A
N/A
DRCM
N/A
NEXT USED ON
N/A
TASK ORDER 21
ZION FUEL CANISTER LOADING PROCESS
SIZE
B
DWG NO.
DWG-205592-ME-0001
REV
A
SCALE: SHOWN
SHEET: 3 OF 4

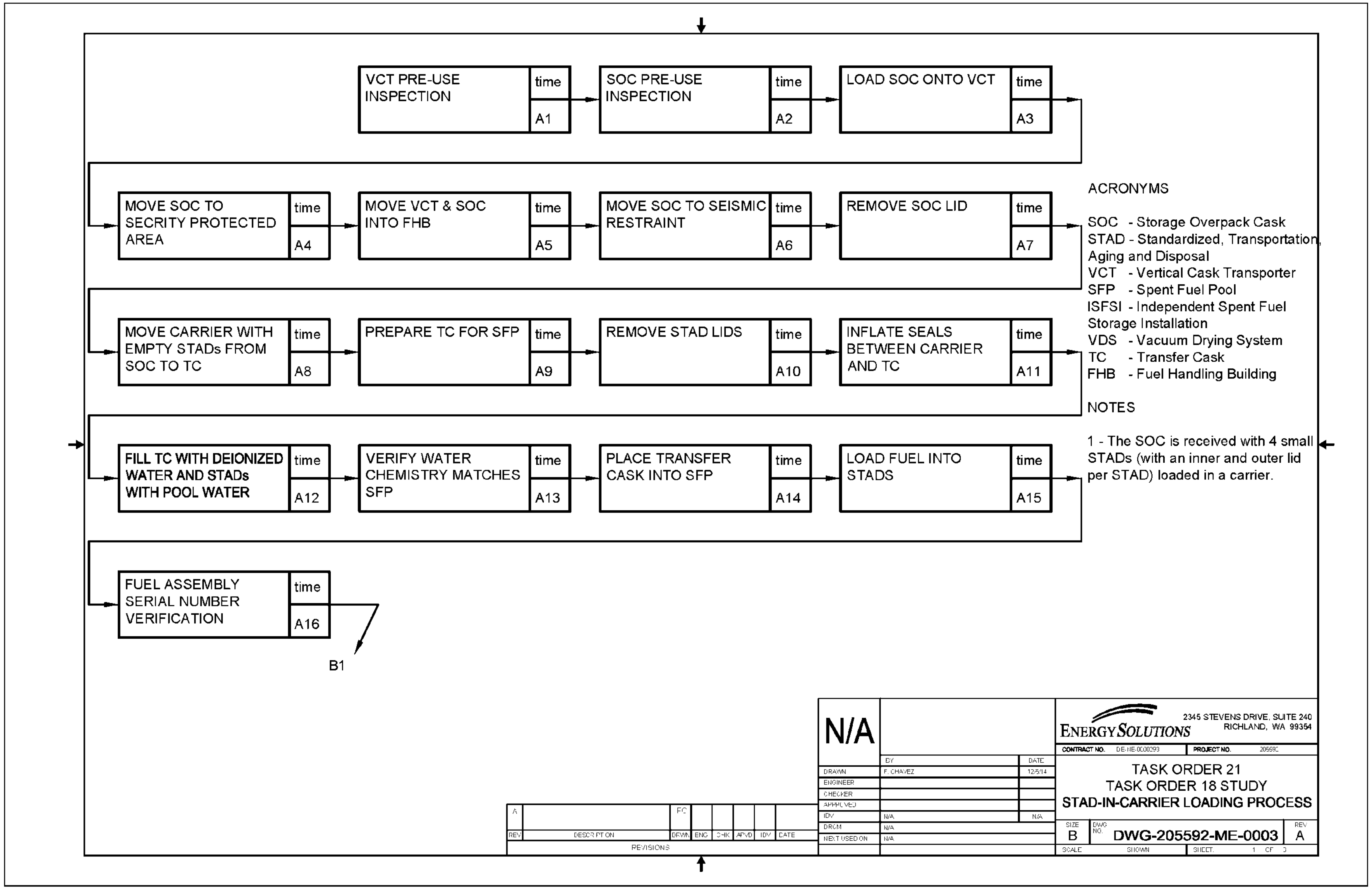


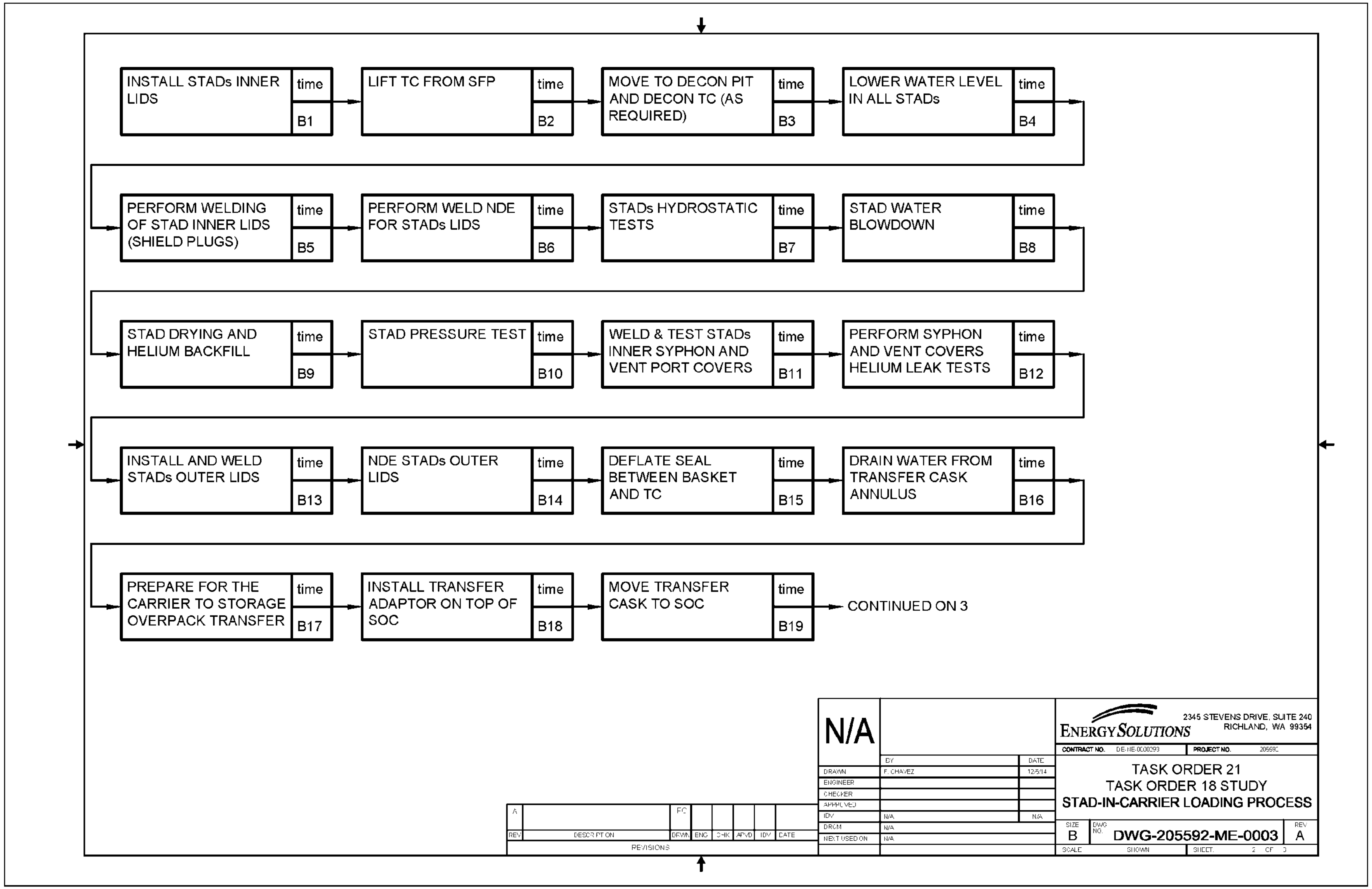
CONTINUED FROM SH 3
MOVE MTC TO DECON PIT 0.5 55
REMOVE RIGGING FROM TSC 1 56
REMOVE TRANSFER ADAPTER 1.5 57
SET VCC LID 2 58
CHECK VCC VENTS 0.5 59
PERFORM FIRE HAZARDS WALKDOWN 1 60
MOVE VCC TO VCT 0.5 61
Step 10, Time = 10.512 hrs
PERFORM VCC DOSE RATES 1 62
MOVE SUPPORT EQUIPMENT TO ISFSI 0.5 63
MOVE VCT TO HAUL ROAD 1.26 64
REPLACE SECURITY BARRIERS 0.25 65
MOVE VCT/VCC/TSC TO ISFSI PAD 3 66
MOVE SECURITY BARRIER AT ISFSI AND OPEN GATE 0.25 67
MOVE VCT INTO POSITION AT ISFSI 0.5 68
POSITION VCC ON PAD 0.5 69
INSTALL VENT SCREENS 0.5 70
MOVE EQUIPMENT FROM ISFSI 0.5 71
REPLACE SECURITY BARRIERS 0.25 72
REV DESCRIPTION DRWN ENG CHK APVD IDV DATE
A FC
REVISIONS
N/A
Booz | Allen | Hamilton
Exelon. Nuclear Partners
NAC INTERNATIONAL
ENERGYSOLUTIONS
2345 STEVENS DRIVE, SUITE 240
RICHLAND, WA 99354
CONTRACT NO. DE-NE-0000293
PROJECT NO. 205592
BY DATE
DRAWN F. CHAVEZ 12/5/14
ENGINEER
CHECKER
APPROVED
IDV N/A N/A
DRCM N/A
NEXT USED ON N/A
TASK ORDER 21
ZION FUEL CANISTER LOADING PROCESS
SIZE B
DWG NO. DWG-205592-ME-0001
REV A
SCALE: SHOWN
SHEET: 4 OF 4

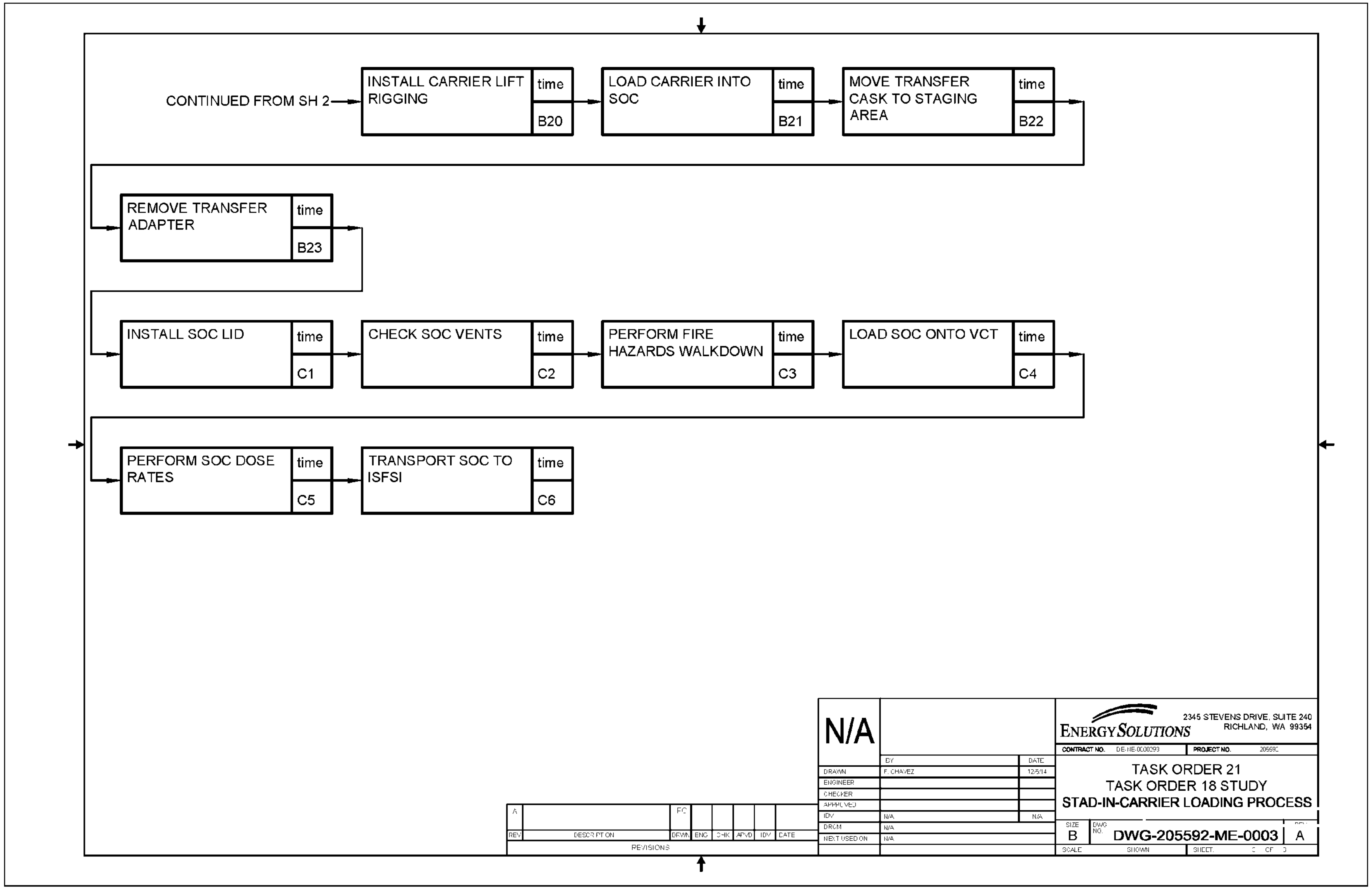

VCT PRE-USE INSPECTION
time
A1
SOC PRE-USE INSPECTION
time
A2
LOAD SOC ONTO VCT
time
A3
MOVE SOC TO SECRITY PROTECTED AREA
time
A4
MOVE VCT & SOC INTO FHB
time
A5
MOVE SOC TO SEISMIC RESTRAINT
time
A6
REMOVE SOC LID
time
A7
REMOVE CAN LID
time
A8
LIFT CAN WITH STADs FROM SOC
time
A9
PLACE CAN INTO TRANSFER CASK
time
A10
REMOVE STAD LIDS
time
A11
FILL TRANSFER CASK WITH DEIONIZED WATER AND STADs WITH POOL WATER
time
A12
INSTALL INFLATABLE SEAL BETWEEN CAN AND TRANSFER CASK
time
A13
VERIFY WATER CHEMISTRY MATCHES FUEL POOL
time
A14
PLACE TRANSFER CASK INTO FUEL HANDLING POOL
time
A15
LOAD FUEL INTO STADS
time
A16
FUEL ASSEMBLY SERIAL NUMBER VERIFICATION
time
A17
B1
ACRONYMS
STAD - Standardized Transporattion Aging and Disposal Canister
SOC - Storage Overpack Cask
TC - Transfer Cask
VCT - Vertical Cask Transporter
SFP - Spent Fuel Pool
ISFSI - Independent Spent Fuel Storage Installation
VDS - Vacuum Drying System
FHB - Fuel Handling Building
NDE - Non-Destructive Examination
NOTES
1 - The SOC is recieved with can (with lid) and 4 or 5 STADs (with one lid per STAD) inside.
N/A
BY
DATE
DRAWN
F. CHAVEZ
12/5/14
ENGINEER
CHECKER
APPROVED
IDV
N/A
N/A
DRCM
N/A
NEXT USED ON
N/A
REV
DESCRIPTION
DRWN
ENG
CHK
APVD
IDV
DATE
REVISIONS
ENERGYSOLUTIONS
2345 STEVENS DRIVE, SUITE 240
RICHLAND, WA 99354
CONTRACT NO. DE-NE-0000293
PROJECT NO. 205592
TASK ORDER 21
STAD IN CAN LOADING PROCESS
SIZE B
DWG NO. DWG-205592-ME-0002
REV A
SCALE SHOWN
SHEET 1 OF 3


INSTALL STADs LIDS
time
B1
LIFT TRANSFER CASK FROM FUEL POOL
time
B2
LOWER WATER LEVEL IN ALL STADs
time
B3
PERFORM WELDING OF STAD LIDS
time
B4
PERFORM WELD NDE FOR STAD LIDS
time
B5
STAD HYDROSTATIC TEST
time
B6
STAD WATER BLOWDOWN
time
B7
STAD DRYING AND HELIUM BACKFILL
time
B8
STAD PRESSURE TEST
time
B9
INSTALL STAD SYPHON AND VENT PORT COVERS
time
B10
PERFORM SYPHON AND VENT COVER HELIUM LEAK TESTS
time
B11
BLOWDOWN CAN WATER LEVEL BELOW SHIELDING DISK
time
B12
INSTALL CAN LID
time
B13
WELD CAN LID
time
B14
NDE CAN LID WELD
time
B15
DRY AND BACKFILL CAN WITH HELIUM
time
B16
CAN PRESSURE TEST
time
B17
INSTALL CAN SYPHON AND VENT PORT COVERS
time
B18
PERFORM CAN SYPHON AND VENT COVER LEAK TEST
time
B19
CONTINUED ON 3
N/A
ENERGYSOLUTIONS
2345 STEVENS DRIVE, SUITE 240
RICHLAND, WA 99354
CONTRACT NO. DE-NE-0000293
PROJECT NO. 205592
BY
DATE
DRAWN
F. CHAVEZ
12/5/14
ENGINEER
CHECKER
APPROVED
IDV
N/A
N/A
DRCM
N/A
NEXT USED ON
N/A
TASK ORDER 21
STAD IN CAN LOADING PROCESS
SIZE
B
DWG NO.
DWG-205592-ME-0002
REV
A
SCALE
SHOWN
SHEET
2 OF 3
REV
DESCRIPTION
DRWN
ENG
CHK
APVD
IDV
DATE
REVISIONS


CONTINUED FROM SH 2
DEFLATE SEAL BETWEEN CAN AND TRANSFER CASK
time
B20
DRAIN WATER FROM CAN AND TRANSFER CASK ANNULUS
time
B21
DECON TRANSFER CASK
time
B22
PREPARE FOR THE CAN TO STORAGE OVERPACK TRANSFER
time
B23
MOVE TRANSFER CASK TO SOC
time
B24
LOAD CAN INTO SOC
time
B25
MOVE TRANSFER CASK TO STAGING AREA
time
B26
INSTALL SOC LID
time
C1
LOAD SOC ONTO VCT
time
C2
TRANSPORT SOC TO STORAGE PAD
time
C3
A
FC
REV
DESCRIPTION
DRWN
ENG
CHK
APVD
IDV
DATE
REVISIONS
N/A
BY
DATE
DRAWN
F. CHAVEZ
12/5/14
ENGINEER
CHECKER
APPROVED
IDV
N/A
N/A
DRCM
N/A
NEXT USED ON
N/A
ENERGYSOLUTIONS
2345 STEVENS DRIVE, SUITE 240
RICHLAND, WA 99354
CONTRACT NO. DE-NE-0000293
PROJECT NO. 205592
TASK ORDER 21
STAD IN CAN LOADING PROCESS
SIZE
B
DWG NO.
DWG-205592-ME-0002
REV
A
SCALE: SHOWN
SHEET: 3 OF 3


VCT PRE-USE INSPECTION
time
A1
SOC PRE-USE INSPECTION
time
A2
LOAD SOC ONTO VCT
time
A3
MOVE SOC TO SECRITY PROTECTED AREA
time
A4
MOVE VCT & SOC INTO FHB
time
A5
MOVE SOC TO SEISMIC RESTRAINT
time
A6
REMOVE SOC LID
time
A7
MOVE CARRIER WITH EMPTY STADs FROM SOC TO TC
time
A8
PREPARE TC FOR SFP
time
A9
REMOVE STAD LIDS
time
A10
INFLATE SEALS BETWEEN CARRIER AND TC
time
A11
FILL TC WITH DEIONIZED WATER AND STADs WITH POOL WATER
time
A12
VERIFY WATER CHEMISTRY MATCHES SFP
time
A13
PLACE TRANSFER CASK INTO SFP
time
A14
LOAD FUEL INTO STADS
time
A15
FUEL ASSEMBLY SERIAL NUMBER VERIFICATION
time
A16
B1
ACRONYMS
SOC - Storage Overpack Cask
STAD - Standardized, Transportation, Aging and Disposal
VCT - Vertical Cask Transporter
SFP - Spent Fuel Pool
ISFSI - Independent Spent Fuel Storage Installation
VDS - Vacuum Drying System
TC - Transfer Cask
FHB - Fuel Handling Building
NOTES
1 - The SOC is received with 4 small STADs (with an inner and outer lid per STAD) loaded in a carrier.
N/A
BY
DATE
DRAWN
F. CHAVEZ
12/5/14
ENGINEER
CHECKER
APPROVED
IDV
N/A
N/A
DRCM
N/A
NEXT USED ON
N/A
ENERGYSOLUTIONS
2345 STEVENS DRIVE, SUITE 240
RICHLAND, WA 99354
CONTRACT NO.
PROJECT NO.
TASK ORDER 21
TASK ORDER 18 STUDY
STAD-IN-CARRIER LOADING PROCESS
SIZE
B
DWG NO.
DWG-205592-ME-0003
REV
A
SCALE
SHOWN
SHEET
REV
DESCRIPTION
DATE
REVISIONS


INSTALL STADs INNER LIDS
time
B1
LIFT TC FROM SFP
time
B2
MOVE TO DECON PIT AND DECON TC (AS REQUIRED)
time
B3
LOWER WATER LEVEL IN ALL STADs
time
B4
PERFORM WELDING OF STAD INNER LIDS (SHIELD PLUGS)
time
B5
PERFORM WELD NDE FOR STADs LIDS
time
B6
STADs HYDROSTATIC TESTS
time
B7
STAD WATER BLOWDOWN
time
B8
STAD DRYING AND HELIUM BACKFILL
time
B9
STAD PRESSURE TEST
time
B10
WELD & TEST STADs INNER SYPHON AND VENT PORT COVERS
time
B11
PERFORM SYPHON AND VENT COVERS HELIUM LEAK TESTS
time
B12
INSTALL AND WELD STADs OUTER LIDS
time
B13
NDE STADs OUTER LIDS
time
B14
DEFLATE SEAL BETWEEN BASKET AND TC
time
B15
DRAIN WATER FROM TRANSFER CASK ANNULUS
time
B16
PREPARE FOR THE CARRIER TO STORAGE OVERPACK TRANSFER
time
B17
INSTALL TRANSFER ADAPTOR ON TOP OF SOC
time
B18
MOVE TRANSFER CASK TO SOC
time
B19
CONTINUED ON 3
N/A
BY
DATE
DRAWN
F. CHAVEZ
12/5/14
ENGINEER
CHECKER
APPROVED
IDV
N/A
N/A
DRCM
N/A
NEXT USED ON
N/A
REV
DESCRIPTION
DRWN
ENG
CHK
APVD
IDV
DATE
REVISIONS
ENERGYSOLUTIONS
2345 STEVENS DRIVE, SUITE 240
RICHLAND, WA 99354
CONTRACT NO.
PROJECT NO.
TASK ORDER 21
TASK ORDER 18 STUDY
STAD-IN-CARRIER LOADING PROCESS
SIZE
B
DWG NO.
DWG-205592-ME-0003
REV
A
SCALE
SHOWN
SHEET
2 OF 3


CONTINUED FROM SH 2
INSTALL CARRIER LIFT RIGGING
time
B20
LOAD CARRIER INTO SOC
time
B21
MOVE TRANSFER CASK TO STAGING AREA
time
B22
REMOVE TRANSFER ADAPTER
time
B23
INSTALL SOC LID
time
C1
CHECK SOC VENTS
time
C2
PERFORM FIRE HAZARDS WALKDOWN
time
C3
LOAD SOC ONTO VCT
time
C4
PERFORM SOC DOSE RATES
time
C5
TRANSPORT SOC TO ISFSI
time
C6
N/A
ENERGYSOLUTIONS
2345 STEVENS DRIVE, SUITE 240
RICHLAND, WA 99354
TASK ORDER 21
TASK ORDER 18 STUDY
STAD-IN-CARRIER LOADING PROCESS
B
DWG-205592-ME-0003
A

