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Prepared for the U.S. Department of Energy
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TIME AND DOSE ASSESSMENT OF BARGE SHIPMENT AND AT-REACTOR HANDLING OF A CASTOR V/21 SPENT FUEL STORAGE CASK

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SUMMARY

This report contains the results of a time/motion analysis and a radiation dose assessment made during the receipt from barge transport and the loading of CAst iron cask for Storage and Transport Of Radioactive material (CASTOR) V/21 storage casks with spent nuclear fuel at the Surry Power Station in Virginia during 1987. The study was a cooperative effort between Pacific Northwest Laboratory (PNL) and Virginia Electric and Power Company (Virginia Power), and was funded by the U.S. Department of Energy (DOE) Transportation Program Office.

In this study, cask handling activities were tracked at the Surry Power Station, tracing the transfer of the empty spent fuel storage cask from an ocean-going vessel to a barge for river transport through the activities required to place the loaded storage cask at an at-reactor storage location. The results of the study are summarized in Table S.1.

TABLE S.1. Measured Time/Dose Observations

Activities	Minimum[a] Time (hr)	Turnaround[b] Time (days)	Occupational Dose (person-mrem)
Remove empty cask from ship, place on barge, transport, transport by heavy-haul trailer from dock to reactor site	8	1	0
Receive empty storage cask, load with 21 PWR spent fuel assemblies, ready for pad storage	33	4	364
Transport loaded storage cask to pad storage	3	1	27
Total	44	6	391

(a) Minimum Time = Summation of minimum time required to complete each handling step that was observed during three cask loadings.
(b) Turnaround Time = Actual clock time, equivalent to minimum time and delays due to backshifts not worked, etc.

As shown by the data in Table S.1, the occupational dose associated with receiving a CASTOR V/21 storage cask by barge is zero, because the cask is empty and there is no background area dose rate (in excess of natural background dose). Loading of a CASTOR V/21 storage cask with spent fuel and transferring it to pad storage results in 391 person-mrem of exposure.

The time/motion dose information collected in this study can be used to estimate the dose expected to result from the shipment of a loaded cask using a barge and a railcar. Combining the dose rates for the loaded casks with the observed time/motion/personnel measurements for handling activities results in an estimate of approximately 56 person-mrem of exposure for removing a loaded cask from a reactor site or transfer of a cask from a barge to a railcar. Over 24% of the occupational dose occurs when four workers remove the protective cover from the storage cask before the transporter is removed from the barge.

CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

This report contains a complete handling-time/dose assessment for barge transport and at-reactor loading of a CASTOR V/21 storage cask.

Study results are based on the transport by barge and loading of CASTOR V/21 storage casks with spent fuel at the Surry Power Station in Virginia during 1987. Cask handling activities are tracked from the transfer of the empty spent fuel storage cask from the ocean-going ship to the barge for river transport through the activities required to place the loaded storage cask at an at-reactor storage location. An overview of the handling activities included in the analysis is shown in Figure 1.1.

The CASTOR V/21 storage cask was developed by Gesellschaft fur Nuklear-service mbh (GNS) of the Federal Republic of Germany (FRG). The casks, which were transported by ship to the United States, are described in Section 1.1,

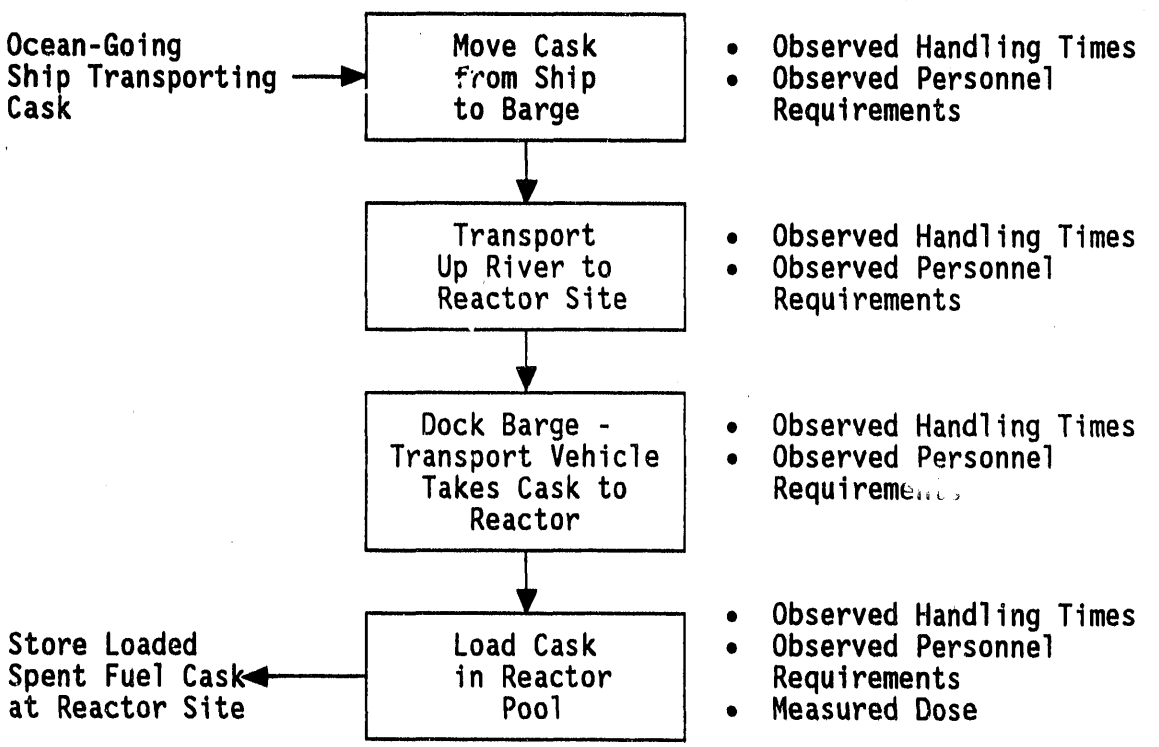


FIGURE 1.1. Overview of Major Activities Included in Handling Time and Dose Study

and the spent fuel assemblies, on which the dose measurements are based, are characterized in Section 1.2. A description of the activities and handling times and facilities required for the cask loadings is provided in Chapter 2.0. These handling times represent the minimum time values observed during the barge off-loading and in-pool spent fuel loading of the second, third, and fourth CASTOR V/21 casks handled at the Surry Power Station. The actual turnaround time for cask handling is also provided, and a comparison of minimum time to actual time is presented. A detailed assessment of occupational dose that could potentially be received during handling operations is presented in Chapter 3.0.