17 APPENDIX F – DATABASE OF KEY CHARACTERISTICS RELATIVE TO THE USE OF DRY CASK STORAGE SYSTEMS AT OPERATIONAL NUCLEAR POWER STATIONS

Plant Name	Owner	Reactor Vendor	Reactor Type	Units	Pool Arrangement	Refueling Cycle	Storage Vendor	Crane Info	Cask Pit Info	Heavy Loads Issues	Floor Loading Issues	Truckbay Access
ANO 1	Entergy	Babcock & Wilcox	PWR	One	Separate from U2	18	Holtec	No Issues	10x10	No Issues	New Transfer Facility	No Issues
ANO 2	Entergy	Combustion Engineering	CE PWR	One	Separate from U1	18	Holtec	No Issues	10x10	No Issues	New Transfer Facility	No Issues
Beaver Valley	First Energy	Westinghouse	PWR-3L	Two		18	ISFSI in Design Stages	Under Evaluation		Under Evaluation	Under Evaluation	Under Evaluation
Braidwood	Exelon	Westinghouse	PWR-4L	Two	One pool for both units	18	Holtec	No Issues		Safe Load Path Established	No Issues	No Issues
Browns Ferry	TVA	General Electric	BWR-4	Three	U1 & U2 Connected, U3 Separate w/Pit	24	Holtec	No Issues	Crash Pad, No Decon Pit	No Issues	No Issues	No Issues
Brunswick	Duke	General Electric	BWR-4	Two	Two Separate Pools	24	TN/AREVA	No Issues	Standard Pit, Decon Area, No Walls	No Issues	No Issues	No Issues
Byron	Exelon	Westinghouse	PWR-4L	Two	One pool for both units	18		No Issues		No Known Issues	No Known Issues	No Known Issues
Calloway	Ameren	Westinghouse	PWR-4L	One	Single Unit / Single Pool	18	Holtec	No Issues	Have Drawing	No Issues	No Issues	No Issues
Calvert Cliffs	Exelon	Combustion Engineering	CE PWR	Two	Two Connected Pools	24	TN/AREVA	No Issues	25 x 25 with decon area	No Issues	Some, but Resolved	No Issues
Catawba	Duke	Westinghouse	PWR-4L	Two	Two Separate Pools	18	NAC	No Issues	9'6 by 9'6	No Issues	No Issues	No Issues
Clinton	Exelon	General Electric	BWR-6	One	Single Unit / Single Pool	24	None	Currently Being Upgraded		Currently Being Evaluated	Currently Being Evaluated	Currently Being Evaluated
Columbia 2	Energy Northwest	General Electric	BWR-5	One	Single Unit / Single Pool	24	Holtec	No Issues		No Known Issues	No Known Issues	No Known Issues
Cooper	NPPD	General Electric	BWR-4	One	Single Unit / Single Pool	24	TN/AREVA	No Issues	Tight - Special Yoke	No Issues	Safe Load Path Established	No Issues
Commanche Peak	Luminant	Westinghouse	PWR-4L	Two	Separate Interconnected Pools	18	Holtec	Recently Upgraded	In pool w/ wash pit on different elevation	Cask can't sit on refuel building floor	Siesmic Restraints Required in truckbay	No Issues
DC Cook	AEP	Westinghouse	PWR-4L	Two	One Shared Pool	18	Holtec	No Issues	Pit & Washdown Area	No Issues	No Issues	No Issues
Davis Besse	First Energy	Babcock & Wilcox	PWR	One	Single Unit / Single Pool	24	TN/AREVA	135T SFP	20x20 with Wash Pit	No Issues	No Issues	No Issues
Diablo Canyon	PG&E	Westinghouse	PWR-4L	Two	Two Separate Pools	24	Holtec	No Issues	In-Pool w/Separate Cask Pit for Welding	No Issues	No Issues	No Issues
Dresden	Exelon	General Electric	BWR-3	Two	Separate Pool	24	Holtec	Safe Load Paths		No Issues	No Issues	No Issues
Duane Arnold	FPL	General Electric	BWR-4	One	Single Unit / Single Pool	24	TN/AREVA	100t - cannot perform full lift	15x15 can be isolated from the SFP	No Issues	No Issues	No Issues

Plant Name	Owner	Reactor Vendor	Reactor Type	Units	Pool Arrangement	Refueling Cycle	Storage Vendor	Crane Info	Cask Pit Info	Heavy Loads Issues	Floor Loading Issues	Truckbay Access
Fermi 2	DTE	General Electric	BWR-4	One	Single Unit / Single Pool	18	Holtec	No Issues	Work done in DSP	Yes, work done in DSP	Yes, work done in DSP	Yes, stackup done outside
Fort Calhoun	OPPD	Combustion Engineering	CE PWR	One	Single Unit / Single Pool	18	TN/AREVA	No Known Issues		No Known Issues	No Known Issues	No Known Issues
Ginna	Exelon	Westinghouse	PWR-2	One	Single Unit / Single Pool	18	TN/AREVA					
Grand Gulf	Entergy	General Electric	BWR-6	One	Single Unit BWR 6 Arrangement	24	Holtec	No Issues	Transfer Canal (BWR-6) Decon Pit			
H. P. Robinson	Duke	Westinghouse	PWR-3L	One	Single Unit/Single Pool	18	TN/AREVA	No Issues	9x9 with Support Platforms for Welding	No issues	No issues	Fuel Building Panels are Removed for Access
Hatch	SNC	General Electric	BWR-4	Two	Two Pools, One Cask Pit	24	Holtec	No Issues	20x18 Pit with Separate Cask Washdown Pit	No issues	No issues	
Hope Creek	PSEG	General Electric	BWR-4	One	Single Unit, One Pool	18	Holtec	Polar Crane that can a problem be at times	10x12 pit w/Handling Area	No Issues	No Issues	No Issues
Indian Point	Entergy	Westinghouse	PWR-4L	Two	Two Separate Pools	24	Holtec	Mods performed at both units to accommodate	Wash pits available, but not used	No Issues (see crane info)	No Issues (see crane info)	No Issues (see crane info)
J. A. Fitzpatrick	Entergy	General Electric	BWR-4	One	Single Unit, One Pool	24	Holtec	No Issues	10x10 w/Cask Decon Pit	"Softener" Above the Torus	No Issues	No Issues
LaSalle	Exelon	General Electric	BWR-5	Two	Two Interconnect Pools	24	Holtec	No Issues		No Issues	No Issues	No Issues
Limerick	Exelon	General Electric	BWR-4	Two	Two Interconnect Pools	24	TN/AREVA	No Issues		No Issues	No Issues	No Issues
McGuire	Duke	Westinghouse	PWR-4L	Two	Two Units, Separate Pools	18	NAC	No Issues	9'6" by 9'6"	No Issues	No Issues	No Issues
Millstone 2	Dominion	Combustion Engineering	CE PWR	One	Separate from U3	18	TN/AREVA	No Issues	20x20 with Wash Pit	No Issues	No Issues	No Issues
Millstone 3	Dominion	Westinghouse	PWR-4L	One	Separate from U2	18	TN/AREVA	No Issues	20x20 with Wash Pit	No Issues	No Issues	No Issues
Nine Mile 1	Exelon	General Electric	BWR-2	One	Separate from U2	24	TN/AREVA	No Issues	Inside SFP	No Issues	No Issues	No Issues
Nine Mile 2	Exelon	General Electric	BWR-5	One	Separate from U1	24	TN/AREVA	No Issues	Outside SFP	No Issues	No Issues	No Issues
North Anna	Dominion	Westinghouse	PWR-3L	Two	One pool for both units	18	TN/AREVA	125T SFP	17x17	No Issues	No Issues	No issues
Monticello	Xcel	General Electric	BWR-3	One	Single Unit / Single Pool	24						
Oconee	Duke	Babcock & Wilcox	B&W PWR	Three	U1 & U2 Share, U3 Separate	24	TN/AREVA	No Issues	9' by 9' with Multiple Shelves	No Issues	No Issues	No Issues
Oyster Creek	Exelon	General Electric	BWR-2	One	Single Unit / Single Pool	24	TN/AREVA	No Issues	Adequate / Crash Pad No Decon Pit	No Issues	No Issues	No Issues
Palisaides	Entergy	Combustion Engineering	CE PWR	One	One Unit / One Pool	18		No Issues	In-Pool Pit and Washdown Pit	No Issues	No Issues	No Issues
Palo Verde	APS	Combustion Engineering	CE PWR	Three	Three Separate Pools	18	TN, but may be switching to NAC Magnastor	No Issues		Will upgrade for Magnastor	No Issues	No Issues
Peach Bottom	Exelon	General Electric	BWR-4	Two	Two Separate Pools	24	TN/AREVA	No Issues	In-Pool Pit	No Issues	No Issues	No Issues

Plant Name	Owner	Reactor Vendor	Reactor Type	Units	Pool Arrangement	Refueling Cycle	Storage Vendor	Crane Info	Cask Pit Info	Heavy Loads Issues	Floor Loading Issues	Truckbay Access
Perry	First Energy	General Electric	BWR-6	One	Single Unit BWR 6 Arrangement w/ 2 Pools	24	Holtec	Continuing/Trying to Resolve	14x13 with Shelf	Resolved	Resolved	No Issues
Pilgrim	Entergy	General Electric	BWR-3	One	Single Unit / Single Pool	24	Holtec	Evaluation In Progress	In-Pool Crash Pad	Evaluation In Progress	Evaluation In Progress	Airlock Work In Progress
Point Beach	NMC	Westinghouse	PWR-2L	Two	Single Pool	18	TN/AREVA	No Issues	In-Pool Only	Resolved	No Issues	No Issues
Prairie Island	Xcel	Westinghouse	PWR-2L	Two		18						
Quad Cities	Exelon	General Electric	BWR-3	Two	Interconnected	24	Holtec	No Issues	In-Pool with Sragging Area - No Decon Pit	Safe Load Path Established	No Issues	No Issues
River Bend	Entergy	General Electric	BWR-6	One	Single Unit BWR 6 Arrangement	24	Holtec	125T SFP	Separate from SFP, 14x16 with mods	No Issues	No Issues	Mods required for each move in/out
Salem	PSEG	Westinghouse	PWR-4L	Two		18						
Seabrook	FPL	Westinghouse	PWR-4L	One	Single Unit / Single Pool	18	TN/AREVA	Recent Upgrade	14x23 and can be isolated	Safe Load Path Established	No Issues	No Issues
Sequoyah	TVA	Westinghouse	PWR-4L	Two	Shared Pool	18	Holtec	No Issues	In-Pool Pit	No Issues	No Issues	No Issues
Sheron Harris	Duke	Westinghouse	PWR-3L	One	Single Unit with Four Interconnected Pools	18	None	No Issues	12 x 12 Connected to All Pools	No Issues	No Issues	No Issues
St. Lucie	FPL	Combustion Engineering	CE PWR	Two	Two Separate Pools	18						
South Texas	NRG	Westinghouse	PWR-4L	Two		18						
Surry	Dominion	Westinghouse	PWR-3L	Two	One pool for both units	24	Various / TN/AREVA	125T SFP	17x17	No Issues	No Issues	No issues
Susquehanna	Exelon	General Electric	BWR-4	Two	Two Pools on RFF One Cask Loading Pit	24	TN/AREVA	No Issues	One Pit (10x15) No Decon Pit	Safe Load Path Established	No Issues	No Issues
Three Mile Island	Exelon	Babcock & Wilcox	B&W PWR	One	Single Unit / Single Pool	24						
Turkey Point	FPL	Combustion Engineering	CE PWR	Two	Shared Pool	18						
V. C. Summer	SCE&G	General Electric	PWR-3L	One	Single Unit / Single Pool	18	Holtec	Upgraded to 125T SFP	12x13 w/ decon pit	In Progress	In Progress	No Issues
Waterford	TVA	Combustion Engineering	CE PWR	One	Single Unit / Single Pool	18			20x20 with Wash Pit	Safe Load Path Established	Can't Set Cask Down	Current issue with HVAC
Watts Bar	TVA	Westinghouse	PWR-4L	One	Single Unit / Single Pool	18	Holtec	Evals in Progress	Loading pit in pool with washdown outside	In Progress	In Progress	In Progress
Wolf Creek	WCN	Westinghouse	PWR-4L	One	Single Unit / Single Pool	18	No Currently Dry Storing	N/A	N/A	N/A	N/A	N/A

Note: if no information was available, the cell was left empty.

18 APPENDIX G – INVESTIGATION OF CANISTER DRYING PROCESSES AND TECHNOLOGIES

The objective of this investigation was to provide a synopsis of the basic technology in use today for fuel storage canister drying and to identify opportunities to reduce canister drying time as a means to reduce the overall canister loading duration.

Overview of the Vacuum Drying Process for Dry Fuel Storage

Beginning with the development and first use of dry fuel storage at commercial reactors it has been the practice to remove water and water vapor from the loaded canister. This is done to maintain the structural integrity of the fuel, the fuel basket, and the storage canister. The degree to which this drying process is performed, that is, how dry is dry enough has been the subject of much technical review. The fuel storage canister drying process and the resulting end state condition are especially important today due to the uncertainty of the timing of a final repository and the long-term aging effects of dry storage on the fuel and its storage canister.

Virtually all used fuel[9] dry storage systems currently in use have three basic components, a fuel basket into which the fuel is placed, a steel shell canister with integral bottom and top covers, and an outer concrete or metal shell or enclosure for shielding and physical protection. Vacuum drying involves only the fuel basket and canister. Dry storage preparations are essentially the same for all dry storage systems currently in use in the U.S. The STAD(s) or an empty canister is placed into a transfer cask, which in turn is placed in the fuel pool. Once all fuel assemblies have been loaded into the fuel canister, the lid is installed and the transfer cask with a loaded canister inside is removed from the fuel pool. From there it is usually moved to a decontamination pit or other shielded work area. The transfer cask is decontaminated and a small amount of water is drained from the canister to allow for canister lid welding or bolting. The bulk of the water inventory, up to 3000 gallons for some types of canisters in use today, is kept in the canister for As Low As Reasonably Achievable (ALARA) dose protection until lid welding or bolting is complete.

The next phase in canister preparation is dewatering and vacuum drying. First the remaining bulk water is drained from the canister through a drain tube, which in most cases extends to the bottom of the canister. This is achieved by using helium to “blow down” the bulk water and force it out of the canister through the drain tube.

After most of the free standing water is removed a vacuum pump is connected to the canister using flexible hoses and vacuum drying commences. During this process moisture and the

[9] The terms “used fuel” and “spent fuel” are used interchangeably throughout this report.

residual free water in the canister are vaporized as the internal pressure is reduced. The resultant vapor and residual gasses are removed from the canister through the vent ports by the vacuum pump. The internal decay heat of the fuel assists in the vaporization process as the canister internals and fuel temperatures increase during the drying process. Temperature rise and duration are carefully monitored and regulated by the dry cask storage system per the Technical Specifications. Controlling the canister internal temperature protects the fuel cladding from heat-induced damage. The vacuum pumping operation is continued until the canister internal cavity pressure is reduced to a specified value. For example, the vacuum limit for the Zion Nuclear Power Station dry cask storage system canisters is at or below 10 torr, which corresponds to one-half the vapor pressure of water at 72°F.

Once the specified canister internal pressure (vacuum) is achieved, the canister is isolated from the vacuum pump and the pump is turned off. At that point, if free water still exists in the canister, the water will vaporize and increase the canister pressure to above the 10 torr acceptance criterion. In the case of Zion, the dryness verification minimum hold period is ten minutes. Upon successful completion of the dryness verification, the vacuum pump is restarted and the canister continues to be evacuated until the NUREG-1536 [39] recommended pressure of less than 3torr is reached. The continued reduction in cavity pressure from 10 torr to less than 3 torr removes any residual non-condensing and oxidizing gases to a level of less than 1 mole. The canister is then backfilled with high purity helium (≥ 99.995%) to a positive pressure. Helium is an inert gas that virtually eliminates the potential for fuel and canister oxidation and subsequent long-term degradation.

In general, the vacuum drying process has been used successfully with a wide variety of fuel types (PWR and BWR) and canister sizes, but drying durations have varied from hours to multiple days. The main contributing factors to this variability are the internal fuel basket design, the neutron absorption material composition in the fuel basket cells, the age of each fuel assembly (decay heat), the physical condition of the fuel cladding, and the Dry Cask Storage (DCS) System Technical Specification acceptance criterion for dryness.

Opportunities for Vacuum Drying Improvement

- Basic Methods

  Currently, two basic methods are employed in the drying process – conventional vacuum drying (use helium to blow down the bulk water and then apply a vacuum) and Forced Helium Dehydration (FHD) where a forced flow of helium gas (moisture is removed from the helium by condensing, demoisturizing, and preheating the gas outside the canister) is used instead of applying decreased pressure (vacuum) to effect the drying. One major nuclear utility that uses both drying methods has found that the durations for vacuum drying and FHD are about the same. The major DCS designers are actively researching improvements to both methodologies and their continued efforts should be encouraged, but a substantial breakthrough in drying duration reduction does not seem likely just by changing from vacuum drying to FHD.

- Fuel Basket Design

  The fuel basket designs have improved over time. Among the changes made by some DCS suppliers is a reduction in total horizontal surface area. This reduces the gross collection area for free standing water and maximizes draining to the bottom of the canister. Every effort should be made during the STAD design phase to minimize horizontal surfaces in the canister basket and shell projections.

- Neutron Absorption Material Composition

  Probably the most effective method of reducing the vacuum drying process time is to use a metal matrix neutron absorbing material instead of the more porous Boral™ or borated aluminum plate used in some canister designs as a neutron fuel moderating material for criticality control. The more recent use of these borated metal matrix composite (MMC) materials has reduced vacuum drying durations significantly. Vacuum drying durations for the metal matrix materials are often less by one-half to a third (i.e., 8 to 14 hours versus 36 to 40 hours). At the present time MMC materials are generally more costly than Boral™, but the cost differential should be weighed against the predicted vacuum drying time savings during the development of the STAD system.

- Vacuum Drying System (VDS) Equipment

  The VDS process essentially uses three alternative modes: "standard" vacuum drying pump, forced helium dehydration, and a new automated system now employed at Duke Energy facilities. All of the systems include piping, control and flow valves, and measurement and test equipment. The Duke McGuire and Catawba plants had been using a standard set of vacuum drying equipment. Catawba subsequently switched from a standard VDS to an automated LT-1000 Phoenix system that was developed by EMS Solutions. The Catawba automated system routinely outperforms the standard equipment set deployed at McGuire by four hours (18-20 hours versus 22-24). This four-hour differential is a direct comparison given both sites used the same DCS system design and canister fabricator, which uses identical neutron absorbing material. In addition to reducing vacuum drying durations, the automated VDS produces more consistent dryness conditions in each canister. The STAD system could benefit by using an automated vacuum drying system that incorporates industry-wide lessons learned as the starting point for development of a universal VDS for each STAD size.

Other process improvements are possible by replacing poorly insulated hoses to reduce heat loss (for FHD system) and by using standardized pumps and ancillary equipment so that failed components can be replaced quickly thus reducing down time. Selecting the right size vacuum pump is important so that the canister volume can be evacuated as quickly as possible, but not so fast as to freeze the moisture inside the canister.

There have been numerous lessons-learned as the canister VDS have evolved. For example, both the fuel type and canister configuration have been altered or modified to include: oversized fill and vent ports; tilting (shimming) the canister bottom to create a low spot for the water to collect; applying external heat if the SNF is too cool to assist in the drying process.

Once the critical canister dimensions and configurations are known a standard VDS could be designed and undergo a test program, the objective of which would be to establish a universal VDS. This universal VDS should have identical replacement parts and standardized operating procedures. There would likely be one VDS for each of the three STAD sizes.

- Fuel Assembly Age and Material Condition

The age of fuel assemblies is a significant factor in canister vacuum drying durations. In general, older fuel usually has less residual heat as compared to fuel having been removed more recently from the reactor. Of course, the collective heat load from all used fuel at each reactor site cannot be modified, however, by developing a strategic canister loading plan for the entire used fuel inventory, a mix of used fuel assembly heat per canister can be achieved; the result of which could be canisters with approximately uniform total heat loads and subsequently consistent vacuum drying durations.

The physical condition of the fuel is another factor that can drastically affect vacuum drying durations. Cracked or otherwise damaged fuel cladding, such as pin hole leaks, may cause water retention in a fuel pin. The presence of a single damaged fuel assembly in a dry storage canister can potentially increase the vacuum drying time. Developing a load plan for all or at least a large number of used fuel assemblies at one time provides as opportunity to deal with these anomalies in the most efficient way possible and thus minimize the vacuum drying difficulties.

Another fuel material condition that can affect vacuum drying duration is the presence of water trapping configurations. For example, some older fuel has control rod dashpots that lack drain holes at their base. By developing a plan to modify these fuel assemblies well before fuel loading to dry storage takes place, vacuum drying durations can be dramatically reduced. These types of physical challenges are more common in older fuel, but many commercial reactor sites still have many such fuel assemblies to deal with.

- Canister Drying Criteria

  Assuming all options are available, there is an opportunity to redefine or confirm the criteria of a canister being considered in a vacuum dried condition versus NUREG-1536 [39] recommended pressure of less than 3torr with a 10 minute hold. DOE and industry concurrence on the end state vacuum dried condition is essential to establishing utility confidence in the STAD program.

Summary of Typical Drying Times in the Field

Table 18-1 was developed for use in the time and motion studies.

Table 18-1. Typical SNF Canister Drying Times in the Field.

Vacuum Equipment	Vacuum Drying Times - Hours Canister Neutron Absorption Material		
	Boral™ or Borated Aluminum Alloy	Borated Metal Matrix Composite	Canister Type
Zion "Standard Vacuum Equipment"	32 - 40	12 - 16	MAGNASTOR 37 PWR
Duke "Standard Vacuum Equipment"	22 - 24	NA	MAGNASTOR 37 PWR
Duke "Enhanced Vacuum Equipment"	18 -20	NA	MAGNASTOR 37 PWR
Exelon "Forced Helium Dehydration Equipment"	NA	8 - 16	Holtec MPC 68 BWR//32 PWR

Alternative Residual Moisture Removal Methods

In addition to the drying techniques that are currently being used for DCS systems, a study on alternative residual moisture removal methods was performed, in order to determine if any drying techniques used outside of the nuclear industry warrant further investigations due to offering improved drying times. The results from this study are provided in Appendix K, which also includes a history pertaining to the use and requirements of SNF canister drying technologies. Alternative residual moisture removal methods could include:

- Adapting one of the processes used to dry natural gas to dry a STAD[10]
    - Drying of natural gas (substituting helium for natural gas in the following process) - absorption of H2O by triethylene glycol (TEG). Absorption is done in a glycol contactor (tray column or packet bed) by countercurrent flow of wet gas (20-35°C) and TEG. TEG is enriched (by H_2O) and flows out in the bottom of contactor, then runs through flash and heat exchanger into reboiler. In the reboiler the H2O is boiled out. Temperature inside should not exceed 208°C (406°F) due to decomposition temperature of TEG. Regenerated (lean) TEG is then recycled back through heat exchanger and additional cooling unit back into the top of contactor.
    - Absorption of H2O by solid desiccants, most often by molecular sieve, silica gel or alumina. As a minimum, two beds systems are used. Typically one bed is drying gas and the other is being regenerated.
    - Expansion of natural gas which causes the *Joule – Thomson* effect. The wet natural gas under pressure is throttled and expanded into flash tanks and, as the consequence of the pressure decrease, the temperature decreases. The lower temperature of the gas stream leads to partial condensation of H2O vapors. Created droplets are removed from the gas stream by a demister inside the flash. Essential part of the system is injection of hydrate inhibitors (methanol or monoethylene glycol – MEG). This prevents hydrate formation and thus plugging. In cases where there is insufficient pressure difference between the underground gas storage (UGS) and distribution network available, an additional external cooler is required.

  ADVANTAGES: Minimal operating extremes from a process standpoint. Minimal thermal impact on high burnup (HBU) fuel cladding.

  DISADVANTAGES: Reviewer questions would almost certainly include material/chemical compatibility with the fuel cladding, exposed fuel and canister materials, which is required in the SRP. Material compatibility evaluations conducted for chemical used may prove unsuitable for use in this application.

It is noted that an inadequate review of material compatibility resulted in a hydrogen ignition event within a canister during the welding process in May, 1996[11]. This resulted in issuance of NRC Bulletin regarding chemical interactions in July, 1996[12].

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[10] *Comparison of Methods for Dehydration of Natural Gas Stored in Underground Gas Storages.* (Department of Process Engineering, Faculty of Mechanical Engineering, Czech Technical University, Prague, Czech Republic)
[11] *Hydrogen Gas Ignition during Closure Welding of a VSC-24 Multi-Assembly Sealed Basket* (NRC Information Notice 96-34).

- Adapt Purge Gas Drying Technology[13].
    - Although the initial drying efforts used in the early 80's indicate that vacuum drying was faster than purge drying[14], re-evaluation may be warranted. The ultra-dry nitrogen purge drying process is used in the Laser Manufacturing Industry today, where ultra-dry nitrogen with a dew point of -70 degrees Celsius (-94 degrees Fahrenheit) is introduced under pressure into an enclosure or cavity to remove moisture and create a much drier internal environment than standard desiccant can. This drying method appears to provide positive results. Several models (portable, rackmounted) of nitrogen enhanced purging systems (NEPS) appear to be available off-the-shelf[13]. With the NEPS unit, ultra-dry gas (typically nitrogen) enters the cavity or enclosure through a single port and is pressurized to a pre-determined PSI before a valve opens and the gas backflows back into the unit. There it passes a dew point monitor and displays the current dew-point temperature. The nitrogen is then vented to the atmosphere and a new cycle commences. This cycling continues until the equipment reaches the required dew-point level, at which point it automatically shuts off. An inert gas that would not be subject to neutron activation (like helium) would likely have to be substituted for the nitrogen.

  ADVANTAGES: Provides means for heat removal as compared to vacuum drying process.

  DISADVANTAGES: May actually take longer than current vacuum drying processes.

- Review and adapt Helium Purification Systems that were designed for use on gas cooled reactors[15]
    - Gas cooled reactor helium coolants use a purification system that uses reactor helium recirculating fan differential pressure as the motive force. The anticipated major non-radioactive, gaseous contaminants (H2O, CO2, H2, CO, and CH4) were recognized as being deleterious to both materials and fuel. A two-step purification system for removal of these contaminants was proposed in which first all oxidizable gases are oxidized to H2O and CO2 and then the H2O and CO2 are removed from the helium by fixed bed co-sorption[15]. This type of system could be scaled to the total volume capacity required for the STAD and made as a portable skid-based system for use.

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[12] *Chemical, Galvanic, or other Reactions in Spent Fuel Storage and Transportation Casks* (NRC Bulletin 96-04)
[13] *Nitrogen Enhanced Purging Systems by AGM Container Controls* (http://www.agmcontainer.com/products/neps.html)
[14] *Technical Basis for Storage of Zircaloy-Clad Spent Fuel in Inert Gases* (PNL-4835)
[15] *Removal of Hydrogen, Carbon Monoxide, and Methane from Gas Cooled Reactor Helium Coolants* (ORNL-TM-20)

ADVANTAGES: Means to eliminate all contaminants without undue thermal impact on fuel.

DISADVANTAGES: Reviewer questions would almost certainly include material/chemical compatibility with the fuel cladding, exposed fuel and canister materials, which is required in the SRP. Material compatibility evaluations conducted for chemical used may prove unsuitable for use in this application.

- Use of supercritical fluids to remove moisture.
  - Supercritical fluids blur the line between liquid and gas. Supercritical fluids can absorb moisture that is removed when the pressure is reduced and the supercritical fluid is discharged as a gas. Supercritical N2O or CO2 is used with acetone to remove moisture from micro-electromechanical systems (MEMS), and spices. This requires high pressure (1,000 psi).

DISADVANTAGES: N2O is highly oxidizing, and the use of acetone would produce mixed waste, ruling out use of this drying process for STADs

<u>Summary</u>

It must be recognized that the removal of residual moisture from within the STAD will be one of two specific activities (seal welding being the other) that are not predicated by site specific attributes. The STAD seal weld design (linear length of seal weld and weld groove design) will result in a repeatable, definable duration of weld filler material installation when using the same welding system. The duration of residual moisture removal efforts may also be consistently achieved provided that the drying method and equipment used to facilitate the residual moisture removal process is appropriate for use with the STAD canister design and the fuel it contains.

Regardless of the above, enhancements in these two time dependent processes both have a point of diminishing returns within a typical unit loading sequence. When viewing the entire unit activity (i.e. the loading process of one STAD system around the clock with no limitation on resources and complete equipment fidelity) qualitatively, it is reasonable to expect a duration of no more than six days (based on MAGNASTOR loading duration at Zion). Of this duration (144 hours), the duration of the vacuum drying (using "standard vacuum drying equipment" and drying DPCs containing Boral™ or borated aluminum alloy) and helium backfill process is around 33 hours, which indicates that the rest of the activities needed to conduct a single unit require 111 hours to complete. The drying process thus represents only approximately 23% of the total elapsed time spent performing said single unit.

As previously mentioned elsewhere in this report, the activity durations for currently used canister drying equipment (both "Enhanced Vacuum Drying Equipment" and Forced Helium Dehydration) are about even with no clear 'best athlete' in the total elapsed time arena

(18 hours). Still, this represents an overall savings of 15 hours (33 hours for Zion – 18 hours for enhanced drying) (or just over one 12 hour shift) in a unit process.

Given that the current throughput could require as many as 24 casks to be loaded in a single campaign (where a campaign is the complete duty cycle of loadings), this is an overall savings of 15 loading-days on a schedule that would be expected to require (assuming back to back loading with no interruptions and no parallel unit loading activities) 144 days to be completed, thereby reducing the total duration of the loading campaign to 129 days. Any improvements that result in reducing the duration of the drying process could have a significant improvement in the overall campaign duration.

Licensee users of industry-provided equipment to facilitate residual moisture removal have optimized the equipment within their realm of control (operation). For vacuum drying equipment – improved pumps, connections and higher accuracy instrumentation have all served the industry well in reducing drying durations to the extent practical. For users of forced helium dehydration, to date the system has had little in the way of improvements from an equipment perspective. Only operational enhancements have made any improvements in drying durations.

Given the overall process and duration of specific activities when compared to impact on overall duration and material longevity – it may be that no real benefit in improving drying durations can be readily found or implemented. Using a STAD that has been designed and fabricated to facilitate enhanced residual moisture removal will no doubt provide best results in drying. Additional investment in enhanced drying processes may result in very limited improvements in overall duration of activities when viewed qualitatively.

19 APPENDIX H – DETAILED TIME CALCULATIONS

Table 19-1. BWR DPC Reference Case

BWR DPC									
Step	Task Location Legend: FHB preparation area Fuel pool Cask decon pit ISFSI Task Category Legend: A Gen Handling & Prep B Fuel Movement/Verif C Drain/Dry/Backfill D Welding E NDE/Testing	Task Category Code	Linear Step Time Baseline (hrs)	Technology Improvement (hrs saved)	Percent on Clock (parallel savings)	Time saved per DPC by Parallel Ops (hrs)	Step Time with Tech. Savings Alone (hrs)	Step Time with Parallel Savings Alone (hrs)	Step Time with Tech & Parallel Savings (hrs)
1	Move Transporter & SC into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
2	Move SC to under seismic restraint	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
3	Remove the SC lid and install adapter	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
4	Load spacers	A	0.8	0.0	100%	0.0	0.8	0.8	0.8
5	Move DPC into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
6	TC preparation	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
7	Move TC into decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
8	TC preparation	A	4.4	0.0	100%	0.0	4.4	4.4	4.4
9	Place DPC into TC	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
10	Place TC/DPC into SFP	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
11	Start fuel moves	B	0.5	0.0	50%	0.3	0.5	0.3	0.3
12	Fuel moves	B	33.4	0.0	50%	16.7	33.4	16.7	16.7
13	Fuel verification	B	4.4	0.0	50%	2.2	4.4	2.2	2.2
14	Install DFC lids/spacers	A	3.0	0.0	100%	0.0	3.0	3.0	3.0
15	Install DPC lid	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
16	Remove TC/DPC from SFP	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
17	Place TC/DPC into the decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
18	Decon TC/DPC	A	4.1	0.0	100%	0.0	4.1	4.1	4.1
19	Remove 70 gallons water	C	0.8	0.0	100%	0.0	0.8	0.8	0.8
20	Test for hydrogen	E	0.5	0.0	100%	0.0	0.5	0.5	0.5
21	Perform lid fit up	A	4.0	0.0	100%	0.0	4.0	4.0	4.0
22	Weld DPC inner plate (all passes)	D	4.5	0.0	100%	0.0	4.5	4.5	4.5
23	NDE DPC inner plate (all passes)	E	3.0	0.0	100%	0.0	3.0	3.0	3.0
24	Hydro pressure test DPC inner plate	E	1.0	0.0	100%	0.0	1.0	1.0	1.0
25	Blowdown DPC	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
26	Set up to the VDS	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
27	Vacuum dry DPC	C	27.0	4.6	100%	0.0	22.4	27.0	22.4
28	Helium backfill DPC	C	2.0	0.0	100%	0.0	2.0	2.0	2.0
29	Weld and test inner port covers	D	4.0	0.0	100%	0.0	4.0	4.0	4.0
30	Helium leak test port covers	E	1.2	0.0	100%	0.0	1.2	1.2	1.2
31	Weld DPC outer plate	D	1.5	0.0	100%	0.0	1.5	1.5	1.5
32	NDE DPC outer plate	E	1.0	0.0	100%	0.0	1.0	1.0	1.0
33	Install TC retaining lugs	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
34	Prep TC/DPC for stack up	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
35	Remove TC/DPC from the decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
36	Place TC/DPC in stack up	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
37	Engage TC seismic restraint	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
38	Remove yoke from FHB hook	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
39	Rig DPC to FHB hook	A	1.8	0.0	100%	0.0	1.8	1.8	1.8
40	Transfer DPC to SC	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
41	Remove rigging	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
42	Close transfer adapter	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
43	Install yoke	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
44	Disengage TC seismic restraint	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
45	Move TC to decon pit	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
46	Remove rigging from DPC	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
47	Remove transfer adapter	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
48	Set SC lid	A	2.0	0.0	50%	1.0	2.0	1.0	1.0
49	Check SC vents	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
50	Perform fire hazards walkdown	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
51	Move SC to Transporter	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
52	Perform SC dose rates	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
53	Move support equipment to ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
54	Move Transporter to haul road	A	1.3	0.0	50%	0.7	1.3	0.7	0.7
55	Replace security barriers	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
56	Move Transporter/SC/DPC to ISFSI pad	A	3.0	0.0	50%	1.5	3.0	1.5	1.5
57	The security barrier at ISFSI and open gate	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
58	Move Transporter into position at ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
59	Position SC on pad	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
60	Install vent screens	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
61	Move equipment from ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
62	Replace security barriers	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
			144.8 (6d)	4.6 (0.2d)		29.3 (1.2d)	140.2 (5.8d)	115.6 (4.8d)	111.0 (4.6d)

Table 19-2. PWR DPC Reference Case (Zion)

Step	Zion Dry Fuel Loading	Step Time (hrs)	Process Time (per TSC) On Clock?	Off-clock Time	Clock Time
	Legend: Outside protected area; FHB preparation area; Fuel pool; Cask decon pit; ISFSI				
1	VCT pre-use inspection	1.0		1.0	
2	VCC pre-use inspection	1.0		1.0	
3	Load VCC onto VCT	0.8		0.8	
4	Move VCC to security protected area	0.5		0.5	
5	Move VCT & VCC into FHB	0.5	x		0.5
6	Move VCC to under seismic restraint	0.5	x		0.5
7	Remove the VCC lid and install adapter	1.5	x		1.5
8	Load spacers	0.8	x		0.8
9	Move TSC into FHB	0.5	x		0.5
10	MTC preparation	2.0	x		2.0
11	Move MTC into decon pit	0.5	x		0.5
12	MTC preparation	4.4	x		4.4
13	Place TSC into MTC	1.0	x		1.0
14	Place MTC/TSC into SFP	2.6	x		2.6
15	Start fuel moves	0.5	x		0.5
16	Fuel moves	14.0	x		14.0
17	Fuel verification	1.6	x		1.6
18	Install DFC lids/spacers	3.0	x		3.0
19	Install TSC lid	0.5	x		0.5
20	Remove MTC/TSC from SFP	2.6	x		2.6
21	Place MTC/TSC into the decon pit	0.5	x		0.5
22	Decon MTC/TSC	4.1	x		4.1
23	Remove 70 gallons water	0.8	x		0.8
24	Test for hydrogen	0.5	x		0.5
25	Perform lid fit up, welder setup	4.0	x		4.0
26	Weld TSC lid root weld start	0.7	x		0.7
27	Weld TSC lid root weld finish	1.5	x		1.5
28	NDE TSC lid root weld	1.0	x		1.0
29	Weld TSC lid intermediate weld	1.5	x		1.5
30	NDE TSC lid intermediate weld	1.0	x		1.0
31	Weld TSC lid final weld	1.5	x		1.5
32	NDE TSC lid final weld	1.0	x		1.0
33	Hydro pressure test TSC lid	1.0	x		1.0
34	Weld closure ring	1.5	x		1.5
35	NDE closure ring	1.0	x		1.0
36	Blowdown TSC	1.0	x		1.0
37	Set up to the VDS	1.0	x		1.0
38	Vacuum dry TSC	30.0	x		30.0
39	Helium backfill TSC	2.0	x		2.0
40	Weld and test inner port covers	4.0	x		4.0
41	Helium leak test port covers	1.2	x		1.2
42	Weld and test and outer port covers	4.0	x		4.0
43	Install MTC retaining lugs	1.5	x		1.5
44	Prep MTC/TSC for stack up	2.0	x		2.0
45	Remove NTC/TSC from the decon pit	0.5	x		0.5
46	Place NTC/TSC in stack up	1.5	x		1.5
47	Engage MTC seismic restraint	1.0	x		1.0
48	Remove yoke from FHB hook	0.5	x		0.5
49	Rig TSC to FHB hook	1.8	x		1.8
50	Transfer TSC to VCC	1.0	x		1.0
51	Remove rigging	1.5	x		1.5
52	Close transfer adapter	0.5	x		0.5
53	Install yoke	0.5	x		0.5
54	Disengage MTC seismic restraint	1.0	x		1.0
55	Move MTC to decon pit	0.5	x		0.5
56	Remove rigging from TSC	1.0	x		1.0
57	Remove transfer adapter	1.5	x		1.5
58	Set VCC lid	2.0	x		2.0
59	Check VCC vents	0.5	x		0.5
60	Perform fire hazards walkdown	1.0	x		1.0
61	Move VCC to VCT	0.5	x		0.5
62	Perform VCC dose rates	1.0	x		1.0
63	Move support equipment to ISFSI	0.5	x		0.5
64	Move VCT to haul road	1.3	x		1.3
65	Replace security barriers	0.3	x		0.3
66	Move VCT/VCC/TSC to ISFSI pad	3.0	x		3.0
67	The security barrier at ISFSI and open gate	0.3	x		0.3
68	Move VCT into position at ISFSI	0.5	x		0.5
69	Position VCC on pad	0.5	x		0.5
70	Install vent screens	0.5	x		0.5
71	Move equipment from ISFSI	0.5	x		0.5
72	Replace security barriers	0.3	x		0.3
	TOTAL clock time for one canister (hrs)				130.0
	Total off-clock time for one canister (hrs)			3.3	

Table 19-3. Large BWR STAD Canisters

Large BWR STAD

Task Location Legend: FHB preparation area; Fuel pool; Cask decon pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step	Task	Task Category Code	Linear Step Time Baseline (hrs)	Technology Improvement (hrs saved)	Percent on Clock (parallel savings)	Time saved per STAD by Parallel Ops (hrs)	Step Time with Tech. Savings Alone (hrs)	Step Time with Parallel Savings Alone (hrs)	Step Time with Tech & Parallel Savings (hrs)
1	Move Transporter & SC into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
2	Move SC to under seismic restraint	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
3	Remove the SC lid and install adapter	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
4	Load spacers	A	0.8	0.0	100%	0.0	0.8	0.8	0.8
5	Move STAD into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
6	TC preparation	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
7	Move TC into decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
8	TC preparation	A	4.4	0.0	100%	0.0	4.4	4.4	4.4
9	Place STAD into TC	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
10	Place TC/STAD into SFP	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
11	Start fuel moves	B	0.5	0.0	50%	0.3	0.5	0.3	0.3
12	Fuel moves	B	16.9	0.0	50%	8.5	16.9	8.5	8.5
13	Fuel verification	B	2.2	0.0	50%	1.1	2.2	1.1	1.1
14	Install DFC lids/spacers	A	3.0	0.0	100%	0.0	3.0	3.0	3.0
15	Install STAD lid	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
16	Remove TC/STAD from SFP	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
17	Place TC/STAD into the decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
18	Decon TC/STAD	A	4.1	0.0	100%	0.0	4.1	4.1	4.1
19	Remove 70 gallons water	C	0.7	0.0	100%	0.0	0.7	0.7	0.7
20	Test for hydrogen	E	0.5	0.0	100%	0.0	0.5	0.5	0.5
21	Perform lid fit up	A	4.0	0.0	100%	0.0	4.0	4.0	4.0
22	Weld STAD inner plate (all passes)	D	4.4	0.0	100%	0.0	4.4	4.4	4.4
23	NDE STAD inner plate (all passes)	E	2.9	0.0	100%	0.0	2.9	2.9	2.9
24	Hydro pressure test STAD inner plate	E	1.0	0.0	100%	0.0	1.0	1.0	1.0
25	Blowdown STAD	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
26	Set up to the VDS	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
27	Vacuum dry STAD	C	28.0	4.8	100%	0.0	23.2	28.0	23.2
28	Helium backfill STAD	C	2.1	0.0	100%	0.0	2.1	2.1	2.1
29	Weld and test inner port covers	D	4.0	0.0	100%	0.0	4.0	4.0	4.0
30	Helium leak test port covers	E	1.2	0.0	100%	0.0	1.2	1.2	1.2
31	Weld STAD outer plate	D	1.5	0.0	100%	0.0	1.5	1.5	1.5
32	NDE STAD outer plate	E	1.0	0.0	100%	0.0	1.0	1.0	1.0
33	Install TC retaining lugs	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
34	Prep TC/STAD for stack up	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
35	Remove TC/STAD from the decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
36	Place TC/STAD in stack up	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
37	Engage TC seismic restraint	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
38	Remove yoke from FHB hook	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
39	Rig STAD to FHB hook	A	1.8	0.0	100%	0.0	1.8	1.8	1.8
40	Transfer STAD to SC	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
41	Remove rigging	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
42	Close transfer adapter	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
43	Install yoke	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
44	Disengage TC seismic restraint	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
45	Move TC to decon pit	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
46	Remove rigging from STAD	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
47	Remove transfer adapter	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
48	Set SC lid	A	2.0	0.0	50%	1.0	2.0	1.0	1.0
49	Check SC vents	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
50	Perform fire hazards walkdown	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
51	Move SC to Transporter	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
52	Perform SC dose rates	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
53	Move support equipment to ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
54	Move Transporter to haul road	A	1.3	0.0	50%	0.7	1.3	0.7	0.7
55	Replace security barriers	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
56	Move Transporter/SC/STAD to ISFSI pad	A	3.0	0.0	50%	1.5	3.0	1.5	1.5
57	The security barrier at ISFSI and open gate	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
58	Move Transporter into position at ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
59	Position SC on pad	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
60	Install vent screens	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
61	Move equipment from ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
62	Replace security barriers	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
			126.9 (5.3d)	4.8 (0.2d)		19.9 (0.8d)	122.1 (5.1d)	107.0 (4.5d)	102.2 (4.3d)

Table 19-4. Large PWR STAD Canisters

Large PWR STAD

Task Location Legend: FHB preparation area; Fuel pool; Cask decon pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step	Task	Task Category Code	Linear Step Time Baseline (hrs)	Technology Improvement (hrs saved)	Percent on Clock (parallel savings)	Time saved per STAD by Parallel Ops (hrs)	Step Time with Tech. Savings Alone (hrs)	Step Time with Parallel Savings Alone (hrs)	Step Time with Tech & Parallel Savings (hrs)
1	Move Transporter & SC into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
2	Move SC to under seismic restraint	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
3	Remove the SC lid and install adapter	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
4	Load spacers	A	0.8	0.0	100%	0.0	0.8	0.8	0.8
5	Move STAD into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
6	TC preparation	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
7	Move TC into decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
8	TC preparation	A	4.4	0.0	100%	0.0	4.4	4.4	4.4
9	Place STAD into TC	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
10	Place TC/STAD into SFP	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
11	Start fuel moves	B	0.5	0.0	50%	0.3	0.5	0.3	0.3
12	Fuel moves	B	8.1	0.0	50%	4.1	8.1	4.1	4.1
13	Fuel verification	B	1.1	0.0	50%	0.6	1.1	0.6	0.6
14	Install DFC lids/spacers	A	3.0	0.0	100%	0.0	3.0	3.0	3.0
15	Install STAD lid	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
16	Remove TC/STAD from SFP	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
17	Place TC/STAD into the decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
18	Decon TC/STAD	A	4.1	0.0	100%	0.0	4.1	4.1	4.1
19	Remove 70 gallons water	C	0.7	0.0	100%	0.0	0.7	0.7	0.7
20	Test for hydrogen	E	0.5	0.0	100%	0.0	0.5	0.5	0.5
21	Perform lid fit up	A	4.0	0.0	100%	0.0	4.0	4.0	4.0
22	Weld STAD inner plate (all passes)	D	4.4	0.0	100%	0.0	4.4	4.4	4.4
23	NDE STAD inner plate (all passes)	E	2.9	0.0	100%	0.0	2.9	2.9	2.9
24	Hydro pressure test STAD inner plate	E	1.0	0.0	100%	0.0	1.0	1.0	1.0
25	Blowdown STAD	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
26	Set up to the VDS	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
27	Vacuum dry STAD	C	28.0	4.8	100%	0.0	23.2	28.0	23.2
28	Helium backfill STAD	C	2.1	0.0	100%	0.0	2.1	2.1	2.1
29	Weld and test inner port covers	D	4.0	0.0	100%	0.0	4.0	4.0	4.0
30	Helium leak test port covers	E	1.2	0.0	100%	0.0	1.2	1.2	1.2
31	Weld STAD outer plate	D	1.5	0.0	100%	0.0	1.5	1.5	1.5
32	NDE STAD outer plate	E	1.0	0.0	100%	0.0	1.0	1.0	1.0
33	Install TC retaining lugs	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
34	Prep TC/STAD for stack up	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
35	Remove TC/STAD from the decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
36	Place TC/STAD in stack up	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
37	Engage TC seismic restraint	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
38	Remove yoke from FHB hook	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
39	Rig STAD to FHB hook	A	1.8	0.0	100%	0.0	1.8	1.8	1.8
40	Transfer STAD to SC	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
41	Remove rigging	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
42	Close transfer adapter	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
43	Install yoke	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
44	Disengage TC seismic restraint	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
45	Move TC to decon pit	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
46	Remove rigging from STAD	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
47	Remove transfer adapter	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
48	Set SC lid	A	2.0	0.0	50%	1.0	2.0	1.0	1.0
49	Check SC vents	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
50	Perform fire hazards walkdown	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
51	Move SC to Transporter	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
52	Perform SC dose rates	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
53	Move support equipment to ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
54	Move Transporter to haul road	A	1.3	0.0	50%	0.7	1.3	0.7	0.7
55	Replace security barriers	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
56	Move Transporter/SC/STAD to ISFSI pad	A	3.0	0.0	50%	1.5	3.0	1.5	1.5
57	The security barrier at ISFSI and open gate	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
58	Move Transporter into position at ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
59	Position SC on pad	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
60	Install vent screens	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
61	Move equipment from ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
62	Replace security barriers	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
			117.0 (4.9d)	4.8 (0.2d)		15.0 (0.6d)	112.2 (4.7d)	102.1 (4.3d)	97.3 (4.1d)