1.1 CASTOR V/21 CASK DESCRIPTION

The GNS CASTOR V/21 storage cask, for which the data presented in this study is based, is designed to store 21 pressurized water reactor (PWR) spent fuel assemblies. A cask is approximately 4.8 meters high, 2.4 meters in diameter, and weighs approximately 80 metric tons. A diagram of the cask is shown in Figure 1.2. Two stainless steel lids seal the cask. Each lid is sealed with multiple metal and elastomer O-rings. The cask also has four trunnions bolted on the top end and two trunnions bolted on the bottom end for a total of six trunnions per cask. A top view and a side corner view of the cask are shown in Figure 1.3.

The cask is designed to handle a range of burnup and spent fuel decay time combinations that meet the design requirements of a dose rate at the cask surface of less than 200 mrem/hr and at 2 meters from the cask of less than 10 mrem/hr.

The characteristics of the fuel that was used as the basis for this study are presented in the following section.

1.2 SPENT FUEL CHARACTERISTICS AND RESULTING CASK DOSE RATES

Information on the spent fuel loaded into the fourth cask at the Surry Power Station is presented in Table 1.1. This particular fuel is representative of the fuel loaded into each of the four casks that were handled at

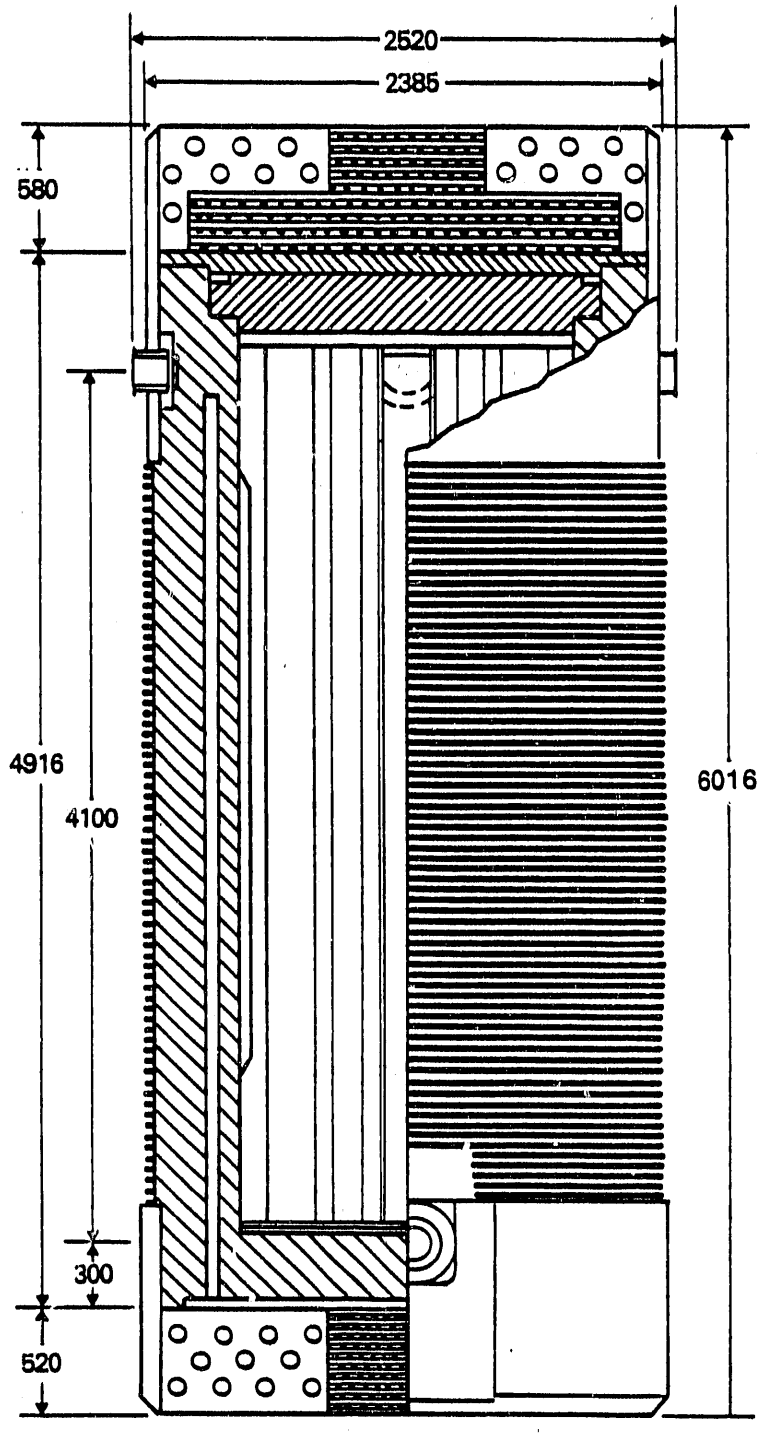
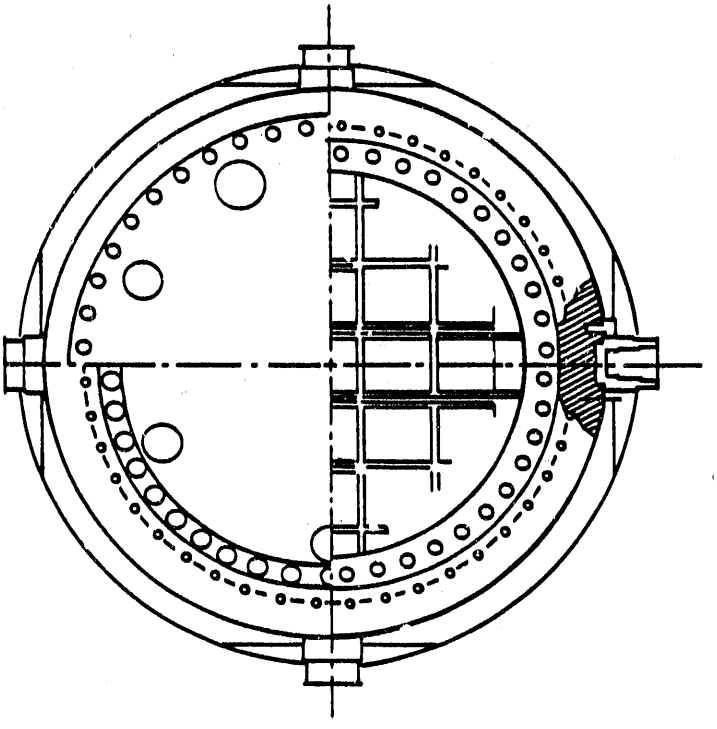
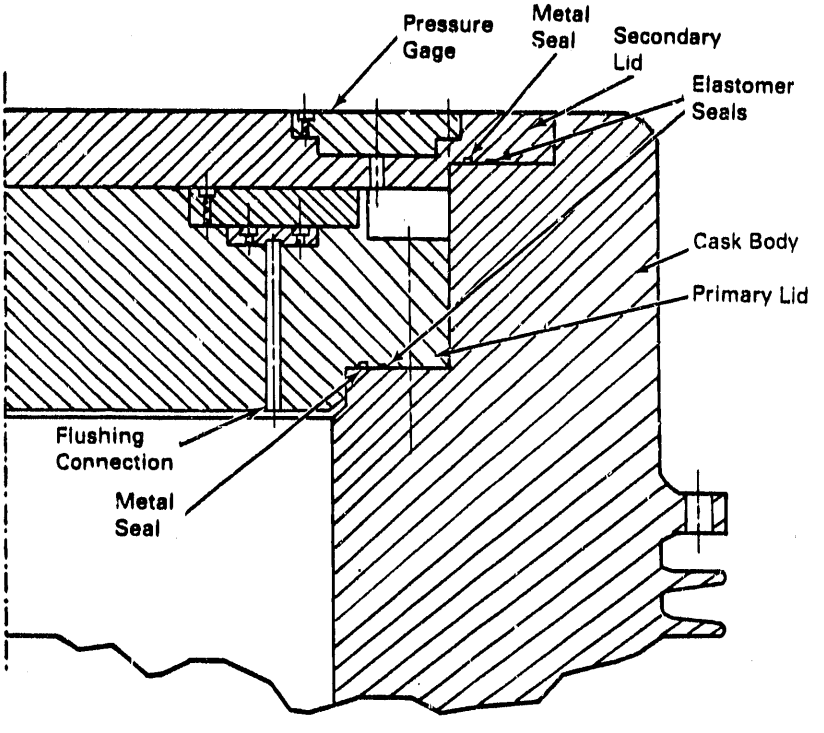