Table 19-5. Medium BWR STAD Canisters

Medium BWR STAD

Task Location Legend: FHB preparation area; Fuel pool; Cask decon pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step	Task	Task Category Code	Linear Step Time Baseline (hrs)	Technology Improvement (hrs saved)	Percent on Clock (parallel savings)	Time saved per STAD by Parallel Ops (hrs)	Step Time with Tech. Savings Alone (hrs)	Step Time with Parallel Savings Alone (hrs)	Step Time with Tech & Parallel Savings (hrs)
1	Move Transporter & SC into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
2	Move SC to under seismic restraint	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
3	Remove the SC lid and install adapter	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
4	Load spacers	A	0.8	0.0	100%	0.0	0.8	0.8	0.8
5	Move STAD into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
6	TC preparation	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
7	Move TC into decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
8	TC preparation	A	4.4	0.0	100%	0.0	4.4	4.4	4.4
9	Place STAD into TC	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
10	Place TC/STAD into SFP	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
11	Start fuel moves	B	0.5	0.0	50%	0.3	0.5	0.3	0.3
12	Fuel moves	B	12.3	0.0	50%	6.2	12.3	6.2	6.2
13	Fuel verification	B	1.6	0.0	50%	0.8	1.6	0.8	0.8
14	Install DFC lids/spacers	A	3.0	0.0	100%	0.0	3.0	3.0	3.0
15	Install STAD lid	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
16	Remove TC/STAD from SFP	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
17	Place TC/STAD into the decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
18	Decon TC/STAD	A	4.1	0.0	100%	0.0	4.1	4.1	4.1
19	Remove 70 gallons water	C	0.4	0.0	100%	0.0	0.4	0.4	0.4
20	Test for hydrogen	E	0.5	0.0	100%	0.0	0.5	0.5	0.5
21	Perform lid fit up	A	4.0	0.0	100%	0.0	4.0	4.0	4.0
22	Weld STAD inner plate (all passes)	D	3.2	0.0	100%	0.0	3.2	3.2	3.2
23	NDE STAD inner plate (all passes)	E	2.1	0.0	100%	0.0	2.1	2.1	2.1
24	Hydro pressure test STAD inner plate	E	1.0	0.0	100%	0.0	1.0	1.0	1.0
25	Blowdown STAD	C	0.5	0.0	100%	0.0	0.5	0.5	0.5
26	Set up to the VDS	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
27	Vacuum dry STAD	C	14.0	2.4	100%	0.0	11.6	14.0	11.6
28	Helium backfill STAD	C	1.1	0.0	100%	0.0	1.1	1.1	1.1
29	Weld and test inner port covers	D	4.0	0.0	100%	0.0	4.0	4.0	4.0
30	Helium leak test port covers	E	1.2	0.0	100%	0.0	1.2	1.2	1.2
31	Weld STAD outer plate	D	1.1	0.0	100%	0.0	1.1	1.1	1.1
32	NDE STAD outer plate	E	0.7	0.0	100%	0.0	0.7	0.7	0.7
33	Install TC retaining lugs	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
34	Prep TC/STAD for stack up	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
35	Remove TC/STAD from the decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
36	Place TC/STAD in stack up	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
37	Engage TC seismic restraint	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
38	Remove yoke from FHB hook	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
39	Rig STAD to FHB hook	A	1.8	0.0	100%	0.0	1.8	1.8	1.8
40	Transfer STAD to SC	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
41	Remove rigging	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
42	Close transfer adapter	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
43	Install yoke	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
44	Disengage TC seismic restraint	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
45	Move TC to decon pit	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
46	Remove rigging from STAD	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
47	Remove transfer adapter	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
48	Set SC lid	A	2.0	0.0	50%	1.0	2.0	1.0	1.0
49	Check SC vents	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
50	Perform fire hazards walkdown	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
51	Move SC to Transporter	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
52	Perform SC dose rates	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
53	Move support equipment to ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
54	Move Transporter to haul road	A	1.3	0.0	50%	0.7	1.3	0.7	0.7
55	Replace security barriers	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
56	Move Transporter/SC/STAD to ISFSI pad	A	3.0	0.0	50%	1.5	3.0	1.5	1.5
57	The security barrier at ISFSI and open gate	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
58	Move Transporter into position at ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
59	Position SC on pad	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
60	Install vent screens	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
61	Move equipment from ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
62	Replace security barriers	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
			103.2 (4.3d)	2.4 (0.1d)		17.3 (0.7d)	100.8 (4.2d)	85.9 (3.6d)	83.5 (3.5d)

Table 19-6. Medium PWR STAD Canisters

Medium PWR STAD

Task Location Legend: FHB preparation area; Fuel pool; Cask decon pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step	Task	Task Category Code	Linear Step Time Baseline (hrs)	Technology Improvement (hrs saved)	Percent on Clock (parallel savings)	Time saved per STAD by Parallel Ops (hrs)	Step Time with Tech. Savings Alone (hrs)	Step Time with Parallel Savings Alone (hrs)	Step Time with Tech & Parallel Savings (hrs)
1	Move Transporter & SC into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
2	Move SC to under seismic restraint	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
3	Remove the SC lid and install adapter	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
4	Load spacers	A	0.8	0.0	100%	0.0	0.8	0.8	0.8
5	Move STAD into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
6	TC preparation	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
7	Move TC into decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
8	TC preparation	A	4.4	0.0	100%	0.0	4.4	4.4	4.4
9	Place STAD into TC	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
10	Place TC/STAD into SFP	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
11	Start fuel moves	B	0.5	0.0	50%	0.3	0.5	0.3	0.3
12	Fuel moves	B	4.6	0.0	50%	2.3	4.6	2.3	2.3
13	Fuel verification	B	0.6	0.0	50%	0.3	0.6	0.3	0.3
14	Install DFC lids/spacers	A	3.0	0.0	100%	0.0	3.0	3.0	3.0
15	Install STAD lid	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
16	Remove TC/STAD from SFP	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
17	Place TC/STAD into the decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
18	Decon TC/STAD	A	4.1	0.0	100%	0.0	4.1	4.1	4.1
19	Remove 70 gallons water	C	0.4	0.0	100%	0.0	0.4	0.4	0.4
20	Test for hydrogen	E	0.5	0.0	100%	0.0	0.5	0.5	0.5
21	Perform lid fit up	A	4.0	0.0	100%	0.0	4.0	4.0	4.0
22	Weld STAD inner plate (all passes)	D	3.2	0.0	100%	0.0	3.2	3.2	3.2
23	NDE STAD inner plate (all passes)	E	2.1	0.0	100%	0.0	2.1	2.1	2.1
24	Hydro pressure test STAD inner plate	E	1.0	0.0	100%	0.0	1.0	1.0	1.0
25	Blowdown STAD	C	0.5	0.0	100%	0.0	0.5	0.5	0.5
26	Set up to the VDS	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
27	Vacuum dry STAD	C	14.0	2.4	100%	0.0	11.6	14.0	11.6
28	Helium backfill STAD	C	1.1	0.0	100%	0.0	1.1	1.1	1.1
29	Weld and test inner port covers	D	4.0	0.0	100%	0.0	4.0	4.0	4.0
30	Helium leak test port covers	E	1.2	0.0	100%	0.0	1.2	1.2	1.2
31	Weld STAD outer plate	D	1.1	0.0	100%	0.0	1.1	1.1	1.1
32	NDE STAD outer plate	E	0.7	0.0	100%	0.0	0.7	0.7	0.7
33	Install TC retaining lugs	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
34	Prep TC/STAD for stack up	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
35	Remove TC/STAD from the decon pit	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
36	Place TC/STAD in stack up	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
37	Engage TC seismic restraint	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
38	Remove yoke from FHB hook	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
39	Rig STAD to FHB hook	A	1.8	0.0	100%	0.0	1.8	1.8	1.8
40	Transfer STAD to SC	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
41	Remove rigging	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
42	Close transfer adapter	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
43	Install yoke	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
44	Disengage TC seismic restraint	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
45	Move TC to decon pit	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
46	Remove rigging from STAD	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
47	Remove transfer adapter	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
48	Set SC lid	A	2.0	0.0	50%	1.0	2.0	1.0	1.0
49	Check SC vents	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
50	Perform fire hazards walkdown	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
51	Move SC to Transporter	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
52	Perform SC dose rates	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
53	Move support equipment to ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
54	Move Transporter to haul road	A	1.3	0.0	50%	0.7	1.3	0.7	0.7
55	Replace security barriers	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
56	Move Transporter/SC/STAD to ISFSI pad	A	3.0	0.0	50%	1.5	3.0	1.5	1.5
57	The security barrier at ISFSI and open gate	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
58	Move Transporter into position at ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
59	Position SC on pad	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
60	Install vent screens	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
61	Move equipment from ISFSI	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
62	Replace security barriers	A	0.3	0.0	50%	0.2	0.3	0.2	0.2
			94.5 (3.9d)	2.4 (0.1d)		13.0 (0.5d)	92.1 (3.8d)	81.6 (3.4d)	79.2 (3.3d)

Table 19-7. Small BWR STADs-in-Can

Small BWR STADs-in-Can

Task Location Legend: FHB preparation area; Fuel pool; Cask decon pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step		Task Category Code	Linear Step Time Baseline (hrs)	Technology Improvement (hrs saved)	Percent on Clock (parallel savings)	Time saved per STAD by Parallel Ops (hrs)	Step Time with Tech. Savings Alone (hrs)	Step Time with Parallel Savings Alone (hrs)	Step Time with Tech & Parallel Savings (hrs)
A5	Move VCT & SOC into PCT	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
A6	Move SOC to seismic restraint	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
A7	Remove the SOC lid	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
A8	Remove Can lid	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
A9	Lift Can with STADs from SOC	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A10	Place Can into Transfer Cask	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A11	Remove STAD lids	A	4.0	0.0	100%	0.0	4.0	4.0	4.0
A12	Fill Transfer Cask with deionized water	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A13	Install inflatable seal between Can and Transfer Cask	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A14	Verify water chemistry matches fuel pool	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
A15	Place Transfer Cask into fuel pool	A	2.6	0.0	50%	1.3	2.6	1.3	1.3
A16	Fuel moves	B	14.3	0.0	50%	7.2	14.3	7.2	7.2
A17	Fuel verification	B	1.8	0.0	50%	0.9	1.8	0.9	0.9
B1	Install 4 STAD lids	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
B2	Lift Transfer Cask from fuel pool	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
B3	Lower water level in 4 STADs	C	0.5	0.0	45%	0.3	0.5	0.2	0.2
B4	Perform welding of 4 STAD inner lids (all passes)	D	9.3	0.0	47%	5.0	9.3	4.3	4.3
B5	Perform weld NDE for 4 STAD inner lids (all passes)	E	3.2	0.0	33%	2.2	3.2	1.1	1.1
B6	STAD hydrostatic test (all 4)	E	2.0	0.0	25%	1.5	2.0	0.5	0.5
B7	STAD water blowdown (all 4)	C	0.8	0.0	88%	0.1	0.8	0.7	0.7
B8	STAD drying and helium backfill (all 4)	C	18.2	3.1	25%	13.7	15.1	4.6	3.8
B9	STAD leak test (all 4)	E	4.9	0.0	25%	3.7	4.9	1.2	1.2
B10	Weld STAD siphon and vent port covers (all 8)	D	8.0	0.0	25%	6.0	8.0	2.0	2.0
B11	Perform siphon and vent cover He leak tests (all 8)	E	2.4	0.0	100%	0.0	2.4	2.4	2.4
B12	Blowdown Can water level below shielding disk	C	0.5	0.0	100%	0.0	0.5	0.5	0.5
B13	Install Can lid	A	4.0	0.0	100%	0.0	4.0	4.0	4.0
B14	Weld Can lid	D	4.6	0.0	100%	0.0	4.6	4.6	4.6
B15	NDE Can lid weld	E	3.0	0.0	100%	0.0	3.0	3.0	3.0
B16	Dry and backfill Can with helium	C	8.0	0.0	50%	4.0	8.0	4.0	4.0
B17	Can pressure test	E	1.0	0.0	100%	0.0	1.0	1.0	1.0
B18	Install Can siphon and vent port covers	D	4.0	0.0	100%	0.0	4.0	4.0	4.0
B19	Perform Can siphon and vent cover leak test	E	1.2	0.0	100%	0.0	1.2	1.2	1.2
B20	Deflate seal between Can and Transfer Cask	A	0.3	0.0	100%	0.0	0.3	0.3	0.3
B21	Drain water from Can/Transfer Cask annulus	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
B22	Decon Transfer Cask	A	4.1	0.0	100%	0.0	4.1	4.1	4.1
B23	Prepare for the Can to SOC transfer	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
B24	Move Transfer Cask to SOC	A	6.8	0.0	100%	0.0	6.8	6.8	6.8
B25	Load Can into SOC	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
B26	Move Transfer Cask to staging area	A	6.5	0.0	100%	0.0	6.5	6.5	6.5
C1	Install SOC lid	A	2.0	0.0	50%	1.0	2.0	1.0	1.0
C2	Load SOC onto VCT	A	2.0	0.0	50%	1.0	2.0	1.0	1.0
C3	Transport SOC to storage pad	A	7.3	0.0	50%	3.7	7.3	3.7	3.7
			147.9 (6.2d)	3.1 (0.1d)		51.3 (2.1d)	144.8 (6d)	96.6 (4d)	95.8 (4d)

Table 19-8. Small PWR STADs-in-Can

Small PWR STADs-in-Can

Task Location Legend: FHB preparation area; Fuel pool; Cask decon pit; ISFSI

Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing

Step		Task Category Code	Linear Step Time Baseline (hrs)	Technology Improvement (hrs saved)	Percent on Clock (parallel savings)	Time saved per STAD by Parallel Ops (hrs)	Step Time with Tech. Savings Alone (hrs)	Step Time with Parallel Savings Alone (hrs)	Step Time with Tech & Parallel Savings (hrs)
A5	Move VCT & SOC into PCT	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
A6	Move SOC to seismic restraint	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
A7	Remove the SOC lid	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
A8	Remove Can lid	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
A9	Lift Can with STADs from SOC	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A10	Place Can into Transfer Cask	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A11	Remove STAD lids	A	4.0	0.0	100%	0.0	4.0	4.0	4.0
A12	Fill Transfer Cask with deionized water	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A13	Install inflatable seal between Can and Transfer Cask	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A14	Verify water chemistry matches fuel pool	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
A15	Place Transfer Cask into fuel pool	A	2.6	0.0	50%	1.3	2.6	1.3	1.3
A16	Fuel moves	B	6.6	0.0	50%	3.3	6.6	3.3	3.3
A17	Fuel verification	B	0.8	0.0	50%	0.4	0.8	0.4	0.4
B1	Install 4 STAD lids	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
B2	Lift Transfer Cask from fuel pool	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
B3	Lower water level in 4 STADs	C	0.5	0.0	45%	0.3	0.5	0.2	0.2
B4	Perform welding of 4 STAD inner lids (all passes)	D	9.3	0.0	47%	5.0	9.3	4.3	4.3
B5	Perform weld NDE for 4 STAD inner lids (all passes)	E	3.2	0.0	33%	2.2	3.2	1.1	1.1
B6	STAD hydrostatic test (all 4)	E	2.0	0.0	25%	1.5	2.0	0.5	0.5
B7	STAD water blowdown (all 4)	C	0.8	0.0	88%	0.1	0.8	0.7	0.7
B8	STAD drying and helium backfill (all 4)	C	18.2	3.1	25%	13.7	15.1	4.6	3.8
B9	STAD leak test (all 4)	E	4.9	0.0	25%	3.7	4.9	1.2	1.2
B10	Weld STAD siphon and vent port covers (all 8)	D	8.0	0.0	25%	6.0	8.0	2.0	2.0
B11	Perform siphon and vent cover He leak tests (all 8)	E	2.4	0.0	100%	0.0	2.4	2.4	2.4
B12	Blowdown Can water level below shielding disk	C	0.5	0.0	100%	0.0	0.5	0.5	0.5
B13	Install Can lid	A	4.0	0.0	100%	0.0	4.0	4.0	4.0
B14	Weld Can lid	D	4.6	0.0	100%	0.0	4.6	4.6	4.6
B15	NDE Can lid weld	E	3.0	0.0	100%	0.0	3.0	3.0	3.0
B16	Dry and backfill Can with helium	C	8.0	0.0	50%	4.0	8.0	4.0	4.0
B17	Can pressure test	E	1.0	0.0	100%	0.0	1.0	1.0	1.0
B18	Install Can siphon and vent port covers	D	4.0	0.0	100%	0.0	4.0	4.0	4.0
B19	Perform Can siphon and vent cover leak test	E	1.2	0.0	100%	0.0	1.2	1.2	1.2
B20	Deflate seal between Can and Transfer Cask	A	0.3	0.0	100%	0.0	0.3	0.3	0.3
B21	Drain water from Can/Transfer Cask annulus	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
B22	Decon Transfer Cask	A	4.1	0.0	100%	0.0	4.1	4.1	4.1
B23	Prepare for the Can to SOC transfer	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
B24	Move Transfer Cask to SOC	A	6.8	0.0	100%	0.0	6.8	6.8	6.8
B25	Load Can into SOC	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
B26	Move Transfer Cask to staging area	A	6.5	0.0	100%	0.0	6.5	6.5	6.5
C1	Install SOC lid	A	2.0	0.0	50%	1.0	2.0	1.0	1.0
C2	Load SOC onto VCT	A	2.0	0.0	50%	1.0	2.0	1.0	1.0
C3	Transport SOC to storage pad	A	7.3	0.0	50%	3.7	7.3	3.7	3.7
			139.2 (5.8d)	3.1 (0.1d)		47.0 (2d)	136.1 (5.7d)	92.2 (3.8d)	91.5 (3.8d)

Table 19-9. Small BWR STADs-in-Carrier

Step	Task Location Legend: FHB preparation area; Fuel pool; Cask decon pit; ISFSI. Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing	Task Category Code	Linear Step Time Baseline (hrs)	Technology Improvement (hrs saved)	Percent on Clock (parallel savings)	Time saved per STAD by Parallel Ops (hrs)	Step Time with Tech. Savings Alone (hrs)	Step Time with Parallel Savings Alone (hrs)	Step Time with Tech & Parallel Savings (hrs)
A5	Move VCT and SOC into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
A6	Move SOC to seismic restraint	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
A7	Remove the SOC lid	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
A8	Move Carrier with empty STADs from SOC to TC	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
A9	Prepare TC for SFP	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A10	Remove STAD lids	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A11	Fill TC & STADs with deionized water	A	2.2	0.0	100%	0.0	2.2	2.2	2.2
A12	Install inflatable seal between Carrier and TC	A	1.2	0.0	100%	0.0	1.2	1.2	1.2
A13	Verify water chemistry matches fuel pool	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
A14	Place TC into fuel pool	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
A15	Load fuel into STADs	B	13.8	0.0	50%	6.9	13.8	6.9	6.9
A16	Fuel verification	B	2.3	0.0	50%	1.2	2.3	1.2	1.2
B1	Install 4 STAD inner lids	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
B2	Lift TC from fuel pool	A	5.2	0.0	100%	0.0	5.2	5.2	5.2
B3	Move to decon pit and deconTC	A	4.6	0.0	100%	0.0	4.6	4.6	4.6
B4	Deflate seal between Carrier and TC	A	0.3	0.0	100%	0.0	0.3	0.3	0.3
B5	Lower water level in 4 STADs	C	0.5	0.0	45%	0.3	0.5	0.2	0.2
B6	Perform welding of 4 STAD inner lids (all passes)	D	9.3	0.0	47%	5.0	9.3	4.3	4.3
B7	Perform weld NDE for 4 STAD inner lids (all passes)	E	3.2	0.0	33%	2.2	3.2	1.1	1.1
B8	STAD hydrostatic test (all 4)	E	2.0	0.0	25%	1.5	2.0	0.5	0.5
B9	Perform welding of 4 STAD outer lids (all passes)	D	9.3	0.0	47%	5.0	9.3	4.3	4.3
B10	Perform weld NDE for 4 STAD outer lids (all passes)	E	3.2	0.0	33%	2.2	3.2	1.1	1.1
B11	STAD water blowdown (all 4)	C	0.8	0.0	88%	0.1	0.8	0.7	0.7
B12	STAD drying and helium backfill (all 4)	C	18.2	3.1	25%	13.7	15.1	4.6	3.8
B13	STAD leak test (all 4)	E	4.9	0.0	25%	3.7	4.9	1.2	1.2
B14	Weld & test STAD inner siphon and vent port covers (all 8)	D	8.0	0.0	25%	6.0	8.0	2.0	2.0
B15	Perform siphon and vent cover He leak tests (all 8)	E	2.4	0.0	100%	0.0	2.4	2.4	2.4
B16	Drain water from Carrier/TC annulus	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
B17	Prepare for the Carrier to SOC transfer	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
B18	Install transfer adapter on top of SOC	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
B19	Move TC to SOC	A	5.3	0.0	100%	0.0	5.3	5.3	5.3
B20	Install Carrier lift rigging	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
B21	Load Carrier into SOC	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
B22	Move TC to staging area	A	6.5	0.0	100%	0.0	6.5	6.5	6.5
B23	Remove transfer adapter	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
C1	Install SOC lid	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
C2	Check SOC vents	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
C3	Perform fire hazards walkdown	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
C4	Load SOC onto VCT	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
C5	Survey SOC dose rates	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
C6	Transport SOC to storage pad	A	7.5	0.0	50%	3.8	7.5	3.8	3.8
			136.3 (5.7d)	3.1 (0.1d)		53.3 (2.2d)	133.2 (5.6d)	83.1 (3.5d)	82.3 (3.4d)

Table 19-10. Small PWR STADs-in-Carrier

Step	Task Location Legend: FHB preparation area; Fuel pool; Cask decon pit; ISFSI Task Category Legend: A Gen Handling & Prep; B Fuel Movement/Verif; C Drain/Dry/Backfill; D Welding; E NDE/Testing	Task Category Code	Linear Step Time Baseline (hrs)	Technology Improvement (hrs saved)	Percent on Clock (parallel savings)	Time saved per STAD by Parallel Ops (hrs)	Step Time with Tech. Savings Alone (hrs)	Step Time with Parallel Savings Alone (hrs)	Step Time with Tech & Parallel Savings (hrs)
A5	Move VCT and SOC into FHB	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
A6	Move SOC to seismic restraint	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
A7	Remove the SOC lid	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
A8	Move Carrier with empty STADs from SOC to TC	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
A9	Prepare TC for SFP	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A10	Remove STAD lids	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
A11	Fill TC & STADs with deionized water	A	2.2	0.0	100%	0.0	2.2	2.2	2.2
A12	Install inflatable seal between Carrier and TC	A	1.2	0.0	100%	0.0	1.2	1.2	1.2
A13	Verify water chemistry matches fuel pool	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
A14	Place TC into fuel pool	A	2.6	0.0	100%	0.0	2.6	2.6	2.6
A15	Load fuel into STADs	B	6.1	0.0	50%	3.1	6.1	3.1	3.1
A16	Fuel verification	B	1.3	0.0	50%	0.7	1.3	0.7	0.7
B1	Install 4 STAD inner lids	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
B2	Lift TC from fuel pool	A	5.2	0.0	100%	0.0	5.2	5.2	5.2
B3	Move to decon pit and deconTC	A	4.6	0.0	100%	0.0	4.6	4.6	4.6
B4	Deflate seal between Carrier and TC	A	0.3	0.0	100%	0.0	0.3	0.3	0.3
B5	Lower water level in 4 STADs	C	0.5	0.0	45%	0.3	0.5	0.2	0.2
B6	Perform welding of 4 STAD inner lids (all passes)	D	9.3	0.0	47%	5.0	9.3	4.3	4.3
B7	Perform weld NDE for 4 STAD inner lids (all passes)	E	3.2	0.0	33%	2.2	3.2	1.1	1.1
B8	STAD hydrostatic test (all 4)	E	2.0	0.0	25%	1.5	2.0	0.5	0.5
B9	Perform welding of 4 STAD outer lids (all passes)	D	9.3	0.0	47%	5.0	9.3	4.3	4.3
B10	Perform weld NDE for 4 STAD outer lids (all passes)	E	3.2	0.0	33%	2.2	3.2	1.1	1.1
B11	STAD water blowdown (all 4)	C	0.8	0.0	88%	0.1	0.8	0.7	0.7
B12	STAD drying and helium backfill (all 4)	C	18.2	3.1	25%	13.7	15.1	4.6	3.8
B13	STAD leak test (all 4)	E	4.9	0.0	25%	3.7	4.9	1.2	1.2
B14	Weld & test STAD inner siphon and vent port covers (all 8)	D	8.0	0.0	25%	6.0	8.0	2.0	2.0
B15	Perform siphon and vent cover He leak tests (all 8)	E	2.4	0.0	100%	0.0	2.4	2.4	2.4
B16	Drain water from Carrier/TC annulus	C	1.0	0.0	100%	0.0	1.0	1.0	1.0
B17	Prepare for the Carrier to SOC transfer	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
B18	Install transfer adapter on top of SOC	A	1.5	0.0	100%	0.0	1.5	1.5	1.5
B19	Move TC to SOC	A	5.3	0.0	100%	0.0	5.3	5.3	5.3
B20	Install Carrier lift rigging	A	1.5	0.0	50%	0.8	1.5	0.8	0.8
B21	Load Carrier into SOC	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
B22	Move TC to staging area	A	6.5	0.0	100%	0.0	6.5	6.5	6.5
B23	Remove transfer adapter	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
C1	Install SOC lid	A	2.0	0.0	100%	0.0	2.0	2.0	2.0
C2	Check SOC vents	A	0.5	0.0	100%	0.0	0.5	0.5	0.5
C3	Perform fire hazards walkdown	A	1.0	0.0	100%	0.0	1.0	1.0	1.0
C4	Load SOC onto VCT	A	0.5	0.0	50%	0.3	0.5	0.3	0.3
C5	Survey SOC dose rates	A	1.0	0.0	50%	0.5	1.0	0.5	0.5
C6	Transport SOC to storage pad	A	7.5	0.0	50%	3.8	7.5	3.8	3.8
			127.6 (5.3d)	3.1 (0.1d)		48.9 (2d)	124.5 (5.2d)	78.7 (3.3d)	77.9 (3.2d)

20 APPENDIX I – TASK ORDER 21 STATEMENT OF WORK REQUIREMENTS

Using experience designing, licensing, and supplying SNF cask systems to commercial utilities in the U.S., operational experience in loading such casks, and the assumptions and requirements identified in this task order, the contractor shall develop standardized canister design concepts and perform operational studies of innovative approaches, as described below, that will increase DOE's understanding of potential alternatives to using DPCs with the goal of maximizing waste management system flexibility and ease of disposal, while minimizing the utility impacts, potential re-packaging needs, and overall system costs.

1. *The Contractor shall outline operational approaches for, and assess the associated impacts of, moving the required SNF throughput quantities identified below in a standardized canister to an on-site dry storage facility. An emphasis shall be placed on identifying innovative operational approaches that minimize impacts in terms of avoiding or minimizing any impacts to other utility operations as well as minimizing impacts directly attributable to performing the effort (e.g. duration, cost, dose, etc.).*

   Three different capacity standardized canisters for each SNF assembly type (PWR or BWR) shall be considered:
   - *4-, 12-, and 21-PWR assembly capacity canisters; and*
   - *9-, 32-, and 44-BWR assembly capacity canisters.*

   For each canister size (i.e., 4-PWR/9-BWR, 12-PWR/32-BWR, and 21-PWR/44-BWR), the exterior dimensions for the PWR and BWR canisters must be the same. For the 4- and 9-assembly capacity canisters, a "canister-in-canister" approach shall be assessed to reduce in-plant cask handing operations, e.g. using an outer canister containing multiple 4-PWR or 9-BWR canisters. The Contractor shall also make a determination on the number of inner canisters that will minimize impacts to utility operations and implementation.

   The operational approach outlined for each canister option shall include: a description of the standardized canister concept and associated storage system; a description of the set of tasks required to load canisters with SNF and move the required SNF throughput to dry-storage, including a work process flow diagram; the estimated durations for the tasks and worker dose incurred in performing those tasks; a listing of the major equipment items that would be required, and the estimated total cost and cost break-down for moving the required SNF throughput. Cost estimates shall be based on techniques such as material takeoffs, vendor quotations, recent nuclear facility costs, past operational experience, and/or engineering judgment (i.e., for envisioned new equipment or processes). The cost estimates and the associated justification must be sufficiently detailed to allow external review and reproduction. The detailed cost estimates should be included as an appendix in the final report.

For comparison purposes, the operational approaches outlined for the different capacities of standardized canisters shall be compared with the same set of information (described in the paragraphs above) for DPCs at or close to the largest capacities being used in industry today. Comparisons should be based on packaging an equivalent amount of spent nuclear fuel with like characteristics.

This effort to outline the operational approaches for the standardized canister capacities shall initially focus on the following two cases (one for a PWR and one for a BWR) that assume the utility site has a single reactor having an 18-month operating cycle. The work on these initial cases should be presented at the initial and second progress review meetings. Additional cases for evaluation by the Contractor are discussed below under Item 3.

2. *In performing the work under this task order, the Contractor shall take into account two primary constraints: 1) the minimum number of SNF assemblies to be moved (i.e., the required SNF throughput); and 2) the maximum amount of calendar time available between refueling outages for dry cask storage activities as indicated below:*

    - *Required SNF throughputs values are as follows for each reactor type:*
        - *Each BWR reactor must move at least 900 SNF assemblies to dry storage over a recurring six-year period.*
        - *Each PWR reactor must move at least 370 SNF assemblies to dry storage over a recurring six-year period.*
    - *A maximum of 12 continuous weeks should be assumed to mobilize, perform a cask loading campaign, and demobilize. Mobilization and demobilization that occurs outside of the power plant (even if elsewhere on site) does not need to fit into the 12-week window. A maximum frequency of one campaign per calendar year should be assumed.*

    From projected domestic operating nuclear power plant spent fuel discharges, bounding values of 900 BWR and 370 PWR SNF assemblies were chosen as the amount of SNF that must be moved from wet to dry storage at each reactor over recurring six year periods to maintain the status quo in the spent fuel pool. A six-year recurring period is chosen because it is a common whole-number multiple for 18-month and 24-month operating cycles. Some reactors permanently discharge more fuel than others each refueling outage due to cycle length or other variables. Other variables that could cause differences in actual discharges are power uprates, operating cycle length changes and capacity factor. The 900BWR/370PWR values are considered reasonable for use in this study based on actual nationwide projected discharge data at this time.

3. *The Contractor shall perform a parametric study to assess how the operational approaches identified under Item 1 above, including associated characteristics*

(durations, worker dose, cost, etc.), are expected to vary as a function of the number of reactors at a given site, the type of reactors at the site, and the reactor cycle length for the cases indicated in the table below. All reactors on a given site may be assumed to be of the same reactor type and have the same operating cycle length.

CASE	***REACTOR TYPE***	***NUMBER OF REACTORS ON SITE***	***OPERATING CYCLE LENGTH (months)***
*1**	*BWR*	*1*	*18*
2	*BWR*	*1*	*24*
3	*BWR*	*2*	*24*
4	*BWR*	*3*	*24*
*5**	*PWR*	*1*	*18*
6	*PWR*	*1*	*24*
7	*PWR*	*2*	*18*
8	*PWR*	*2*	*24*
9	*PWR*	*3*	*18*

**Case 1 and Case 5 are the two initial cases mentioned in Item 1 above.*

Again, innovative operational approaches for achieving the required SNF throughput and minimizing impacts shall be considered when analyzing these cases. Canister loading campaigns should only take place during times when all reactors on the site are scheduled to be operating to minimize impacts to utility operations.

Typical facility constraints (e.g. shared spent fuel pools or shared lifting equipment for cases with multiple reactors at a site) should be identified by the Contractor based on experience and knowledge of typical conditions in the field. The facility constraints assumed in the development and analysis of innovative operational approaches which achieve the required SNF throughput while minimizing impacts are to be identified and justified for each case evaluated.

A recommendation for the optimum frequency for canister loading campaigns should be determined for each case identified in the table above. For example, multi-reactor sites may require annual canister loading campaigns just to keep up with the required dry storage throughput, but single-reactor sites may be able to maintain the required throughput with biennial or triennial loading campaigns to save on mobilization and demobilization costs.

In addition to those parameters in Items 1 and 2 (e.g., canister capacity, cycle length, etc.), the Contractor shall identify and assess the influence of any other parameters or constraints the Contractor believes to have an important influence on the operational approach proposed for achieving the required SNF throughput.

6. *In considering innovative approaches, the Contractor shall assess potential benefits and issues of using canister concepts in which welding can be avoided or deferred until later when it is not on critical path, e.g. some time prior to downstream transport or disposal. As part of this assessment, the Contractor shall consider canister-in-canister systems for which the inner and/or outer canisters may be non-welded concepts, at least initially. For welded canister concepts, the Contractor shall also consider available automatic (robotic) or semiautomatic equipment. Other innovative canister design features may be considered, however there should be reasonable assurance that each design concept has the capability to meet fundamental licensing requirements for both storage under 10 CFR 72 and transportation under 10 CFR 71. Disposal compatibility and licensing requirements related to disposal may be ignored for this task order.*

7. *The focus of this task order is on the operational requirements involved in loading standardized canisters and moving the required SNF throughput into dry storage in a manner that minimizes impacts to utilities. In developing outlines for innovative operational approaches, some conceptual engineering effort will be required. Engineering sketches, and outline specifications shall be developed, as required, to depict structures, systems, and components which support the proposed innovative operational approaches.*

   Although this effort is not focused on standardized canister design details, key assumptions regarding the canister design and configuration made to support the study shall be provided. Sketches shall also be provided to visualize the general designs/outlines for the following:

   - *Standardized canisters for those capacities and configurations assessed in the study as described in Item 1 above, including the canister-in-canister configurations assessed.*
   - *Associated ancillary equipment to support throughput objectives*
   - *Associated storage cask concepts*
   - *Associated transfer cask concepts to move canisters to their storage location*
   - *Associated transportation cask concepts to move canisters off-site.*

8. *Assumptions: This task order is intended to encourage the successful bidder(s) to think innovatively in terms of canister design and configuration, processes, equipment, and use of personnel to achieve the goal of meeting the required SNF throughput while minimizing impacts to utility operations and required resources. It is recognized that using smaller-capacity and smaller-sized standardized canisters to move fuel into dry storage will likely be more expensive on a per-assembly basis for the storage portion of the integrated waste management system as compared to use of conventional DPCs and canister loading processes. To achieve the required SNF throughput and/or allow innovation subject to certain constraints, the following assumptions should be used in performing the scope of work as described in this section:*

   - *There is no limit on the number of personnel available, loading operations may run up to 24 hours per day, seven days per week. This includes loading personnel and all support services such as health physics, security, chemistry, etc. Relative cost estimates developed under this task order for the different cases examined should take into account personnel costs, including those which may be incurred in complying with the fatigue rule, though operational approaches identified should seek to minimize these costs and other impacts.*

   - *Nuclear power plants have a cask crane capacity of 125 tons and a standard crane sister hook. The crane and all load lifting attachments and below-the-hook lifting devices may be assumed to meet the requirements of NUREG 0612, Section 5.1.6 for single-failure-proof lifting systems. The number of crane picks is a key area of utility concern. Crane and truck or rail bay time is at a premium. Due consideration should be given to minimizing additional crane picks, but the number of crane picks should not be considered a constraint to standardized canister design concepts.*

   - *Higher relative worker dose on a per assembly basis incurred in using standardized canisters having smaller capacities compared to DPCs should not be considered a limitation in developing innovative operational approaches and design concepts because worker dose avoided by not having to re-package DPCs later may more than balance this out. Standardized canister design and processing concepts must, however, keep the concept of ALARA in mind and provide reasonable assurance that users will be able to comply with the personnel dose limits in 10 CFR Part 20.*

   - *Although a detailed analysis supporting canister design concepts is not required for this task order, the Contractor should document and justify key supporting assumptions used in their evaluation of innovative operational approaches including those assumptions used in developing estimates of worker dose rates.*

21 APPENDIX J – INVESTIGATION OF WELDING AND NON-DESTRUCTIVE EXAMINATION PROCESSES AND TECHNOLOGIES

A study has been performed by welding experts within the Team, which has focused on three areas: welding processes, non-destructive examination (NDE) and welding multiple small STAD canisters in parallel. Before addressing these three items, it should be noted that the Team was asked during the Initial Progress Review meeting to look at the potential for additive technology (a technology similar to 3D printing) to be used in the future for welding the lids on spent fuel canisters, noting that any method used to weld/seal the SNF canisters has to use a process approved by the code of record/fabrication code. Currently, these processes are limited to the following: shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), gas tungsten arc welding (GTAW), submerged arc welding (SAW), plasma arc welding (PAW), electron beam welding (EBW), or laser. The key to a successful welding process that can weld the lids on SNF canisters is that it must meet all code requirements, provide a seal with a material as strong as the base materials and be capable of being repaired. In reviewing web-based and technology journals, 3D printing and additive manufacturing technologies exist and a March 2010 article in the Institution of Engineering and Technology magazine[16] described a welding technique discovered by researchers at Cranfield University who were working on Ready-to-use Additive Manufacturing (RUAM), a technology that aims to improve industry's ability to manufacture high precision functional parts for a range of applications from small turbine blade repairs to making large aerospace structures. The RUAM project involves integrating additive manufacturing and multi-axis precision grinding into a single machine tool. The RUAM process is capable of producing a range of geometries and features to fit various demands. It uses innovative additive layer welding techniques such as cold metal transfer (CMT), which allows for flexible welding strategies at high speeds - deposition rates of more than 1kg/hour are currently possible. The successive process allows strategies and materials to be mixed, and permits existing metal work pieces to be amended. It was also noted that the American Society of Mechanical Engineers (ASME) is holding for the first time a conference on Additive Manufacturing and 3D Printing in August 2015. It can be concluded that additive technology is a growth area, which is worth evaluating for future SNF STAD canister closure methods should the need for higher speed welding processes arise.

21.1 WELDING PROCESSES

Eleven welding processes have been evaluated for use in welding the lids on STAD canisters and the results are summarized in Table 21-1 and described in detail below.

[16] http://eandt.theiet.org/news/2010/march/new-welding-technique.cfm#.VM6ivAdVG0g.email

Table 21-1. Evaluation of Welding Processes for STAD Canisters.

Welding process	Acronym	Can it be automated	Work in RAD zone	Ease of cleaning weld	Ease to add filler material	Code accepted	Simplicity of process (Less equipment to break)	Ease of weld repair using the same welding process
SMAW	Shielded Metal Arc (Stick)	NO	Yes	Hard	Easy	Yes	Simple	Can do
GMAW	Gas Metal Arc (MIG)	Yes	Yes	Easy	Easy	Yes	Above medium	Can do
FCAW	Flux Core Arc	Yes	Yes	Hard	Easy	Yes	Above medium	Can do
SAW	Submerged Arc (subarc)	Yes	Yes	Hard	Easy	Yes	Above medium	Can do
GTAW	Gas Tungsten (TIG)	Yes	Yes	Easy	Easy	Yes	Medium	Can do
PAW	Plasma Arc	Yes	Yes	Easy	Easy	Yes	Above medium	Can do
EBW	Electron Beam	Yes	Yes	Easy	Hard	Yes	Highly complicated	Can not do
Laser		Yes	Yes	Easy	Hard	Yes	Highly complicated	Can not do
FSW	Friction Stir	Yes	Yes	Easy	Hard	NO	Highly complicated	Can not do
ESW	Electroslag	Yes	Yes	Hard	Easy	NO	Highly complicated	Can not do
EGW	Electrogas	Yes	Yes	Easy	Easy	NO	Highly complicated	Can not do

Key

Reason (s) to disallow

Chosen process to perform the closure welds

1. **SMAW (shielded metal arc welding)** is a manual welding process that is not easily automated. The process is basically not appropriate for this application. It also leaves a Flux residue (slag) that that does not lead to easily cleaning in a radiation area. The slag would then be an additional waste stream in a radiation area. These reasons are why the process was rejected as a candidate for performing the closure welds on the STAD canisters.

2. **GMAW (gas metal arc welding)** can be automated for this application very easily. This process can produce welds of high quality and reasonably high deposition rates. The process can perform weld repairs. The overall quality of the welds would not be as high as plasma arc or gas tungsten arc welding and the process is a little more problematic to operate than gas tungsten arc welding. These reasons are why the process was rejected as a candidate for performing the closure welds on the STAD canisters.

3. **FCAW (flux cored arc welding)** is an automatic or semiautomatic welding process that is very easily automated. The process is basically not appropriate for this application. This process also leaves a flux residue that is not easily cleaned in a radiation area. The slag would then be an additional waste stream in a radiation area. This reason is why the process was rejected as a candidate for performing the closure welds on the STAD canisters.

4. **SAW (submerged arc welding)** is an automatic or semiautomatic high deposition welding process that is very easily automated. The process is basically not appropriate for this application. This process also leaves a flux residue that is not easily cleaned in a Radiation area. The slag and unfused flux would then be an additional waste stream in a radiation

area. These reasons are why the process was rejected as a candidate for performing the closure welds on the STAD canisters.

5. **GTAW (gas tungsten arc welding)** can be easily automated for these kinds of welds. This is the most commonly used welding process for RAD closure welding. It is a proven process that has been automated for almost 40 years. The process produces very consistent high quality welds that are capable of passing a RT or UT examination. The process can increase the deposition rates by adding a hot wire addition (where the wire is at an elevated temperature). The process can perform weld repairs. The ability to be used in the repair cycle should not be downplayed. The ability to machine out and repair the defective weld/area is of key importance. There are numerous companies that make very high quality reliable machines. There would need to be a very good reason to use a process other than this one for STAD canister closure welds, which is what the industry is currently using.

6. **PAW (plasma arc welding)** can be easily automated for this application. The process produces very consistent high quality welds that are capable of passing a Radiography Testing (RT) or Ultrasonic Testing (UT) examination. This process has all of the same advantages as GTAW but has a few negatives. The equipment is slightly more expensive and a little more problematic with exact setups and alignment issues. It is not as forgiving to a slightly compromised setup as GTAW. The process can perform weld repairs. This process usually has very narrow or even square butt grooves. The process would not be as accommodating for repairs in wider grooves that were excavated to remove the defect. PAW can perform weld repairs but is not as robust and compliant to all different sizes and shapes of excavations. PAW is a close second to GTAW but it is probably better to follow what the welding industry uses historically on closure welds for casks. These reasons are why the process was rejected as a candidate for performing the closure welds on the STAD canisters.

7. **EBW (electron beam welding)** is an automated welding process that is normally welded in a vacuum. The equipment is highly complicated and does not lend itself to short term outage setups. The process does not lend itself to this configuration and size. The process also does not lend itself to adding filler material (the process is usually autogenous) and as such does not lend itself to doing repairs. These reasons are why the process was rejected as a candidate for performing the closure welds on the STAD canisters.

8. **Laser welding** utilizes highly complicated equipment and does not lend itself to short term outage setups. The process also does not lend itself to adding filler material (the process is usually autogenous) and as such does not lend itself to doing repairs. These reasons are why the process was rejected as a candidate for performing the closure welds on the STAD canisters.

9. **FSW (friction stir welding)** is an automated welding process. The process was just added to ASME B & PV Code Section IX in 2013, but was not referenced anywhere in Section III Div 3 2013 edition. The process also does not lend itself to adding filler material (the process is usually autogenous) and as such does not lend itself to doing repairs. These reasons are why the process was rejected as a candidate for performing the closure welds on the STAD canisters.
10. **ESW (electroslag welding)** is an automated very high deposition process that only can be operated in the vertical position. The process is basically not appropriate for this application. This process also leaves a flux residue that is not easily cleaned in a radiation zone. The slag would then be an additional waste stream in a radiation zone. The process is not allowed per ASME B& PV Code Sect III Div. 3 WB4311 (a) and (b). These reasons are why the process was rejected as a candidate for performing the closure welds on the STAD canisters.
11. **EGW (electrogas welding)** is an automated very high deposition process that only can be operated in the vertical position. The process is basically not appropriate for this application. The process is not allowed per ASME B& PV Code Sect III Div. 3 WB4311 (a) and (b). These reasons are why the process was rejected as a candidate for performing the closure welds on the STAD canisters.

At the present time, there are not enough advantages in other processes to consider anything other than GTAW. This process has a proven track record in the nuclear arena. It is very forgiving, provides welds that are capable of passing any NDE that is required and can repair all shapes of repair areas. There are numerous manufacturers of automated GTAW machines for closure welds on radiation containers and some notable ones include Astro Arc Polysoude (used at the West Valley site for welding high level waste canisters), Liburdi Dimetrics (providing systems for welding low active and high level vitrified waste canisters at the Waste Treatment Plant (WTP), Hanford Site) and Arc Machines (system used to weld DPCs at the Zion Nuclear Power Station).

In addition to the welding process, the reviewer considered other aspects of the welding performed on the STAD canisters, which can achieve faster weld times.

- Optimize the welding parameters for maximizing the weld deposition. Do not let the Welding Procedure Specifications (WPSs) have a wide range for the welders to decide the weld parameters, bead sizes, and how many passes. This should be done in the development stage to maximize deposition and minimize weld beads and total welding time.

- Consider hot wire GTAW[17], noting the deposition rates below, which are taken from the
  - An automatic GTAW cold wire can deposit 1 to 4 lbs/hr
  - An automatic GTAW hot wire can deposit 4 to 18 lbs/hr
- Optimize the weld design, in order to minimize the amount of welding time. As described in Section 4.1.1, and with the goal of minimizing welding time, the small STAD canisters have been designed to have the inner and outer lids welded using only ¼" partial penetration groove welds. In addition, the vent and syphon ports are welded using port covers ("silver dollars") and the outer lid welded onto the canister provides the redundant closure for both the inner lid and the port cover, thus, obviating the need to install and weld outer covers over the port covers.
  Regarding weld thicknesses, it must be noted that the thickness of each weld pass/layer can be no larger than the critical flaw size which is approx. 1/8". The critical flaw size is defined in the ASME B&PV Code, Section 11. If welds are deposited that have a thickness larger than the critical flaw size it is necessary to RT the final weld in lieu of the PT for each weld pass. When PT is used on each layer it assures that there will be no flaws larger than the critical flaw size. Thus, even for the ¼" welds used on the small STAD canisters, it will be necessary to perform the welds in 2 passes.