FIGURE 1.2. CASTOR V/21 Cask Dimensions (in millimeters) (GNS 1983)



a) Top View of Cask Showing Bolt Hole Pattern



b) Side Corner View of Cask Showing Primary and Secondary Lids and Seals

FIGURE 1.3. CASTOR V/21 Lid Configurations (GNS 1983)

TABLE 1.1. Spent Fuel Characteristics

Assembly ID	Initial Enrichment (wt% U235)	Burnup (MWd/MTU)	Decay Heat (watts)	Cooling Time (years)	Activity (curies)	Neutron Source (n/sec)	Photon Source (G/sec)
B04	2.57	21,474	305	11.4	116,700	2.06E+07	6.18E+13
B08	2.57	22,974	329	11.4	125,100	2.79E+07	6.69E+13
B10	2.57	21,981	312	11.4	119,400	2.27E+07	6.35E+13
B12	2.57	21,435	305	11.4	116,700	2.06E+07	6.18E+13
B16	2.57	21,697	312	11.4	119,400	2.27E+07	6.35E+13
B18	2.57	21,947	312	11.4	119,400	2.27E+07	6.35E+13
B20	2.57	22,914	329	11.4	125,100	2.79E+07	6.69E+13
B23	2.57	21,066	312	11.4	119,400	2.27E+07	6.18E+13
B24	2.57	21,956	312	11.4	119,400	2.27E+07	6.35E+13
B28	2.57	21,571	305	11.4	116,700	2.06E+07	6.18E+13
B31	2.57	21,412	305	11.4	116,700	2.06E+07	6.18E+13
B32	2.57	21,634	305	11.4	116,700	2.06E+07	6.18E+13
B40	2.57	21,920	312	11.4	119,400	2.27E+07	6.35E+13
B44	2.57	23,080	329	11.4	125,100	2.79E+07	6.69E+13
B47	2.57	21,920	312	11.4	119,400	2.27E+07	6.35E+13
B50	2.57	21,285	305	11.4	116,700	2.06E+07	6.18E+13
C17	3.12	23,676	338	10.4	127,900	1.96E+07	6.35E+13
P11	3.11	21,488	304	10.9	116,000	1.33E+07	5.68E+13
P30	3.11	21,805	304	10.9	116,000	1.33E+07	5.68E+13
P50	3.11	22,001	304	10.9	116,000	1.33E+07	5.68E+13
P51	3.11	21,930	304	10.9	116,000	1.33E+07	5.68E+13
			6,555		2,503,200		

Notes: Average burnup = 21,960 MWd/MTU. Average cooling time = 11.3 years.

the Surry Power Station in 1987. The average burnup for the spent fuel was 21,960 MWd/MTU, with an average cooling time of 11.3 years. Maximum cask surface dose rates varied from 50 mrem/hr at the outer surface of the primary lid to 15-20 mrem/hr along the cask body.

2.0 SYSTEM DESCRIPTION

As part of the U.S. Nuclear Regulatory Commission (NRC) approval process for the CASTOR V/21 storage cask, a generic handling procedure for cask loading was developed by Virginia Power. This generic procedure was then used to develop necessary station operating procedures for use at the Surry Power Station. These procedures were tested in a simulated loading training exercise and procedure refinements were made. Final drafts of these procedures were reviewed and approved by GNS, Surry Power Station quality assurance personnel, and the station Nuclear Safety and Operating Committee.

The system description of the activities required to receive a cask by barge and then load and store the cask at the reactor site is divided into barge related activities and storage cask loading activities. The purpose of this two-part presentation is to distinguish between the time/motion/dose due solely to cask handling activities on the barge and the occupational dose due to cask loading activities at the reactor. A description of cask handling activities for the barge-related activities is provided in Section 2.1. At-reactor cask loading and cask storage activities are discussed in Section 2.2.

2.1 BARGE-RELATED SPENT FUEL CASK HANDLING ACTIVITIES

The new CASTOR V/21 storage casks are transported by ship from the FRG to the U.S. eastern seaboard. Data collection related to barge-related spent fuel cask handling activities began when the storage casks were removed from the ship and continued to the time they were delivered to the power station's receiving gate. These handling steps can be represented by 13 activities for which information on personnel, time, and distance from the cask were collected. Although the storage cask was empty and no occupational dose was incurred, the personnel/time/motion data were used to estimate the dose that would result from placing a loaded spent fuel storage cask on a barge. This estimate of occupational dose is presented in Section 3.1. The dose rates assumed were those measured for the cask following loading at the reactor.

A summary of the information collected for the 13 barge-handling activities is provided in Table 2.1. As shown in the table, the minimum time required to complete the activities is 482 minutes (8 hours). This total time is equivalent to approximately 42.1 person-hours of labor.

The first four activities involve removing the storage cask from the ship to the dock. where it is lifted by the dock crane servicing the barge. The cask is lifted from its wooden shipping cradle by the crane and then lowered to a metal cradle on a transport unit secured to the barge.

The transport unit is a multiaxle, heavy-haul trailer designed to carry the storage cask from the docked barge to the crane enclosure area of the reactor. An illustration of a storage cask transport unit secured to the barge is shown in Figure 2.1.

TABLE 2.1. Summary of Barge Related Cask Handling Activities

Activity	Crew Members	Time in Area (min)	Personnel Time (person-hr)
AT SHIP DOCK			
Cask removed from ship	4	30	2.0
Cask moved to barge dock crane	2	15	0.5
Raise cask from wood cradle	8	80	10.7
Lower cask to metal cradle on transport unit on barge	8	20	2.7
Secure cask to cradle	2	15	0.5
Barge leaves dock	5	15	1.3
Subtotal		175	17.7
TRANSPORT TO STATION			
Barge travels to James River	5	230	19.2
Barge, tug, transport unit arrive at dock	6	25	2.5
Blocking and bracing removed from transport unit	2	15	0.5
Protective cover removed from cask	4	20	1.3
Transport unit drives off barge	3	5	0.3
Transport unit travels along access road to receiving area, 2 miles	3	10	0.5
Transport unit proceeds to station gate, 100 Yards	3	2	0.1
Subtotal		307	24.4
TOTAL		482	42.1

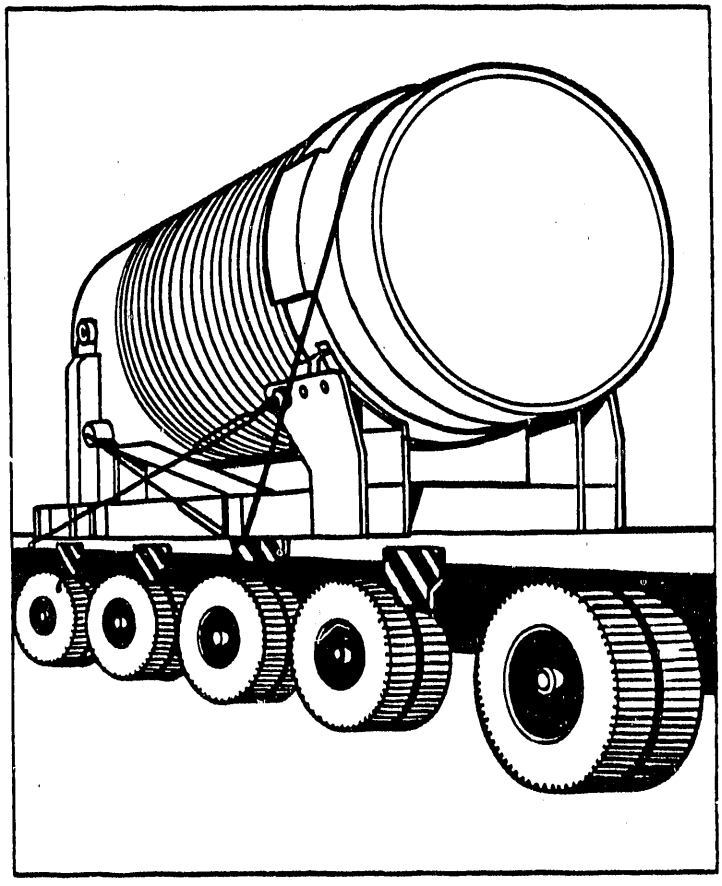


FIGURE 2.1. Storage Cask Resting in Metal Cradle Transport Unit Secured to Barge

Approximately one-half of the barge handling time consists of a tug pushing the loaded barge up the James River to the reactor site. The workers nearest the storage cask during this phase of the operation is the tugboat crew, who are approximately 100 feet away. Barge docking activities consist of docking the barge and releasing the transport unit. The transport unit is then towed 2 miles to the reactor site, as shown in Figure 2.2.

2.2 REACTOR SPENT FUEL CASK LOADING ACTIVITIES

Following the arrival of the empty cask and transporter unit at the reactor gate, a security search is performed and the cask is moved to the Crane Enclosure Area where it is removed from the trailer (with its tilting

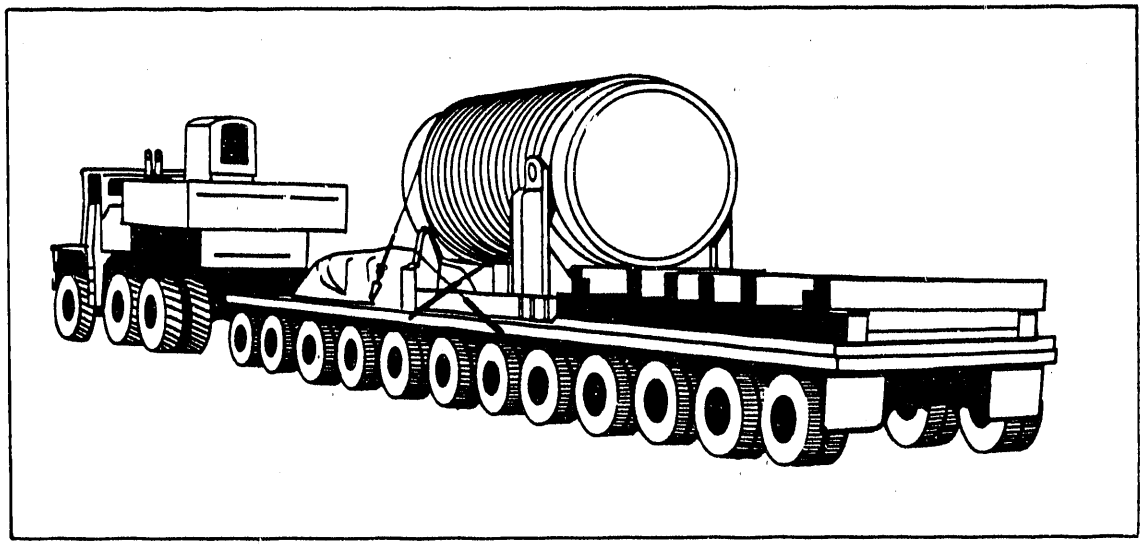


FIGURE 2.2. Heavy-Haul Transport Unit and Cask Enroute from Barge to Reactor

cradle) in a horizontal position, rotated 90 degrees, and lowered to the ground. The overhead crane, which has a capacity of 125 tons, then exchanges lifting yokes, and the cask is upended, disengaged from its tilting cradle, and moved to the north bay of the Decontamination Building. After the two lids are removed, the cask is moved to the Fuel Building. In the Fuel Building, the cask is placed on a submerged cask pad inside the pool for spent fuel assembly loading operations, which are accomplished underwater. Following loading and primary lid replacement, the cask is returned by crane to the Decontamination Building for decontamination, secondary lid installation, and drying and seal testing. The cask is then returned by crane to the Crane Enclosure Area for transport to the storage area.