21.2 NON-DESTRUCTIVE EXAMINATION

Three different aspects of the non-destructive examination (NDE) of the welds have been evaluated: Remote NDE, different NDE processes and automatic NDE.

1. **Remote NDE** – Zion*Solutions* tried this technique during the early stages of DPC loading at the shutdown Zion Nuclear Power Plan with the intent of reducing worker doses. However, the measured dose rates with manual NDE were lower than originally estimated and due to equipment challenges (e.g. dye penetrant delivery), which were leading to the need for research and development, Zion*Solutions* reverted back to a manual PT setup. It was also noted at the time of switching back to the manual PT process that the remote NDE process was not looking to be a significant time saver. The remote NDE system used a solvent washable dye penetrant (same as the manual PT) testing setup, noting that removal of the penetrant is usually a very operator dependent task. It is very hard to mimic the hand pressure or extra effort taken in a small area that cannot be duplicated with a machine. The machine needs to remove enough penetrant but not remove all evidence of the penetrant. There needs to be a very small pink haze left on the surface being tested after the penetrant is removed. This pink haze shows that "all" penetrant is not removed but enough is removed to perform a meaningful test.

[17] American Welding Society Welding Handbook Volume 2, 8th edition, page 83

2. **Different NDE Processes** - Automated UT (Phase Array) has been used in the past (Palisades Nuclear Power Station, Covert, Michigan) on SNF canisters and did provide satisfactory results. It was used on a couple canisters that had welds with questionable quality and has not been used since. In the opinion of the reviewer, if the plan is to perform any volumetric examinations (RT or UT), then due to the challenge of repairing welds in a radiation area and with such restrictions as foreign material exclusion, it is recommended that a progressive PT be performed on each layer to give more assurance of passing the final volumetric examination. This is a very common examination practice on pressure vessels to minimize rework on a deep weld after it is finished. However, if the progressive PTs are performed then there is almost no reason to do the UT. If only the PT exams are performed then the efficiency of the welds is either 80% or 90%. Adding a UT or RT examination would raise the efficiency to 100%. If the design of the canister weld is robust enough to not require 100% then the use of a volumetric exam is not recommended; again because of the schedule impact of having to perform weld repairs in a radiation area.
   In response to a question at the 90% Task Completion Review meeting on the feasibility of using UT to inspect each 1/8" weld pass/layer, rather than PT, V.J. Technologies (VJT) was contacted, who are a company whose services include weld inspection systems. The VJT expert on the use of UT for weld inspection advised that he was not experienced in the use of UT in a partially completed weld and did not believe that it would be successful. With only a single pass to establish the root weld and the remaining groove un-filled, he was concerned that the reflections off the open edges in the weld grove will interfere with the signal from the weld root. He also advised that there may be state of the art UT techniques which make this configuration work, but this would require an investigation to be completed and mock-up testing to confirm the validity of the technique.
3. **Automatic NDE** - Automatic PT exams are common in factories with assembly lines or batch runs of large quantities of parts and typically use a water washable dye penetrant. This is not a common practice for deep groove welds.

Based on the above evaluations, and for the purpose of the time and motion analyses, a manual PT process is recommended to be used.

21.3 WELDING MULTIPLE SMALL STAD CANISTERS IN PARALLEL

Considering the configuration of four small STAD canisters in a carrier, the feasibility of a welding system that would allow all four canisters to be welded in parallel was investigated. Discussions have been held with Liburdi Automation who are the suppliers for the WTP welding systems about welding with multiple welders at the same time and the response was that this was feasible with the proper welding equipment and parameter development, including the development of hardware and software controls such as interlocking the positions of the weld torches and the taking of parameter samples. All of the power supplies going to one common ground is also not a concern and a separate welding operator would run each of the welders. Liburdi Automation has advised that in their line of work it is quite common to run multiple weld heads on the same component, or even the same joint. This is done typically to improve productivity or to control distortion. Figure 21-1, below, shows a photograph of a reactor nozzle mock-up, which required structural weld overlay and the deposition of several hundred pounds of weld wire. To accomplish this, two welding heads were working simultaneously on the same nozzle. Another example is a boiler tube replacement. A typical header will have several hundred tubes that will be welded to it and during an outage it is common to have as many as six weld heads welding tubes to the header at the same time.

Figure 21-1. Photograph of a Reactor Nozzle Mock-up (Courtesy of Liburdi Automation).

Budgetary information on the required welding development for a system to weld four STAD canisters in a carrier, simultaneously, was obtained from Liburdi Automation and is described below.

Welding Development Program

Liburdi Automation recommended Hot Wire (HW) GTAW for this weld and would run the development program using their Gold Track VI HW and H Head. A breakdown of the tasks and expenses are provided below.

1. Welding one canister at a time = $123,420 (without any contingency)
   a. Nominal weld joint parameter development: $34,860
      i. The work would be done on straight coupons representative of upper and lower joints.
      ii. Price includes weld development, coupon design, test cell/equipment setup and equipment rental (rental covers all phases of the project), plus

- 8 coupons are assumed
- Liquid Penetrant Inspection (LPI) and metallography
- Engineering report

b. Testing of parameters on varying root gaps to establish acceptable range: $33,480

i. The work would be done on straight coupons representative of upper and lower joint

ii. Price includes weld development, coupon design, test cell/equipment setup and equipment rental (rental covers all phases of the project), plus

- 8 coupons are assumed
- LPI and metallography
- Engineering report

c. Full scale mock-up welding $30,080

i. Price includes mock-up design, test cell/equipment setup for round weld (using LAWS 4000), plus

- two 29" coupons are estimated and included in the price at $7200 each, one for verification of parameters and one for customer demo
- LPI and metallography
- Engineering report

ii. Procedure Qualification Record (PQR) /Welding Procedure Specification $25,000

- Includes development, materials, setup, mechanical engineering, etc.
- PQR is filled out on customer's template and becomes the customer's property.

2. Welding two canisters at a time – add additional $60,940 to cost of welding one canister at a time, which equals $184,360 (without any contingency applied).

3. Welding four canisters at a time – add additional $109, 520 to cost of welding one canister at a time, which equals $232,940 (without any contingency applied).

4. Estimated schedule for the work is 4 months (without any contingency applied).

22 APPENDIX K – RESIDUAL MOISTURE REMOVAL METHODS

Processing of a STAD Canister will include the following licensed activities:

- Bulk Water Removal (completed by using a pump and/or blowdown using an inert gas)
- Residual Moisture Removal (completed by either Vacuum Drying or Forced Helium Dehydration)
- Backfilling (using Helium)

The end state is the STAD is ultimately dry and inerted to ensure no deleterious conditions are present within the STAD that could result in a degradation of the fuel cladding during storage. Due to concerns identified with potential rod-splitting of used fuel rods if exposed to an oxidizing environment, the Spent Fuel Project Office of the NRC issued Interim Staff Guidance (ISG) – 22 [1]. This ISG states (in part) that:

Once the fuel rods are placed inside of the storage cask and water is removed to a level that exposes any part of the rods to a gaseous atmosphere, reasonable assurance that the spent fuel cladding will be protected against splitting due to fuel oxidation that might occur must be demonstrated. If oxidation occurred, it may lead to loss of retrievability, or to a configuration not adequately analyzed for radiation dose rates or criticality. Further, the release of fuel fines or grain-sized powder into the inner cask environment from ruptured fuel may be a condition outside the licensing basis for the cask system.

This limitation has a direct impact on the means used to perform the Bulk Water removal process as outlined above. Operators have adopted the practice of maintaining the fuel rods in an appropriate environment such as nitrogen or helium to prevent oxidation during the pumpdown/blowdown of the canister. Preferred practice is to continue the blowdown of the canister until the effluent is free of major slugs of bulk water. This helps to minimize the presence of bulk water within the canister that must then be removed by the residual moisture removal process.

Early industry experience (circa 1983) to remove residual moisture from within the canister to acceptable levels included Vacuum Drying and Purge Drying type operations. It was noted that Vacuum Drying appeared to be the more effective method of the two methods examined/used at the time. [2]

In an effort to ensure that the presence of any oxidizing gasses within the canister environment are minimized, the NRC formally captured this philosophy within the Standard Review Plan (SRP) process used to determine the acceptability of a Dry Cask Storage System [3]. Specifically, within this review plan it states that:

"The NRC staff has accepted vacuum drying methods comparable to those recommended in PNL-6365 (Knoll, 1987)… If alternative methods other than vacuum drying are used (such as forced helium recirculation), the reviewer should ensure that additional analyses or tests are provided to sufficiently justify that cover gas moisture and impurity levels as specified in Chapter 9, "Operating Procedures Evaluation" of the SAR are met and will not result in unacceptable cladding degradation."

The purpose and content of the report [4] cited in the NRC SRP is to evaluate the sources for impurity gases within the Dry Cask Storage System, the expected concentrations and if the expected concentration is detrimental to the cladding or exposed fuel within the canister. At the time of this report, only the Vacuum Drying process of residual moisture removal was considered. The report concludes that:

"Conservatively using the higher [evacuation] pressure of 4x10 MPa [3 torr], the residual gas remaining in the 7m3 cask volume amounts to about 1.2 mol. However, reactive gases will comprise only a fraction of this residual gas, especially if the cask was purged with inert gas or was evacuated and backfilled more than once. This was verified by the gas composition measurements obtained during cask performance testing (Table 2), which showed that the actual reactive gas concentrations were below 0.2 vol%, corresponding to 0.6 mol reactive gas in the 7m3 cask volume."

As noted in the NRC SRP *"if alternative methods other than vacuum drying are used (such as forced helium recirculation [18]), the reviewer should ensure that additional analyses or tests are provided to sufficiently justify that cover gas moisture and impurity levels as specified in Chapter 9, "Operating Procedures Evaluation" of the SAR are met and will not result in unacceptable cladding degradation."*

Canister Certificate applications that are submitted for NRC approval do **not** have to meet the requirements as set forth in the SRP. However, it is generally understood that if the application meets the SRP content and requirements the review time will likely be limited and the requests for additional information to address NRC reviewer questions/concerns will be fewer in nature than those applications that are not submitted in accordance with the guidelines as stipulated in the SRP.

Regardless, the approved Certificate must meet current 10 CFR72 [5] requirements. These requirements include:

[18] Current NRC approved Forced Helium Recirculation method is a commercially patented process. The system is a closed loop skid mounted system including a blower, filters, heat exchanger, electric heater and associated instrumentation circulates heated Helium (up to 450 degrees F) and removes residual moisture by 'freezing' the residual moisture out of the Helium stream.

72.44 License Conditions

(a) Each license issued under this part shall include license conditions. The license conditions may be derived from the analyses and evaluations included in the Safety Analysis Report and amendments thereto submitted pursuant to § 72.24. License conditions pertain to design, construction and operation. The Commission may also include additional license conditions as it finds appropriate.

(c) Each license issued under this part must include technical specifications. Technical specifications must include requirements in the following categories:

(1) Functional and operating limits and monitoring instruments and limiting control settings.

(i) Functional and operating limits for an ISFSI or MRS are limits on fuel or waste handling and storage conditions that are found to be necessary to protect the integrity of the stored fuel or waste container, to protect employees against occupational exposures and to guard against the uncontrolled release of radioactive materials; and

(ii) Monitoring instruments and limiting control settings for an ISFSI or MRS are those related to fuel or waste handling and storage conditions having significant safety functions.

72.120 General Considerations

(d) The ISFSI or MRS must be designed, made of materials, and constructed to ensure that there will be no significant chemical, galvanic, or other reactions between or among the storage system components, spent fuel, reactor-related GTCC waste, and/or high level waste including possible reaction with water during wet loading and unloading operations or during storage in a water-pool type ISFSI or MRS. The behavior of materials under irradiation and thermal conditions must be taken into account.

72.122 Overall requirements

(h) Confinement barriers and systems. *(1) The spent fuel cladding must be protected during storage against degradation that leads to gross ruptures or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. This may be accomplished by canning of consolidated fuel rods or unconsolidated assemblies or other means as appropriate.*

(l) Retrievability. 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.

72.166 Handling, storage, and shipping control

The licensee, applicant for a license, certificate holder, and applicant for a CoC shall establish measures to control, in accordance with work and inspection instructions, the handling, storage, shipping, cleaning, and preservation of materials and equipment to prevent damage or *deterioration. When necessary for particular products, special protective environments, such as inert gas atmosphere, and specific moisture content and temperature levels must be specified and provided.*

72.236 Specific requirements for spent fuel storage cask approval and fabrication

(m) To the extent practicable in the design of spent fuel storage casks, consideration should be given to compatibility with removal of the stored spent fuel from a reactor site, transportation, and ultimate disposition by the Department of Energy.

As can be seen from the above information, it is apparent that the NRC- approved certificate for a used fuel canister must include technical specifications that stipulate threshold values for contents that limit the degradation of the fuel cladding to ensure retrievability. Additionally, there can be no significant reactions between or among the fuel and storage system components.

In the area of canister moisture content, current NRC- approved certificates contain either:

- Evacuation of the canister to a pre-determined absolute pressure and a subsequent drop test for some finite duration, or-
- Circulation of helium through the canister until the helium moisture content of the gas exiting the canister is maintained at or below a dew point of 22.9°F for at least 30 minutes.

The atmosphere within the STAD must be dry and free of oxidizing contaminants to ensure no deleterious effects occur that could jeopardize the integrity of the fuel cladding that would challenge the retrievability of the fuel. Based on the results of the PNL report cited in the SRP, the presence of residual moisture to extremely low levels (0.6 mol reactive gas in the 7m3 cask volume) is achieved by nearly complete evacuation of the STAD together with using Ultra-High Purity Helium to ensure that the presence of oxidizing gases to interact with the fuel claddi ng is minimized [4]. Other residual moisture removal methods should strive to ensure that the same ultra-pure environment within the STAD is achieved, or otherwise evaluated for acceptability.

Notwithstanding these requirements, alternate means for residual moisture removal from the canister environment could be examined and submitted to the NRC for approval. Such alternate means could include:

- Adapting one of the processes used to dry natural gas to dry a STAD [6]
  - The approach used to drying of natural gas could be used with helium for canister drying with the following process). Absorption of H2O in the gas by exposure to TEG in a glycol contactor (tray column or packed bed) by countercurrent flow of wet gas (20-35°C) and TEG. TEG is enriched (by H2O) and

flows out in the bottom of contactor, then runs through a flash depressurizer and heat exchanger into re-boiler. In the reboiler the H2O is boiled out. Temperature inside should not exceed 208°C (406°F) due to decomposition temperature of TEG. Regenerated (lean) TEG is then recycled back through heat exchanger and additional cooling unit back into the top of contactor.

- Absorption of H2O by solid desiccants, most often by mole sieve, silica gel or alumina. As a minimum, two beds are used. Typically one bed is drying gas and the other is being regenerated.
- Expansion of natural gas which causes the *Joule – Thomson* effect. The wet natural gas under pressure is throttled and expanded into flash tanks and as the consequence of the pressure decrease the temperature decreases. The lower temperature of the gas stream leads to partial condensation of H2O vapors. Created droplets are removed from the gas stream by a demister inside the flash. Essential part of the system is injection of hydrate inhibitors (MEG). This prevents hydrate formation and thus plugging. In cases where there is insufficient pressure difference between the underground gas storage (UGS) and distribution network available, an additional external cooler is required

ADVANTAGES: Minimal operating extremes from a process standpoint. Minimal thermal impact on High Burnup (HBU) fuel cladding.

DISADVANTAGES: Reviewer questions would almost certainly include material/chemical compatibility with the fuel cladding, exposed fuel and canister materials, which is required in the SRP. Material compatibility evaluations conducted for chemical used may prove unsuitable for use in this application.

It is noted that an inadequate review of material compatibility resulted in a hydrogen ignition event within a Canister during the welding process in May, 1996 [7]. This resulted in issuance of NRC Bulletin regarding chemical interactions in July, 1996 [8].

- Adapt Purge Gas Drying Technology [9].
  - Although the initial drying efforts used in the early 80's indicate that Vacuum Drying was faster than Purge Drying [2], re-evaluation may be warranted. The ultra-dry nitrogen purge drying process is used in the Laser Manufacturing Industry today where ultra-dry nitrogen with a dew point of -70 degrees Celsius (-94 degrees Fahrenheit) is introduced under pressure into an enclosure or cavity to remove moisture and create a much drier internal environment than standard desiccant can. This drying method appears to provide positive results. Several models (portable, rackmounted) of nitrogen enhanced purging systems (NEPS)

appear to be available off-the-shelf [9]. With the NEPS unit, ultra-dry gas (typically nitrogen) enters the cavity or enclosure through a single port and is pressurized to a pre-determined PSI before a valve opens and the gas backflows back into the unit. There it passes a dew point monitor and displays the current dew-point temperature. The nitrogen is then vented to the atmosphere and a new cycle commences. This cycling continues until the equipment reaches the required dew-point level, at which point it automatically shuts off.

ADVANTAGES: Provides means for heat removal as compared to vacuum drying process.

DISADVANTAGES: May actually take longer than current vacuum drying processes.

- Review and adapt Helium Purification Systems that were designed for use on Gas Cooled Reactors [10]
  - Gas Cooled Reactors that use helium coolants employ a purification system that uses reactor helium recirculating fan differential pressure as the motive force. The anticipated major non-radioactive, gaseous contaminants (H2O, CO2, H2, CO, and CH4) were recognized as being deleterious to both materials and fuel. A two-step purification system for removal of these contaminants was proposed in which first all oxidizable gases are oxidized to H2O and CO2 and then the H2O and CO2 are removed from the helium by fixed bed co-sorption [10]. This type of system could be scaled to the total volume capacity required for the STAD and made as a portable skid-based system for use.

ADVANTAGES: Means to eliminate all contaminants without undue thermal impact on fuel.

DISADVANTAGES: Reviewer questions would almost certainly include material/chemical compatibility with the fuel cladding, exposed fuel and canister materials, which is required in the SRP. Material compatibility evaluations conducted for chemical used may prove unsuitable for use in this application.

SUMMARY

It must be recognized by the reader that the removal of residual moisture from within the STAD will be one of two specific activities (seal welding being the other) that are not predicated by site specific attributes. The STAD seal weld design (linear length of seal weld and weld groove design) will result in a repeatable, definable duration of weld filler material installation when using the same welding system. The duration of residual moisture removal efforts may also be consistently achieved provided that the drying method and equipment used to facilitate the residual moisture removal process is used with the STAD canister design and the fuel it contains.

Regardless of the above, enhancements in these two time dependent processes both have a point of diminishing returns within a typical unit loading sequence. When viewing the entire unit activity (i.e. the loading process of one STAD system around the clock with no limitation on resources and complete equipment fidelity) qualitatively, it is reasonable to expect a duration of no more than 6 days (based on MAGNASTOR Loading Duration at ZION). Of this duration (144 hours), the duration of the Vacuum Drying and Helium backfill process is 33 hours, which indicates that the rest of the activities needed to conduct a single UNIT require 111 hours to complete. The drying process thus represents only approximately 23% of the total elapsed time spent performing said single unit.

As previously mentioned elsewhere in the Task Oder report, use of other STAD Drying Equipment (both Vacuum Drying and Forced Helium Recirculation) activity durations are about even with no clear 'best athlete' in the total elapsed time arena (18 hours). Still, this represents an overall savings of 15 hours (or just over one 12 hour shift) in a unit process.

Given that the current throughput could require as many as 24 casks to be loaded in a single CAMPAIGN (where a CAMPAIGN is the complete duty cycle of loadings), this is an overall savings of 15 loading-days on a schedule that would be expected to require (assuming back to back loading with no interruptions and no parallel UNIT loading activities) 144 days to be completed, thereby reducing the total duration of the loading CAMPAIGN to 129 days. Any improvements that result in reducing the duration of the drying process could have a significant improvement in the overall CAMPAIGN duration.

Licensee Users of Industry provided equipment to facilitate residual moisture removal have optimized the equipment within their realm of control (operation). For Vacuum Drying equipment – improved pumps, connections and higher accuracy instrumentation have all served the Industry well in reducing drying durations to the extent practical. For users of Forced Helium Recirculation, to date the system has had little in the way of improvements from an equipment perspective. Only operational enhancements have made any improvements in drying durations.

Given the overall process and duration of specific activities when compared to impact on overall duration and material longevity – it may be that no real benefit in improving drying durations can be readily found or implemented. Using a STAD that has been designed and fabricated to facilitate enhanced residual moisture removal will no doubt provide best results in drying. Additional investment in enhanced drying processes may result in very limited improvements in overall duration of activities when viewed qualitatively.

References:

[1] *Potential Rod Splitting Due to Exposure to an Oxidizing Atmosphere During Short-Term Cask Loading Operations in LWR or Other Uranium Oxide Based Fuel* (Spent Fuel Projects Office Interim Staff Guidance #22)

[2] *Technical Basis for Storage of Zircaloy-Clad Spent Fuel in Inert Gases* (PNL-4835)

[3] *Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility* (NUREG 1536)

[4] *Evaluation of Cover Gas Impurities and their Effects on the Dry Storage of LWR Spent Fuel* (PNL-6465)

[5] *Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor- Related Greater Than Class C Waste* (10 CFR Part 72)

[6] *Comparison of methods for dehydration of natural gas stored in underground gas sto rages.* (Department of Process Engineering, Faculty of Mechanical Engineering, Czech Technical University, Prague, Czech Republic)

[7] *Hydrogen Gas Ignition during Closure Welding of a VSC-24 Multi-Assembly Sealed Basket* (NRC Information Notice 96-34).

[8] *Chemical, Galvanic, or other Reactions in Spent Fuel Storage and Transportation Casks* (NRC Bulletin 96-04)

[9] *Nitrogen Enhanced Purging Systems by AGM Container Controls* (http://www.agmcontainer.com/products/neps.html)

[10] *Removal of Hydrogen, Carbon Monoxide, and Methane from Gas Cooled Reactor Helium Coolants* (ORNL-TM-20)

23 APPENDIX L – DESIGN CONCEPTS FOR THE STAD-IN-CAN AND STAD-IN-CARRIER

Building on the "STAD-in-Can" loading process for small STAD canisters, which was identified at the workshop (see Appendix A), the team developed and evaluated a design concept for this process. In addition, utilizing work performed under Task Order 18[19], the team evaluated a loading approach for small STAD canisters, which utilizes an open-frame carrier, rather than an overpack can; with this design concept referred to as the "STAD-in-Carrier". The results from the development and evaluation of these design concepts are described below.

23.1 MEETING REGULATORY REQUIREMENTS FOR CONFINEMENT

The Nuclear Regulatory Commission (NRC) guidance (NUREG 1536, Chapter 7) for review of the confinement system states that: "Typically, this [redundant seal] means that field closures of the confinement boundary must either have double seal welds or double metallic O-ring seals." The NUREG does not explicitly contemplate the use of hybrid seals that incorporate one mechanical and one welded seal for redundant closure seals. This would be an interesting option to explore with the regulator to see if their expectation for a monitoring/surveillance program for purely mechanical closures would also be required for hybrid (one welded and one mechanical) confinement systems.

The range of confinement options for a STAD-in-Can system that meet the expectations of NUREG 1536, Chapter 7, are captured in Table 23-1. As tabulated, there are 11 ways of achieving the redundant closure seal requirement using an overpack can. The degree of monitoring that would be required for hybrid closure systems is unknown, but may be worth pursuing further with the regulator.

The following table serves to capture multiple seal configurations for the STAD-in-Can concepts and the relative pros and cons of each combination.

[19] DOE A&AS Contract Task Order 18, Generic Design for Small Standardized Transportation, Aging, and Disposal Canister Systems.