Cask handling is performed by five-person team (a shift supervisor and four operators) from Surry Power Station. This team works a single 10-hour shift per day, 7 days a week if necessary. A summary of cask-handling staff is presented in Table 2.2.

A schematic view of the Surry Power Station cask handling facilities is shown in Figure 2.3. The at-reactor cask loading/handling activities are shown in Table 2.3. A description of each activity is provided below.

TABLE 2.2. Reactor Staff Performing Cask Handling Duties

Category	Personnel	Responsibilities
Operations	1 Shift Supervisor	Crane movements, most of hands-on work
Quality Control	1 Inspector (Part-Time)	Calibration of test equipment and tools, checks cask testing results, verifies loading of fuel assemblies
Health Physics	1 Assistant Supervisor 1-3 Technicians (Part-Time) 1-2 Decontamination Technicians (Part-Time)	Dose rate surveys, cask decontamination, housekeeping
Engineering	1 Engineer (Part-Time)	Problem resolution, vendor interface
Security	1-6 Officers (Part-Time)	Station access for vehicles, cask escort to storage pad
Maintenance	1 Technician (Part-Time)	Assistance during transport to storage pad
Contractor	2 Drivers (Part-Time)	Delivery of empty cask and transport to storage pad after loading

Activity 1 - Enter Station and Proceed to Crane Enclosure Area

After arrival of the empty cask at the rear vehicle gate, a security search is performed, and the cask is moved to the Crane Enclosure Area. Since each cask is new, no contamination surveys are conducted.

Activity 2 - Horizontal Lift of Cask and Cradle from Trailer

The horizontal lift beam is attached to the cradle, and the cask and cradle are lifted from trailer rotated 90 degrees, and placed on the Crane Enclosure Area floor.

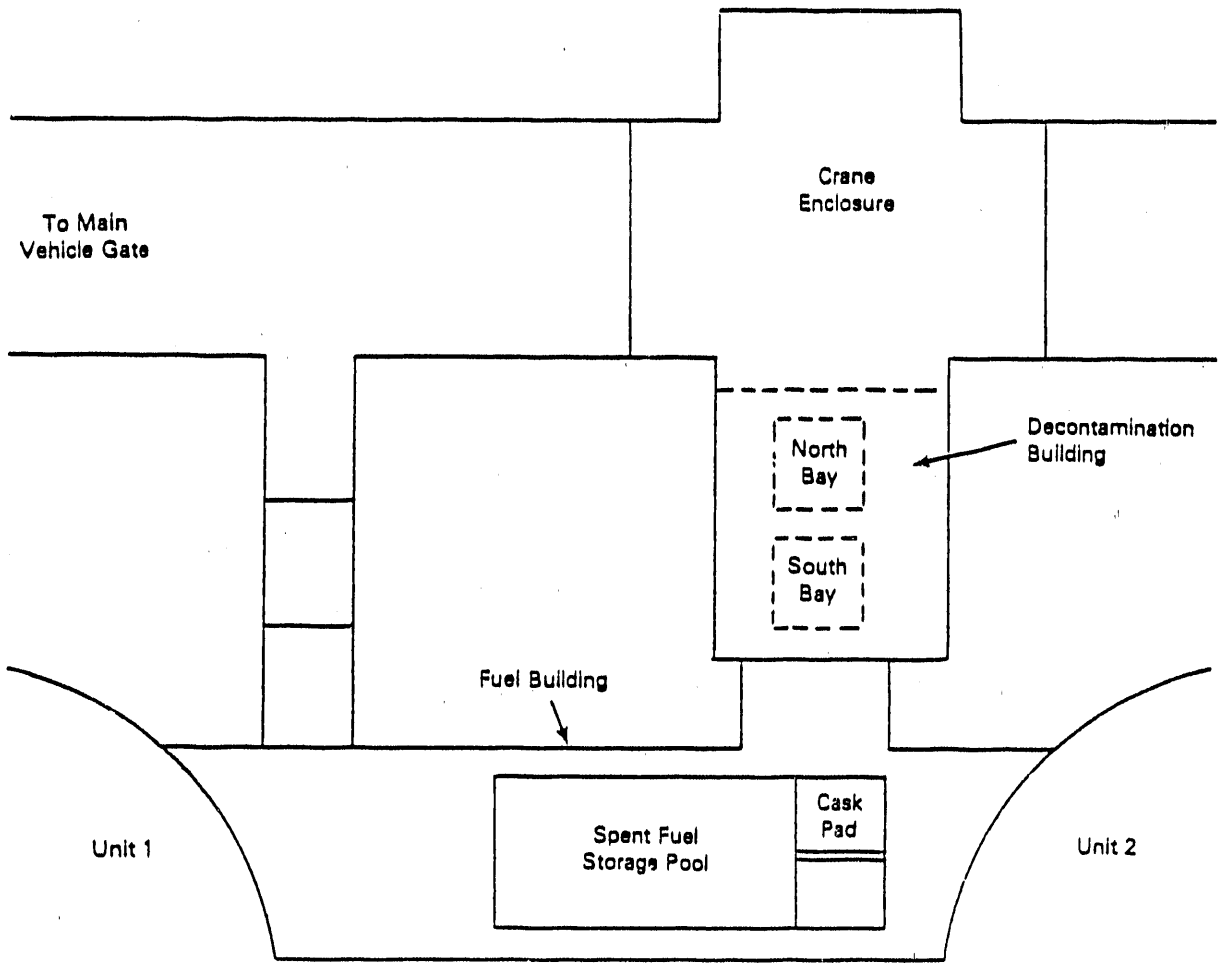


FIGURE 2.3. Surry Power Station Cask Handling Facilities

Activity 3 - Tilt Cask to Vertical and Lift to Work Area in North Bay of Decontamination Building

The vertical lifting yoke is attached to the cask, and the cask is upended to the vertical position and disengaged from its tilting cradle. The cask is raised to clear the Decontamination Building roof, moved over the North Bay hatch, and lowered into the work area.