Table 23-1. Options for Providing Redundant SNF Confinement Closure Seals

	STAD Closure(s)	Overpack Can Closure(s)	Comments					
			Redundant Seals	Confinement Boundary Monitoring Required while in Storage	Facilitate STAD Inspections during Storage	Impact on Loading Schedule	Impact on Processing Costs (compared to existing DPCs with two welded closures[3])	Overpack could be Reused
1	Single structural welded closure[1]	Single structural welded closure	Meets current NRC regulations.	No. STAD with CAN welded (helium leak tested) confinement boundary seals. No monitoring of the confinement boundary seals required.	No. Requires breaching one of two confinement boundaries.	If the Overpack Lid to Shell weld can be installed outside of the Fuel Handling Building (FHB), there may be a small improvement in the overall schedule for a loading activity.	There are minor operational cost increases with this configuration caused by changes in welding rig configuration to deal with small STAD welds followed by large Overpack Can welds	Likely not. Depends on the weld joint design and amount of material that would have to be excavated to remove the Overpack Lid.
2	Single structural welded and single seal welded[2] closures	Single mechanical closure	Meets current NRC regulations.	No. STAD welded (helium leak tested) confinement boundary seals. No monitoring of the confinement boundary seals required.	Yes. Redundant OPERABLE confinement seals remain intact, but the mechanical Overpack Can closure would have to be opened for inspections.	STAD and CAN assembly could potentially be moved outside of the FHB prior to installation of the mechanical closure which may result in an improvement in the overall schedule for campaign loading times.	Depending on the exact mechanical closure design, costs would be expected to be unchanged for this type of configuration with only 2 welds and the same basic configuration for each of those welds	Provided the mechanical closure device receives no damage, the Overpack Can would be deemed reusable.
3	Double structural welded closures	Single mechanical closure	Meets current NRC regulations.	No. 2 STAD welded (helium leak tested) confinement boundary seals. No monitoring of the confinement boundary seals required.	Yes. Redundant OPERABLE confinement seals remain intact, but requires breaching the Overpack mechanical closure to gain access to STAD	If both STAD welds are installed then the STAD and CAN assembly is moved out of the FHB for installation of the CAN mechanical closure, then no appreciable impact on campaign loading times.	Depending on the exact mechanical closure design, costs would be expected to be unchanged for this type of configuration. Dual structural welds on the STAD may be required for lifting & handling design.	Provided the mechanical closure device receives no damage, the Overpack Can would be deemed reusable.
4	Single structural welded closure	Single mechanical closure with a seal weld	Meets current NRC regulations.	No. STAD and CAN welded (helium leak tested) confinement boundary seals. No monitoring of the confinement boundary seals required.	No. Requires breaching one of two confinement boundary seals.	STAD and Can welded closures have to be installed prior to removal from the FHB. This could impact campaign loading times.	Depending on the exact mechanical closure design, costs would be expected to increase slightly as the welding configuration was changed from the small STAD weld to the large Overpack Can weld.	Depends on the weld joint design and amount of material that would have to be excavated to remove the seal weld.

Table 23-1. Options for Providing Redundant SNF Confinement Closure Seals

	STAD Closure(s)	Overpack Can Closure(s)	Comments					
			Redundant Seals	Confinement Boundary Monitoring Required while in Storage	Facilitate STAD Inspections during Storage	Impact on Loading Schedule	Impact on Processing Costs (compared to existing DPCs with two welded closures[3])	Overpack could be Reused
5	One welded and one mechanical closure	Single structural welded closure	Meets current NRC regulations.	No. STAD and can welded (helium leak tested) confinement boundary seals. No monitoring of confinement boundary seals required.	No. Requires breaching one of two confinement boundary seals.	If STAD weld and mechanical closure are installed and then STAD and can assembly is moved out of the FHB for installation of the can structural weld, then no appreciable impact on campaign loading times.	Depending on the exact STAD mechanical closure design, costs would be expected to increase slightly as the welding configuration was changed from the small STAD weld to the large overpack can weld.	Likely not. Depends on the weld joint design and amount of material that would have to be excavated to remove the overpack Lid.
6	One welded and one mechanical closure	Single mechanical closure	Meets current NRC regulations.	Yes. STAD welded (helium leak tested) with redundant mechanical closures may require monitoring between can and STAD boundaries.	Yes. Assuming STAD mechanical closure is OPERABLE. Requires breaching the overpack mechanical closure to gain access to STAD	If STAD weld and mechanical closure are installed and then STAD and can assembly is moved out of the FHB for installation of the can mechanical closure, then no appreciable impact on campaign loading times.	Depending on the exact mechanical closure designs, this would cost less to install since only one welding iteration is required. Operational leak monitoring costs would increase.	Provided the mechanical closure device receives no damage, the overpack can would be deemed reusable.
7	Press fit closure	Double structural welded closure	Meets current NRC regulations.	No. Can provides the redundant welded (helium leak tested) boundary seals. STAD does NOT have a confinement boundary seal.	No. Inspection requires breaching both confinement boundary seals.	No improvement on schedule loading times. Depending on design and operation of press fit closure, loading times may increase.	Depending on the exact press fit closure design, operational costs would be unchanged with two large structural welds.	Likely not. Depends on the weld joint design and amount of material that would have to be excavated to remove the Overpack Lid.
8	Single mechanical closure	Single mechanical closure	Meets current NRC regulations.	Yes. Would require monitoring between seals for loss of confinement.	No. Requires breaching one of two confinement boundary seals.	Depending on operation and design of mechanical closure likely to improve loading times.	Depending on the exact mechanical closure designs, assembly costs would decrease with no welding, but operational monitoring costs would increase.	Provided the mechanical closure device receives no damage, the Overpack can would be deemed reusable.
9	Single mechanical closure	Single structural welded closure	Meets current NRC regulations.	Yes. Monitoring not feasible. CAN weld (helium leak tested) as confinement boundary seal and STAD mechanical closure confinement boundary seal.	No. Requires breaching one of two confinement boundary seal.	Depending on operation and design of mechanical closure, likely to improve loading times.	Depending on the exact mechanical closure design, assembly costs would decrease slightly with only one weld, but operational monitoring costs would increase.	Likely not. Depends on the weld joint design and amount of material that would have to be excavated to remove the Overpack Lid.

Table 23-1. Options for Providing Redundant SNF Confinement Closure Seals

	STAD Closure(s)	Overpack Can Closure(s)	Comments					
			Redundant Seals	Confinement Boundary Monitoring Required while in Storage	Facilitate STAD Inspections during Storage	Impact on Loading Schedule	Impact on Processing Costs (compared to existing DPCs with two welded closures[3])	Overpack could be Reused
10	Single structural welded closure	Single mechanical closure	Meets current NRC regulations.	Yes. Would require monitoring between seal weld and mechanical closure for loss of confinement seal.	No. Requires breaching one of two confinement boundary seals.	Depending on operation and design of mechanical closure, likely to improve loading times.	Depending on the exact closure design, assembly costs would decrease, but operational monitoring costs would increase.	Provided the mechanical closure device receives no damage, the Overpack can would be deemed reusable.
11	Dual welded closures	An open carrier for moving 4 STADs at a time with no closure	Meets current NRC regulations.	No. 2 STAD welded (helium leak tested) confinement boundary seals. No monitoring of the confinement boundary seals required.	Yes. The open carrier would allow visual inspection of the STAD surfaces through the vent ports on the storage cask without any intervening walls from an Overpack Can	Shorter than use of any Overpack can configuration because there is no can closure to deal with.	Slightly lower unit operational costs because no drying operations are required once the fuel is removed from the pool.	The carrier could be reused.

[1] – A structural weld is one that takes multiple passes and structurally joins a substantial lid or end plate to the container body.

[2] – A seal weld is one that only requires a single pass, and merely welds a sealing plate between the lid and the container body.

[3] – It is likely that the hardware costs for four small STADs plus the cost of an overpack can or a carrier with all of the required closures would be greater than the cost of a single TSC in all closure scenarios. This column only addresses processing cost comparisons.

This option review considered the potential for hybrid systems (one welded and one mechanical closure), but does not explicitly recommend their use. Absent an expressed NRC willingness to consider hybrid sealed systems without requiring continuous leak monitoring of the mechanical seals, the only options carried forward in this analysis rely on redundant welded seals for confinement. This eliminates the need for troublesome full time leak monitoring systems for large storage installations with potentially very long storage durations. Moreover, even if we add the constraint of dual welded closures, the STAD-in-Can system offers six options for providing redundant sealing of confinement systems (Options 1, 2, 3, 4, 5, and 7).

If we assume that the STADs are likely to be individually handled subsequent to storage, then there is some safety logic to having both welded closures on the STADs. This would allow the STAD overpack can to use a simple mechanical closure without any welding. Leak monitoring would not be required in this configuration. A purely mechanical closure on the overpack would speed up the process of loading the STAD-in-Can system. That said, a seal weld on the overpack can lid might be desired for foreign material exclusion (FME) control and/or for use of helium in the overpack to enhance heat transfer. Seal welding the overpack can lid does create an extra barrier to future video examination of the external surfaces of the confinement system (the STAD canisters). Given the long periods of storage envisioned, having the ability to perform periodic inspections of the confinement system seems prudent, so the preference remains to use two welded closures on the STADs and a simple mechanical closure on the overpack Can.

As part of our review, we looked at the schedule streamlining potential offered by performing some of the closure welding activities outside of the contamination control area inside the power plant. The various redundant closure options impact where the final redundant closure preparation has to be performed. This is captured in the 5th column of the comments in Table 23-1.

The NRC addresses used fuel canister loading processes. Since the STAD is functionally the same as a used fuel canister, we use the STAD term where the NRC regulations and guidance would normally address use of a used fuel canister. Loading a STAD typically takes place within the structure (and using equipment specifically located herein) that houses the spent fuel pool. For boiling water reactors this area is referred to as the reactor building, while in pressurized water reactors this is the auxiliary building. For simplicity, this area will be referred to simply as the fuel handling building (FHB) for both plant types.

To enhance throughput capability, portions of the STAD loading process (select activities) should be considered for a change of venue (e.g., performance outside of the normal loading process area). This change in venue for selected activities would result in reducing the time the FHB processing area is occupied by a transfer cask with loaded STADs. Moving loaded STADs out of the FHB sooner would free up precious real estate and area specific equipment (primarily the overhead crane used to handle the large loads) to permit initiation of the next loading event.

One of these activities to be considered for a change in venue is the installation of the second lid (redundant seal) on the STAD. There are two possible scenarios for consideration:

- Only the primary confinement boundary seal is installed and qualified prior to movement from the FHB to another on-site location for installation of the required secondary confinement boundary seal.
- The primary confinement boundary seal is installed and qualified and a temporary redundant seal is installed prior to movement from the FHB to an on-site location for installation of the required secondary confinement boundary seal.

In either scenario, it is noted that the 'on-site location' is not clearly defined from a control of radiological materials standpoint. It is very likely that this alternate location for installation of the required secondary confinement boundary seal would be required to meet, to some degree, the same radiological controls as the FHB area.

The following discussion provides insight as to these requirements and the application of these requirements to limit the spread of radioactive materials and the impact of canister confinement seal operability on these requirements.

Recall that under the current regulation (10 CFR 72.236) for spent fuel storage cask approval and fabrication states:

The certificate holder and applicant for a CoC shall ensure that the requirements of this section are met (which includes:)

(e) The spent fuel storage cask must be designed to provide redundant sealing of confinement systems.

While increased efficiency can be realized by moving a portion of the STAD closure process outside of the main FHB production area, there are limited options for completing this work without the full contamination control afforded by the plant's FHB.

As previously noted, STADs are to be processed and sealed within the FHB. The FHB is a portion of the Licensees' facility that has been designed, constructed and licensed to be in compliance with regulation 10 CFR 50, Appendix A – *General Design Criteria for Nuclear Power Facilities*. Of these, the following criterion include:

Criterion 60 - Control of releases of radioactive materials to the environment. The nuclear power unit design shall include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences. Sufficient holdup capacity shall be provided for retention of gaseous and liquid effluents containing radioactive materials, *particularly where unfavorable site environmental conditions can be expected to impose unusual operational limitations upon the release of such effluents to the environment.*

As noted here – "means to control suitably the release of radioactive materials in gaseous and liquid effluents" is a requirement to have the ability to control said releases. In order to ensure that no releases are probable, when working on a STAD outside the FHB, the STAD single boundary seal would have to be evaluated and considered suitable to ensure no possible release of radioactive effluents is probable.

Criterion 61 - Fuel storage and handling and radioactivity control. The fuel storage and handling, radioactive waste, and other systems which may contain radioactivity shall be designed to assure adequate safety under normal and postulated accident conditions. These systems shall be designed (1) with a capability to permit appropriate periodic inspection and testing of components important to safety, (2) with suitable shielding for radiation protection, (3) with appropriate containment, confinement, and filtering systems, (4) with a residual heat removal capability having reliability and testability that reflects the importance to safety of decay heat and other residual heat removal, and (5) to prevent significant reduction in fuel storage coolant inventory under accident conditions.

Until the STAD is fully compliant with 10 CFR 72 design requirements, movement of the STAD will likely still be classified as "fuel movement". Sub-part (3) of GDC 61 may present a challenge to the proposal of moving the STAD outside of the FHB to another area to complete the installation of the redundant seal[20].

Current accepted practice in processing a STAD is that both primary and secondary redundant seals are in place and qualified prior to movement of the STAD outside of the processing area. The following examples serve to illustrate the issue.

One US Nuclear Utility Site moves the STAD from one controlled ventilation building (Spent Fuel Pool Area) to an adjacent controlled ventilation building (Auxiliary Building) before initiating the sealing of the STAD. This is deemed acceptable since 1) the handling is done with a Single Failure Proof Crane, and 2) the processing area is within a controlled environment which is in compliance with GDC 61. The fact that the STAD is processed and sealed within a fully compliant controlled environment prior to movement outside of the controlled environment is important to note here. The proposed movement of the STAD from the controlled environment prior to installation of the redundant seal boundary is not the same scenario.

In another instance, one US Nuclear Utility Site has specific requirements to suspend all Used Fuel movements within the FHB whenever a portion of the Control Emergency Ventilation

[20] For the purposes of the secondary containment technical specifications, once the redundant seals or welds are in place, moving the UFC is no longer considered "movement of irradiated fuel in secondary containment". With only one seal, appropriate technical specifications for movement of irradiated fuel would need to be in place

Equipment System (CREVS) is declared INOPERABLE. However, movement of a processed, sealed and fully compliant with storage license conditions STAD is deemed acceptable since the STAD is now qualified and considered a Part 72 Compliant component rather than a Part 50 component.

WORK LOCATION SUMMARY

For the above-cited 10 CFR 50 General Design Criteria and the scenarios provided, it is reasonable to conclude that the proposal of installing the secondary STAD redundant seal outside of the sealing and processing area in the FHB may not be an acceptable alternative to the normal sealing and processing activities conducted within the confines of the Part 50 facility. Streamlining processing time is not a sufficient rationale for avoiding the strict contamination controls for fuel handling and movement that are in the regulations. In the event that the use of a temporary redundant confinement seal is utilized to facilitate movement of the STAD from the FHB, the alternate on-site location would likely have to meet the same 10 CFR 50 General Design Criteria used to ensure the spread of radioactive materials is controlled in the event of an accident, off-normal or operational occurrence event that could potentially release radioactive material.

23.2 PRIMARY STAD OVERPACK CONFIGURATIONS CONSIDERED

If the double welded closures are installed on the STAD, then a number of simple mechanical lid closure options can be considered for the overpack can. A basic bolted closure was eliminated because a bolt circle requires a flanged surface and that would have increased the outside diameter of the overpack can. Increasing the OD further complicates eventual transportation of the STAD system because of the overall transport cask and impact limiter diameter limitation of 128”. The two most interesting options based on initial literature searches and design reviews were:

- Closures based on those used for sealed source overpacks developed by Los Alamos National Laboratory for sealed neutron sources (see Figure 23-1).
- Closures based on the on-site container (OSC) developed by Sandia National Laboratory from autoclave technology. These OSCs were developed for on-site shipment of chemical weapons from storage to disposal facilities at military depots.

Figure 23-1. Sealed Source Overpack

The initial design of an overpack for sealed neutron sources used a pipe configuration with a screw-on sealing lid. The screw-on lid was originally designed to bind threads and shear off the wrench attachment square when the proper torque was reached. This was fine for an overpack meant for direct disposal but would not serve well as an overpack for STADs that may require removal and reconfiguration for disposal. The current version of the overpack for neutron sources uses a conventional pipe overpack with a blind lid bolted to a flanged sealing surface. This standard configuration does not offer any assembly advantages that would reduce cost or schedule for use in STAD management. No further analysis or review of neutron source overpacks as a potential option for STAD use was conducted.

The basic autoclave design includes a pressure vessel body with a hemispherical pressure vessel lid. The lid is typically mounted on a framework that aligns it with the autoclave body. To close the lid, hydraulic operators pivot the lid on that framework to mate with the pressure vessel body sealing surface. Lugs on the closure lid align with corresponding lugs on a closure ring. As the closure ring rotates around a flange on the pressure vessel body, ramped lugs on the closure ring mate with lugs on the lid and pull it into a tightly sealed position with the autoclave body. Autoclave systems typically use an elastomeric gasket. The choice of elastomer is based on the operating temperature of the autoclave. For the on-site transport use, the gasket simply seals the joint at ambient temperatures, so many materials are acceptable. A soft gasket is used because for both autoclave and on-site transport use, the lid is opened and closed multiple times in a day. A detailed review of this autoclave configuration follows in Section 23.3.

23.3 DETAILED REVIEW OF THE AUTOCLAVE CONFIGURATION

The autoclave system also presents challenges, but there are some design elements that could be useful for a STAD overpack. The first image in Figure 23-2 shows the basic layout of a large industrial autoclave. These systems are closed and sealed with the use of ramped lugs on the closure lid that mate with offset ramped lugs on a closure ring. The closure ring rotates around a flange on the pressure vessel body and engages the ramped lugs on the lid. The lid is aligned with the autoclave body by a rigid, external support frame. As the closure ring is rotated by hydraulics, it pulls the closure lid into the autoclave body with sufficient force to create a tight seal.

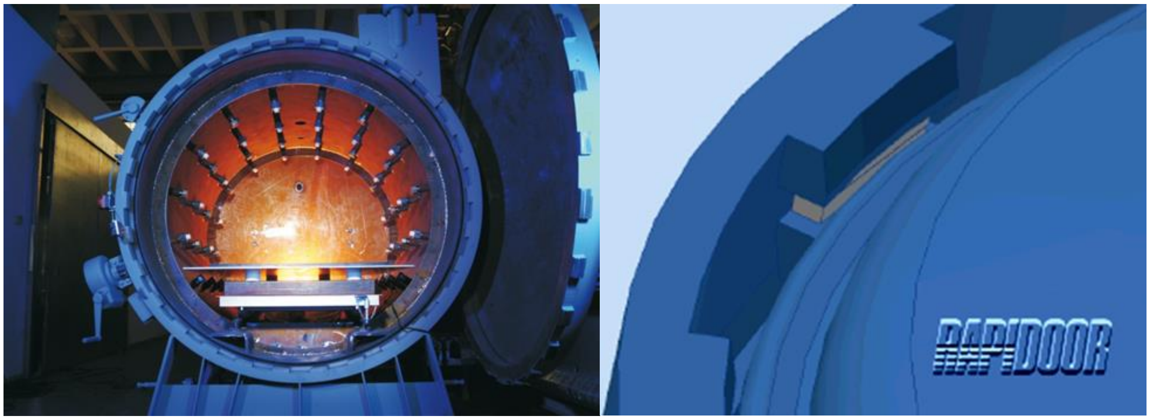


Figure 23-2. Typical Autoclave Closure Mechanisms.

Another feature of the autoclave style lid closure is that the lid does not rotate to lock the joint. Since the lid does not rotate, the gasket only sees a compression load and no shear, or tearing loads are introduced. The same process could be used with a metal O-ring gasket for a joint that would not be opened and closed regularly, as would be the case in a dry storage installation.

Figure 23-3. Industrial Autoclave

The requirement for external lugs and an attached framework for supporting and accurately positioning the lid for sealing are problematic for SNF storage and transport use. Figure 23-3 shows how prominent these protuberances can be.

The Army ameliorated these external interferences somewhat with an enhanced on-site container (EONC) design. The EONC design moved the closure lugs to the interior of the lid and inside the outer shell of the system. The outer shell also contains the locking ring used to secure the lid. This enhanced autoclave based system is shown in Figure 23-4. The hydraulic mechanisms required to rotate the locking ring remained on the outside of the container though. The framework supporting the lid and keeping it aligned with the autoclave body also remained as an external structure. This was not a problem for the Army since the EONC was also the transport container.

Figure 23-4. The Enhanced On-Site Container Used at the Pine Bluff Arsenal.

For SNF management, the STAD overpack needs to be shipped in a separate transport cask, so these external structures are not viable for SNF storage and transport. The added complication of a hydraulically operated lid locking mechanism is also incompatible with the operation of a long-term SNF storage and transportation system.

23.4 AUTOCLAVE INSPIRED MECHANICAL CLOSURE FOR A STAD OVERPACK CAN

Some ideas taken from this design could apply to a STAD overpack can with a mechanical closure. The use of a ramped lug system to secure the lid for storage and transportation could easily be adopted without the hydraulic mechanisms used on the EONC.

The components of a STAD overpack system to contain four small STADs with only a simple mechanical closure are shown in Figure 23-5. This configuration requires the redundant sealing (welding) of confinement systems to both be on the STAD canister.

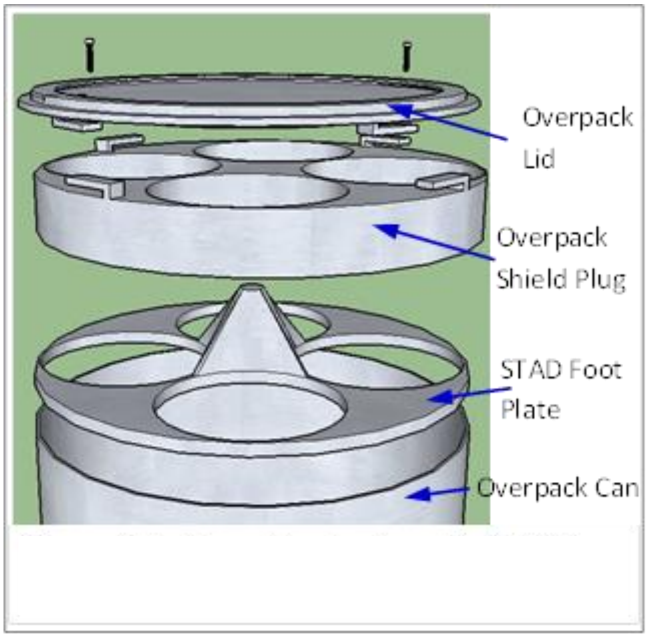


Figure 23-5. Assembly Drawing of a STAD Overpack with a Mechanical Lid Closure.

A STAD foot plate with positioning guide would ensure the feet of the STAD canisters were held in position as the SNF system is rotated horizontally for transport. The base of the Foot Plate is the same thickness as the STAD canister bottom plates, so this would not interfere with SNF cooling. A tapered guide is incorporated into the foot plate to ensure the STADs settle properly into their positioning holes at the bottom of the overpack can. The 9" thick shield plug would be welded to the can overpack body 4.25" below the lip of the overpack shell. This provides space for the 2" thick lid and the 2" tall attachment lugs. Top and bottom fillet welds would securely attach the shield plug to the overpack can body. These welds would be performed at the fabricator's shop.