Activity 4 - Remove Secondary and Primary Lids, Clean Sealing Surfaces, Install Sealing Surface Protectors, Inspect Fuel Basket, and Replace Metallic Seals

TABLE 2.3. Summary of Cask Loading and Handling Activities

1. Enter station to Crane Enclosure Area following security search.
2. Horizontal lift of cask and cradle from trailer.
3. Tilt cask to vertical and lift to work area in North Bay of Decontamination Building.
4. Remove secondary and primary lids, clean sealing surfaces, install sealing surface protectors, inspect fuel basket and replace metallic seals.
5. Attach primary lid to 10-ton hoist and lift.
6. Attach lift yoke to cask and lift from North Bay.
7. Move cask to Fuel Building.
8. Lower top of cask to surface of Spent Fuel Pool and fill cask with water.
9. Lower cask to bottom of Spent Fuel Pool and disengage lift yoke.
10. Load cask with fuel assemblies.
11. Install primary lid.
12. Engage lift yoke, raise cask to surface, and install six primary lid bolts.
13. Install drain pipe through primary lid and pump water from cask.
14. Raise cask from pool, move to work area in the North Bay.
15. Install and torque primary lid bolts, vacuum dry cavity, and test cavity dryness and primary lid seal tightness.
16. Backfill cavity with helium to 800 mbar, and test drain and vent covers for tightness.
17. Install secondary lid, torque lid bolts, and test lid seal.
18. Install seal monitoring instrument.
19. Attach lift yoke to cask and lift from the North Bay.
20. Place cask on prepared surface in the Crane Enclosure Area.
21. Transport cask to on-site storage area.

The secondary lid bolts (46 bolts) are removed, and the lid is removed and placed in storage in the Crane Enclosure Area. The same is done for the primary lid (44 bolts). The two sealing surfaces are cleaned by hand, and plastic sealing surface protectors are installed. The fuel basket is inspected for irregularities. Finally, the primary and secondary lids are temporarily removed from storage to replace their metallic O-ring seals.

Activity 5 - Attach Primary Lid to 10-Ton Hoist and Lift

The 125-ton cask crane trolley also has a 10-ton hoist that is used to lift the primary lid from storage.

Activity 6 - Attach Lift Yoke to Cask and Lift from the North Bay

The lift yoke is attached to the 125-ton crane, and the yoke is lowered to the cask in the North Bay. The cask is then lifted clear of the North Bay roof.

Activity 7 - Move Cask to Fuel Building

The empty cask and the primary lid are moved through a roll-up door to the Fuel Building and positioned over the pool.

Activity 8 - Lower Top of Cask to Surface of Spent Fuel Pool and Fill Cask With Water

The cask is lowered into the pool to a point where the top is just above the water surface. A clean water supply is then used to fill the cask.

Activity 9 - Lower Cask to Bottom of Spent Fuel Pool and Disengage Lift Yoke

The cask is lowered to the bottom of the pool, and the lift yoke is disengaged and raised to the surface. The crane trolley with the lift yoke and primary lid is then moved through the roll-up door, and the door is closed. While outside the roll-up door, a final inspection is made on the underside of the primary lid.

Activity 10 - Load Cask with Fuel Assemblies

Twenty-one spent fuel assemblies are removed from the adjacent storage racks and placed in the cask. Quality control personnel then use an underwater video camera to ensure that the right assemblies are in each basket location.

Activity 11 - Install Primary Lid

The primary lid is returned to the Fuel Building and placed next to the storage pool. A chain-fall is connected between the hoist crane hook and the lid lifting tool. The lid is then lifted, placed over the cask, and lowered

to the top of the cask. The chain-fall is used to slowly lower the lid the last few inches. When the lid is seated, the lid lifting tool is disengaged and removed from the pool.

Activity 12 - Engage Lift Yoke, Raise Cask to Surface, Install Primary Lid Bolts

The lift yoke is lowered into the pool to the cask and is remotely engaged. The loaded cask is raised to the surface and stopped when the top is several feet out of the water. Operations personnel in wet suits then install and hand tighten the lid bolts (6 bolts).

Activity 13 - Install Drain Pipe Through Primary Lid and Pump Water from Cask

A 3/4-inch pipe is inserted to the bottom of the fuel cavity through the drain port of the primary lid. The water in the cavity is then pumped through this pipe to the pool.

Activity 14 - Raise Cask from Pool, Move to Work Area in North Bay

The cask is raised from the pool, moved through the roll-up door to the North Bay, and lowered into the work area. During removal from the pool, clean water sprays are used to remove contaminated pool water from the cask surface. The lift yoke is then disengaged and removed.

Activity 15 - Install and Torque Primary Lid Bolts, Vacuum Dry Cavity, and Test Cavity Dryness and Primary Lid Seal Tightness

Remaining primary lid bolts are installed and torqued in two steps to 500 ft-lbs. Vacuum pumps are then used overnight to draw air and remaining water from the cask. The lid bolts are retorqued at this time, again to 500 ft-lbs, and the cavity dryness and the primary lid seal are tested.

Activity 16 - Backfill Cavity with Helium to 800 mbar, and Test Drain and Vent Covers for Tightness

When cavity dryness and primary lid seal tightness are verified, the cavity is partially filled with helium, then purged and refilled with helium to 800 mbar. Vent covers for the drain and fill ports are installed and tested for tightness.

Activity 17 - Install Secondary Lid, Torque Lid Bolts, and Test for Lid Seal

The secondary lid sealing surface protectors are removed, and the secondary lid is removed from storage and placed on the cask. The secondary lid bolts are installed and torqued in two steps to 620 ft-lbs. The lid is then tested for tightness by pressurizing the interlid space with helium to 1000 mbar and then checking the lid seals for helium leakage.

Activity 18 - Install Seal Monitoring Instrument

The interlid space is pressurized to 7000 mbar, and a pressure monitor is inserted through the secondary lid to monitor this pressure.

Activity 19 - Attach Lift Yoke to Cask and Lift from North Bay

The lift yoke is attached to the 125-ton crane. The yoke is attached to the cask, and the cask is raised clear of the Decontamination Building roof.

Activity 20 - Place Cask on Prepared Surface in the Crane Enclosure Area

The cask is moved to the Crane Enclosure Area floor and lowered to a designated spot. From that spot, the cask either remains in a vertical position for transport to the storage facility or is returned to a horizontal position for transport off-site.

Activity 21 - Transport Cask to On-Site Storage Area

A cask transporter is positioned over the cask, and the cask is raised to travel height. The cask is then transferred to the on-site storage area. The cask is held in a vertical position by the cask transporter during transport, where the cask is to be stored vertically on the storage pad.

A summary of the loading-related cask handling activities is shown in Table 2.4. As shown in the table, the minimum clock time for the 21 major activities, from receiving the cask at the reactor gate to placing the loaded cask in storage, is 2148 min (35.8 hr). These activities require 88.4 person-hr of labor to complete.

The times shown are the best (i.e., the least performance time) for each activity from the three observed cask loadings. Therefore, they represent a "least-time" loading sequence scenario. The total handling time of 35.8 hr

TABLE 2.4. Activity Times and Personnel Requirements for Cask Loading and Handling

	Activity	Crew Members	Time in Area (min)	Personnel Time (person-hr)
1.	Enter station to Crane Enclosure following security search.	1-3	47	0.9
2.	Horizontal lift of cask and cradle from trailer.	4	35	2.3
3.	Tilt cask to vertical and lift to work area in North Bay of Decontamination Building.	2-4	75	4.5
4.	Remove secondary and primary lids, clean sealing surfaces, install sealing surface protectors, inspect fuel basket and replace metallic seals.	2-5	272	13.3
5.	Attach primary lid to 10-ton hoist and lift.	2-3	15	0.6
6.	Attach lift yoke to cask and lift from North Bay.	2	40	1.3
7.	Move cask to Fuel Building.	5-6	22	2.1
8.	Lower top of cask to surface of Spent Fuel Pool and fill cask with water.	6	22	2.2
9.	Lower cask to off bottom of Spent Fuel Pool and disengage lift yoke.	2-6	19	1.3
10.	Load cask with fuel assemblies.	3	150	7.5
11.	Install primary lid.	2-6	92	7.2
12.	Engage lift yoke, raise cask to surface, install 6 primary lid bolts.	4-6	40	3.7
13.	Install drain pipe through primary lid and pump water from cask.	2-6	95	5.4
14.	Raise cask from pool, move to work area in North Bay.	2-6	40	2.4
15.	Install and torque primary lid bolts, vacuum dry cavity and test cavity dryness and primary lid seal tightness.	0-4	712	5.6
16.	Backfill cavity with helium to 800 mbar, and test drain and vent covers for tightness.	2	70	2.3
17.	Install secondary lid, torque lid bolts and test lid seal.	2-4	120	5.2
18.	Install seal monitoring instrument.	2-3	35	1.4
19.	Attach lift yoke to cask and lift from North Bay.	3-6	25	1.8
20.	Place cask on prepared surface in the Crane Enclosure Area.	2-4	40	2.2
21.	Transport cask to onsite storage area.	2-10	182	15.2
	Total		2148 min	88.4 person-hr

is the actual handling time and is not the cask turnaround time at the reactor. Total turnaround time is 6 days as shown below.

Day 1 - Activities 1 through 4
Day 2 - Activities 5 and 6
Day 3 - Activities 7 through part of 16 and 17
Day 4 - Activities 16 through 18
Day 5 - Activities 19 and 20
Day 6 - Activities 21 through 23

The difference between 36 hours and 6 days results from delays due to equipment problems, other station activities with higher priority diverting resources, and using one 10-hour shift per day. This delay could be reduced significantly if multiple shifts were utilized. For example, using two 10-hour shifts/day would result in a 3-day turnaround time. A more detailed activity breakdown of the handling steps for cask-loading operations is provided in the appendix.

3.0 OCCUPATIONAL DOSE EVALUATION

The dose evaluation of barge transport and reactor loading of the CASTOR V/21 storage cask is divided into two parts. The first part presents an estimate of the occupational dose that would be incurred by the handling crew if the storage cask had contained spent fuel assemblies. The dose estimates resulting from this analysis approximate the occupational dose expected from the removal of a loaded storage cask from a reactor site, or the dose expected from the transfer of a loaded cask to a barge from a reactor.

The second part of the occupational dose evaluation consists of the actual dose resulting from cask loading activities. This dose evaluation is based on measured dose rates during cask loading operations and is verified by actual worker dosimeter readings. The evaluation of dose estimates for barge handling crews is presented in Section 3.1. The occupational dose resulting from storage cask loading is presented in Section 3.2. Dose reduction recommendations based on handling experience are presented in Section 3.3.

3.1 ESTIMATED DOSE FOR BARGE SPENT FUEL CASK HANDLING

Information on time in the vicinity of an empty storage cask and distance from the cask was collected for the barge handling crews during all phases of barge transport operations. Combining this information with dose rates measured from the loaded storage casks gives an estimate of occupational dose resulting from barge handling of loaded casks. These doses are shown in Table 3.1.

As shown by Table 3.1 total occupational dose for the barge handling/heavy haul transport is approximately 56 mrem, or 6 mrem/MTU. Over 24% (136 person-mrem) of the estimated occupational dose is incurred during shipping/storage cask and transporter preparations at the dock. The remaining occupational dose is due to cask handling operations within the Crane Enclosure Area (approximately 28 person-mrem) and at the ISFSI (approximately 12 person-mrem). Transportation activities account for roughly 2 person-mrem.

TABLE 3.1. Occupational Dose Estimates for Barge Handling of Loaded Spent Fuel Storage Casks[a]

	Crew Members	Time in Vicinity of Cask (min.)	Average Distance from Cask (ft)	Estimated Dose Rate From Cask (mrem/hr)	Cask Dose (person-mrem)
BARGE TRANSPORT AND DOCK OPERATIONS					
Barge travels up James River	5	230	100	0.00	0.00
Barge, tug, transport unit arrive at dock	6	25	100	0.00	0.00
Blocking and bracing removed from transport unit	2	15	5	5.00	2.50
Protective cover removed from cask	4	20	2	10.00	13.30
Subtotal		290			15.80
TRANSPORT TO CRANE ENCLOSURE					
Transport unit drives off barge	3	5	25	0.00	0.00
Transport unit travels along access road 2 miles to receiving area	3	10	25	0.00	0.00
Transport unit proceeds to station gate, 100 yards	3	2	25	0.00	0.00
Security search	1	45	10	2.00	1.50
Transport unit proceeds to Crane Enclosure	3	2	25	0.00	0.00
Subtotal		64			1.50
CASK REMOVAL FROM TRANSPORT UNIT					
Attach 125-ton crane to lift yoke	6	10	N/A	0.00	0.00
Attach lift yoke to cask	3	10	5	5.00	2.50
Horizontal lift of cask with impact limiters from transport unit	4	30	15	0.00	0.00
Remove impact limiters	6	15	5	5.00	7.50
Cask lowered to LIL on floor of Crane Enclosure	4	5	15	0.00	0.00
Disengage yoke from cask	4	10	5	5.00	3.33
Disengage 125-ton crane from yoke	4	10	N/A	0.00	0.00
Subtotal		90			13.33
CASK PREPARATIONS AND TRANSPORT TO ISFSI					
Lubricate trunions	2	7	2	10.00	2.33
Remove lag vehicle spreader bar	3	5	5	5.00	1.25
Position transporter over cask	5	15	10	2.00	2.50
Extend lift arms to cask trunions	3	5	15	0.00	0.00
Attach lift arms to cask trunions	4	10	5	5.00	3.33
Retract cask lifting arms	4	5	10	2.00	0.67
Check hydraulics	2	15	15	0.00	0.00
Raise cask to travel height	4	3	5	5.00	1.00
Attach restraint sling	2	5	5	5.00	0.83
Attach lag vehicle spreader bar	3	10	5	5.00	2.50
Change vehicle power to diesel	1	2	15	0.00	0.00
Proceed to ISFSI	10	15	15	0.00	0.00
Subtotal		237			14.41
ISFSI OPERATIONS					
Complete security badging	10	15	15	0.00	0.00
Remove lag vehicle spreader bar	3	5	5	5.00	1.25
Position cask at ISFSI	6	30	10	2.00	6.00
Remove restraint sling	2	5	5	5.00	0.83
Lower cask to storage pad	6	5	5	5.00	2.50
Detach lift arms	2	5	5	5.00	0.83
Attach lag spreader beam	3	5	15	0.00	0.00
Remove transporter	6	15	N/A	0.00	0.00
Subtotal		85			11.41
Total		766			56.45

(a) Developed using information provided in the appendix.