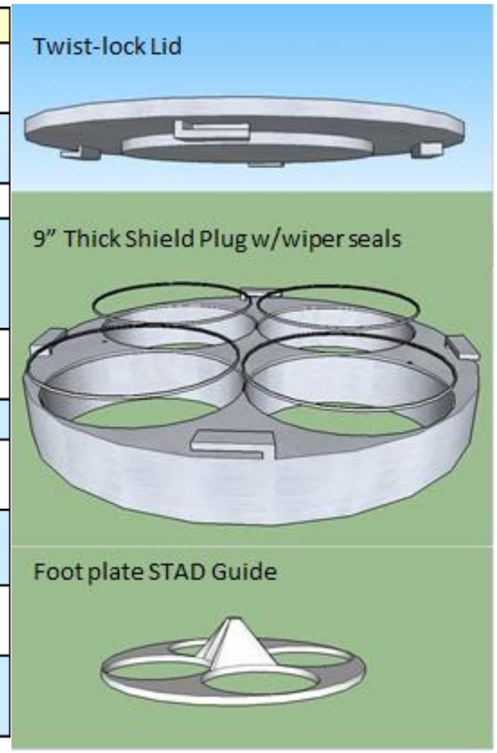
The overpack lid has a disc on the underside that minimizes head space above the STADs when the lid is assembled. This disc prevents the STADs from moving out of their position in the STAD foot plate during transport. Spring steel clips could also be provided on the disc under the overpack lid to further ensure the STADs stay in position as the assembly is rotated to a horizontal position in preparation for shipment and/or for transition into a disposal configuration.

The STAD overpack lid has bolted lifting lugs on its top surface. These are used to lift it into place once the loaded overpack is removed from the pool in the overpack transfer cask. These lifting lugs are also used to brace a handle for rotating the lid 15 degrees into the fully closed position. The lugs on the lid align with indicating marks on the overpack shell when the lid is rotated into the fully closed position. The lugs on the lid and on the shield plug are ramped to create an interference fit as the lid is rotated. Once fully rotated into position, the lid will be secured from rotating into the removal position with either welded tabs, bolted tabs, or with a welded omega seal ring if one is used over this closure.

The individual components of the STAD overpack and key dimensions are shown in Table 23-2.

Table 23-2. STAD Canister and Overpack Can Dimensions.

Table 3.2 STAD & Overpack Can Dimensions (inches)				
Item	**ID**	**OD**	**Length or Thickness**	**Weight, lbs**
Magnastor PWR TSC	71	72	191.8	36,695
4P STAD	28.24	29	196	
Assembled STAD Overpack w/o STADs[1]		73.6	202	17,161
STAD Overpack Shell	72.6	73.6	200	6,704
Overpack Lid[2]		72.6	4	3,232
Stad Overpack Bottom		73.6	2	2,481
STAD Overpack Shield Plug[3]		72.6	9	3,774
STAD Overpack Foot Plate		72.6	2	839
STAD Overpack Footplate Guide[4]		26	12	132



Comments
[1] The overall height of the Overpack Can is reduced to 200" if the lid is welded w/o mechanical lugs
[2] The overpack lid is a 2" thick steel disc, but the attachment lugs are also 2" tall for a total height of 4"
[3] The diameter of the shield plug and foot plate will be adjusted as necessary to suit fabrication processes.
[4] The STAD Ovepack Foot Guide is a star shaped item with radiused arcs between the points of the star. The diameter listed is for the distance between lower points of the star.

The thickness of the overpack shield plug has the same depth as the shield plugs in the STADs. This ensures uniform shielding and minimizes angular streaming radiation. Given the clearances and payload of the STADs as compared to the MAGNASTOR System, it is reasonable to conclude that the MAGNASTOR calculated and field observed dose rates will easily bound those for the STAD. The overpack shield plug also incorporates lifting lugs that mate with corresponding lugs on the overpack lid. These shield plug lifting lugs also weld to the overpack can shell along the periphery to add structural rigidity to the system. This effectively transfers lifting loads to the overpack body without introducing bending loads in the overpack shield plug itself.

Placing the lifting lugs at the periphery of the shield plug precludes incorporating a metal O-ring into this closure design. Any O-ring seal would require a flanged sealing surface that would add to the diameter of the overpack can with ripple effects on the diameters of the transfer cask, transport cask and storage modules. If a leak tight seal[21] is needed for the overpack, then a welded omega seal could be incorporated into the overpack can lid. If one side of the omega seal were welded to the can lid during initial fabrication, then only a single pass closure weld (the omega seal to the overpack shell) would be required once the lid was installed at the power plant. The lid would not have to be installed in the pool since all of the required radiation shielding is provided by the STAD shield plugs and the STAD overpack shield plug.

The overpack can shield plug incorporates drain and vent quick disconnects for filling the overpack can with water and then draining it after the STADs are loaded. The STADs will seal to the shield plug with an edge wiper seal to prevent leakage of low pressure water or gas. An assembly diagram of this system with 4 STADs installed is shown in Figure 23-6.

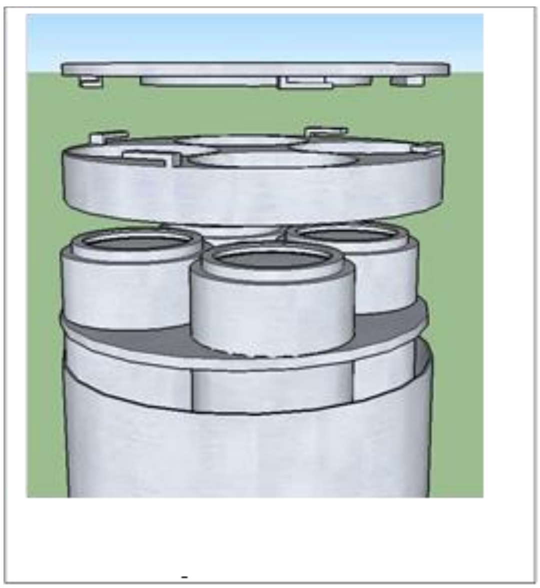


Figure 23-6. Assembly View of STAD Overpack Can with Four Small STAD Canisters.

Since shielding of the contents is provided by the shield plugs in the STADs and in the overpack, the overpack lid does not have to be assembled to the overpack while in the pool. The overpack with loaded STADs would be lifted from the pool into the final assembly frame with the transfer cask. The water would be lowered, any closure welds would be completed and then the overpack can would be drained and dried. Finally, the lid would be fitted and welded as required by the type of closure chosen.

[21] Would be required if the overpack can is filled with helium for thermal performance reasons.

An effort was made to adapt an existing transportable storage canister (TSC) to serve as the STAD overpack, but the largest TSC used by NAC is not large enough to load 4 right circular cylinder STADs with an OD of 29” and the added thickness of an overpack can.

23.5 THERMAL MANAGEMENT OF STAD CONTENTS

The SOW for this Task Order did not explicitly define the fuel to be managed, but information taken from the SOW Task Order 17 (*Spent Nuclear Fuel Transportation Cask Design Study*), suggests a worst case scenario would include all fuel with 65 GWd/MTU burnup, 5% weight enriched initially and only 5 years of pool cooling. Extrapolating from decay heat charts, this means maximum of 2,000 watts/assembly, for a total of 32 kw in each overpack with 4 STADs and 4 assemblies per STAD. No current transport package can handle 32 kw, but this does fall within the thermal management capacity of current dry storage systems. The NAC MAGNASTOR system is licensed for 35.5 kw for PWR fuel and 33 kw for BWR fuel.

Our thermal assessment of 4 STADs with maximum heat load stored in an overpack can is based on limiting thermal analyses of STADs in a carrier done for TO-18. Based on that work, the hottest STADs would require a helium atmosphere in the tightly packaged overpack can to ensure adequate heat transfer rates. That in turn would require a welded closure on the overpack can to contain the helium during long term storage. The welded closure required on the overpack can to retain a pressurized helium atmosphere would add to the overall processing time for most viable closure options. Given the focus of this Task Order on improving processing times to make small STAD canisters viable alternatives for utilities, requiring a welded closure on the overpack can as well as on the STAD makes this arrangement less attractive from an operational standpoint. The welding configuration used to weld the larger diameter overpack can lid would necessarily be different from the machine used to weld the much smaller STAD closures. That means extra personnel exposure needed to set-up and reconfigure the welding machines for each system closure effort. Once the overpack can lid is welded, no further inspection of the STAD external surfaces is possible without cutting the lid off. That would require the full support of an NRC licensed facility with HEPA filters and extensive contamination controls if there is only a single seal weld on the STADs. This combination of limitations and time penalties suggest use of an overpack can with four small STADs is not a viable packaging solution for operating utilities.

23.6 MAINTAINING CLEANLINESS OF STAD EXTERIOR SURFACES

The loading process for the small STADs includes steps to preclude contamination of the exterior surfaces of the STADs with contaminated pool water. The uncertainty over future handling requirements for the STADs places a premium on maintaining their surface cleanliness so future transfers into alternative disposal configurations could be done without returning to a pool. Allowing the external surfaces to become contaminated would preclude many of the handling options for future repacking needs. And future handling of the STADs for repackaging or inspection would then require special contamination controls to prevent the spread of radiation to uncontrolled areas.

Another problem with STADs that have contaminated surfaces is that they could not be placed into dry storage in an open carrier arrangement in a storage module. The air vents in the storage module would serve to spread any contamination present and that is unacceptable for any 10 CFR 72 licensed storage facility. All of the STAD loading processes are therefore designed to prevent external contamination while in the pool, and steps might have to be added to actively rinse the STADs in the case of contamination barrier failure.

23.7 STAD CANISTER OVERPACK CAN DRYING

As described in Section 23.4, the small STADs would insert into the overpack can through openings in the shield plug. The only seal between the STAD and the overpack can shield plug would be wiper seals typically used with rotating machinery. These seals are good for foreign material exclusion, but they cannot take differential pressure. The use of these seals precludes the use of vacuum drying of the overpack can internals when a mechanical closure is used with the lid. High velocity, low pressure dry inert gas could be circulated through the overpack can to facilitate drying when a mechanical lid closure is used, but that could be a lengthy process. The absolute dry conditions required in the STADs where fuel pins are exposed to the internal atmosphere is not required for the overpack can. This can serves a function similar to the storage modules for large DPCs. Storage modules allow atmospheric moisture to enter through vent ports and expose the external surfaces of the DPCs to moisture during storage. If a welded closure is used for the overpack can lid, vacuum drying could be used if the vent and drain ports in the overpack can shield plug were left open when the lid was installed. The offsetting challenge with a welded lid closure on the overpack can is that visual inspection of the STAD external surfaces would only be possible by cutting the overpack can lid closure weld. This could be problematic for aging management systems required for very long storage.

23.8 CONSIDERATION OF A CARRIER ALTERNATIVE FOR HANDLING FOUR SMALL STADS AT A TIME

The use of an overpack can was discussed as an option for lifting and transferring four small STADs at a time to speed the loading and handling of the smallest STAD canisters. As described above, the use of a closed can presents many additional challenges that don't exist with the current storage of large DPCs. Heat transfer is expected to be more challenging with a closed can over the STADs inside a dry storage module. It is not possible to visually inspect the external surfaces of the STADs stored in an overpack can unless the lid of the overpack can is removed. That may require removing the overpack can from the dry storage module in a transfer cask and relocating it to a contamination controlled work area to remove the overpack can lid (depending on the type of lid closure and how redundant seal isolation of the fuel is performed). Even in the best case scenario with both confinement seals welded on the small STADs, visual inspection would require removal of the dry storage module and the overpack can lid to obtain visual access to the STAD surfaces through the small vent and drain ports in the overpack can shield plug. That is a cumbersome process.

As shown in Table 23-2, the weights of the overpack can components are significant and would add to the total weight needed to be handled during any transfer operations involving four small STADs. The overpack can also add noticeably to the overall diameter of the container that has to fit into transfer casks, dry storage modules and transportation casks, necessitating design and licensing of new, larger transport casks. All in all, the added complexity of a STAD-in-Can system for handling four small STADs at a time does not seem to be worth the benefit of reducing the number of lifts.

During execution of Task Order 18, the concept of a "carrier" to move 4 small STADs at a time was proposed. This concept has gained support during the processing and handling reviews we have conducted for Task Order 21. The key benefit of being able to load, transfer and transport four small STADs at a time is preserved. The "carrier" system also eliminates many of the shortcomings of the overpack can. Visual inspection of the external surfaces of the STADs would be possible simply by inserting a video probe through the vent ports in the storage module. Most of the STAD external surfaces could be examined this way.

Heat transfer from the small STADs would not be impeded by a fully enclosing shell like an overpack can. Sufficient surface area of the STADs would be exposed to the naturally circulating air through the dry storage module to eliminate the need for augmented cooling, or the use of extra helium in the closed overpack can to minimize heat build-up in the stored fuel assemblies.

The "carrier" configuration is lighter and uses less material in a design that presents fewer fabrication challenges.

Finally, the external dimensions of a "carrier" can be smaller than those of an overpack can, facilitating the use of existing transfer casks and possibly current transport casks with a content amendment. Fuel loading operations would not be appreciably different between four small STADs in an overpack can, versus four small STADs in the “carrier” lowered into the pool at once. Inflatable seals would be used to prevent contamination of the STAD external surfaces in either system while in the transfer cask in the pool. Additional attention might be required to shielding on the top of the small STADs in the “carrier” to minimize dose while welding the STAD closures, but that is a relatively straightforward design issue. A design for the carrier has been developed under Task Order 18, but a general conceptual comparison of four STADs loaded into an overpack can versus the “carrier is shown in Figure 23-7.

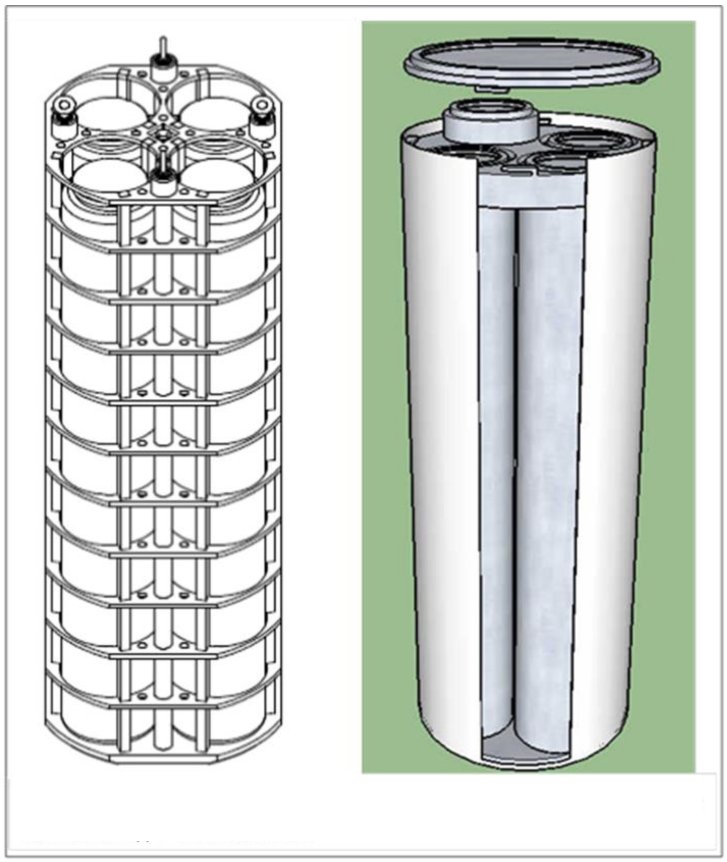


Figure 23-7. Comparison of a Carrier and an Overpack Can for Handling Four Small STAD Canisters

24 APPENDIX M – DUAL TRANSFER CASK TIME SAVINGS FOR LARGE BWR STAD CANISTER

Utilizing Microsoft Project and the detailed time durations for the large BWR STAD canister in Table H-1, Figure 24-1 reflects a total duration over three consecutive transfer cask loads of 345.8 hours, which is an average of 115.27 hours per transfer cask load.

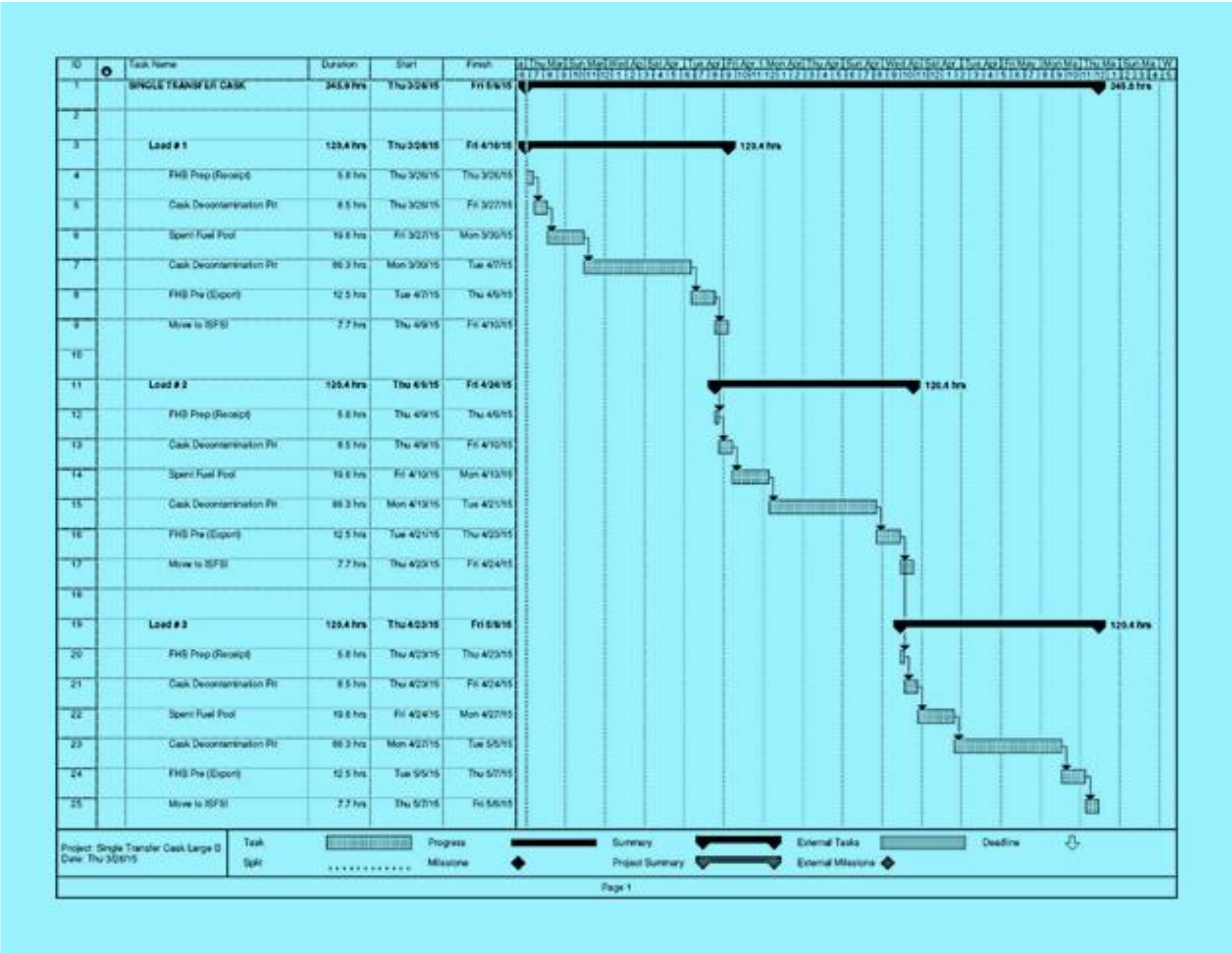


Figure 24-1. Three Consecutive Transfer Cask Loads for the Large BWR STAD Canister Using a Single Transfer Cask

Utilizing Microsoft Project and the detailed time durations for the large BWR STAD canister in Table H-1, Figure 24-2 reflects a total duration over three consecutive transfer cask loads of 289.3 hours, which is an average of 96.43 hours per transfer cask load. This represents an average savings per transfer cask load of 18.84 hours.

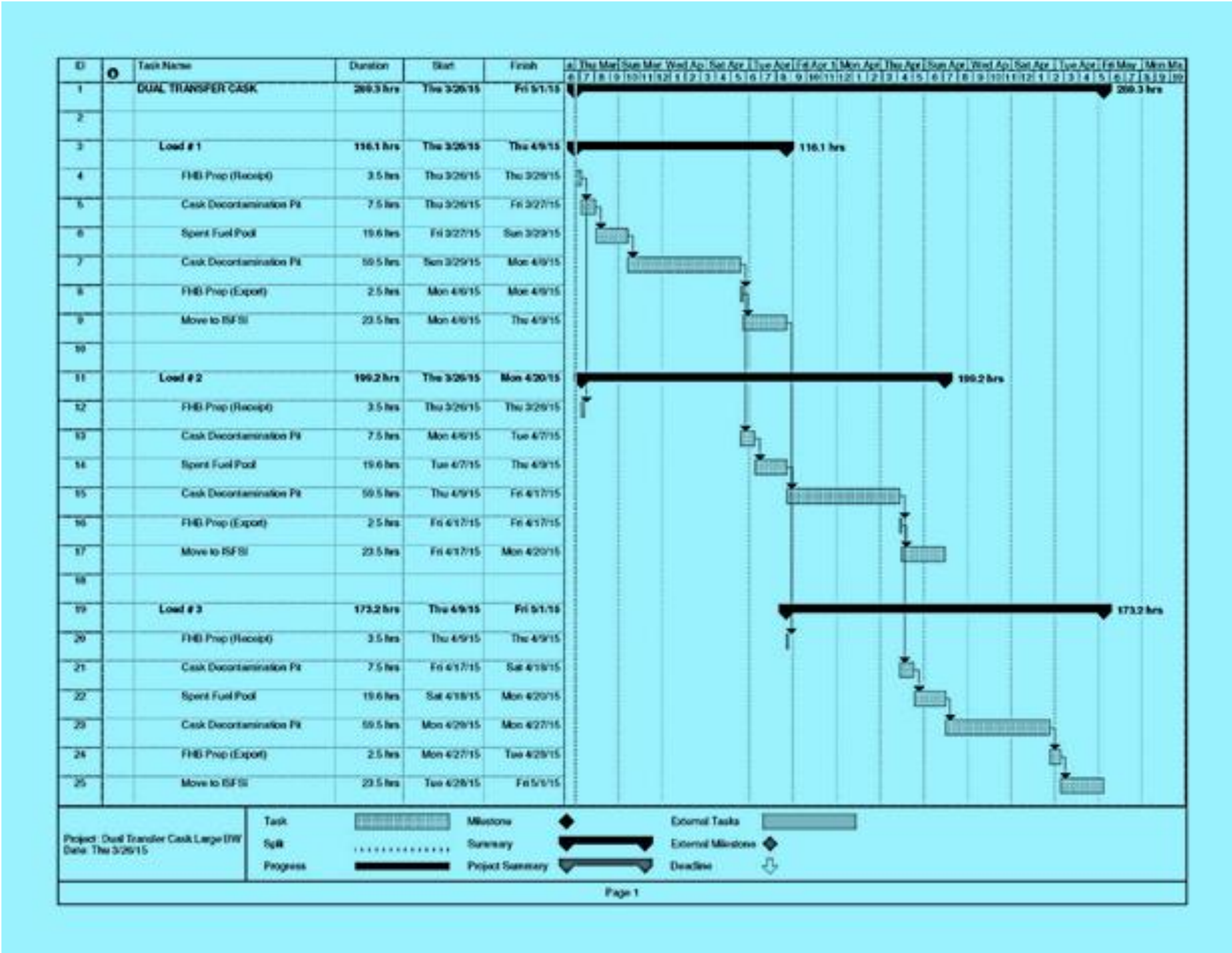


Figure 24-2. Three Consecutive Transfer Cask Loads for the Large BWR STAD Canister Using Dual Transfer Casks