3.2 MEASURED DOSE FOR REACTOR SPENT FUEL CASK LOADING

Occupational dose from reactor spent fuel cask loading activities results from two sources: 1) the dose rate from the storage cask, and 2) the background dose rates for the areas where cask handling activities occur.

Measured background dose rates for reactor cask handling areas are provided in Figure 3.1. Background dose rates for the Crane Enclosure Area range from 0.1 to 1.2 mrem/hr, and average 0.25 mrem/hr. Dose rates for the Decontamination Building range from 0.5 to 2.0 mrem/hr, and average 1.0 mrem/hr. The background dose rate for the Fuel Building ranges from 1.0 to as high as 5 mrem/hr; dose rates for the deck around the cask handling area within the Fuel Building range from 3.0 to 5.0 mrem/hr.

A detailed dose assessment for the spent fuel cask loading operations is provided in the appendix. The results of the dose assessments are summarized in Table 3.2 for the 21 major cask handling activities. Total occupational dose incurred from the time the cask arrives to the reactor gate to the time the loaded storage cask is stored is 390.5 person-mrem, as shown by Table 3.2. Approximately 164 person-mrem of the occupational dose is due to background radiation, which represents approximately 42% of total dose. The three highest dose-incurring activities are:

	Activity	Dose
13	Install drain pipe through primary lid and pump water from cask	74.6 person-mrem
15	Install and torque primary lid bolts, vacuum dry cavity, and test cavity dryness and primary lid seal tightness	55.7 person-mrem
17	Install secondary lid	38.5 person-mrem

These three activities account for 43% of total dose, with Activity 13 accounting for 19% of the total. A breakdown of occupational dose by area in which the dose is incurred is shown in Table 3.3. As indicated by the data in Table 3.3, the majority of background dose results from cask handling activities in the Fuel Building.

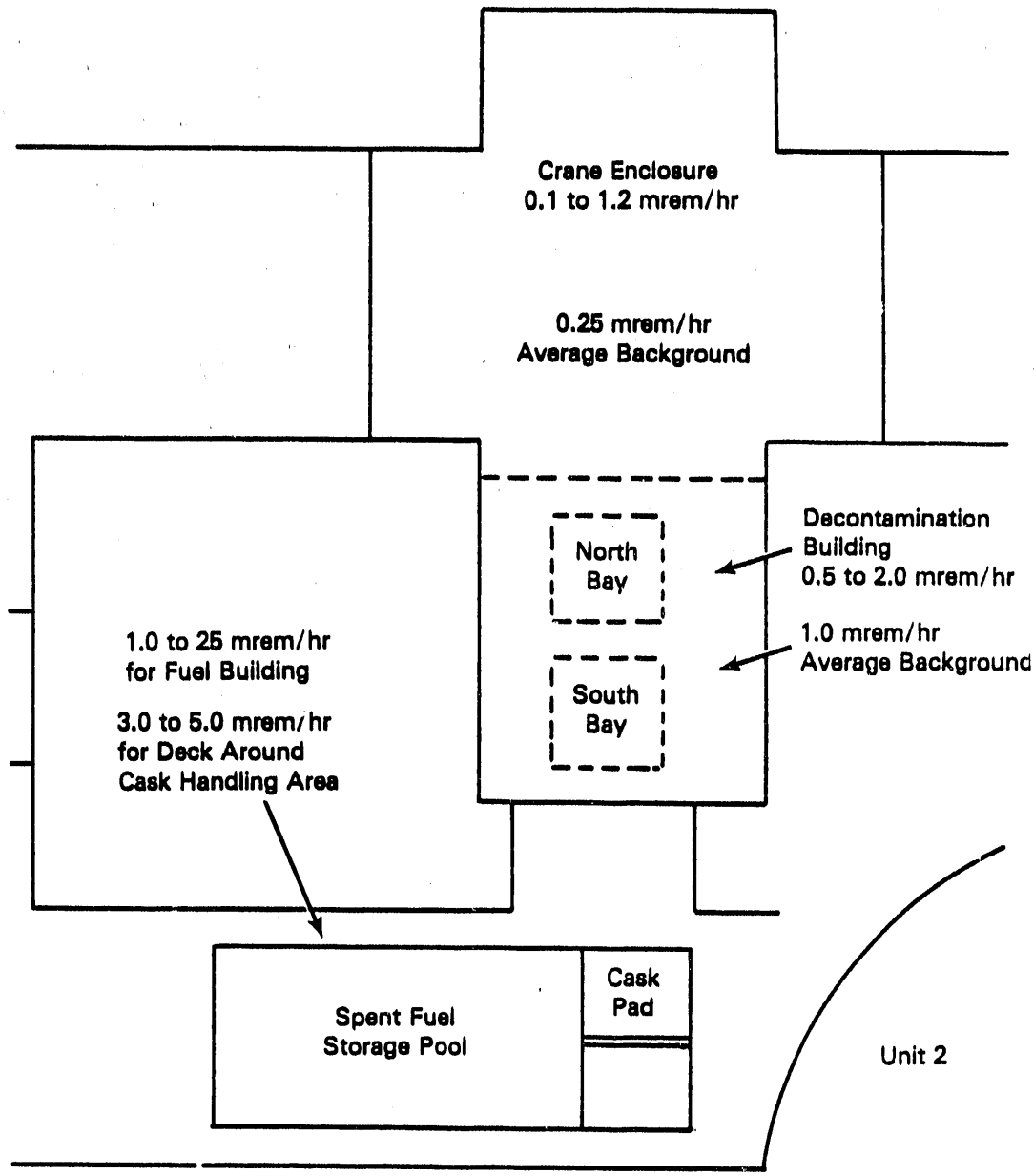


FIGURE 3.1. Background Dose Rates for Reactor Cask Handling Areas

Occupational dose by job category is shown in Table 3.4. As shown, operators receive approximately 44% of all dose, followed by decontamination technicians (28%) and health physics technicians (21%).

TABLE 3.2. Occupational Dose Resulting from At-Reactor Cask Loading Activities

Activity	Dose from Background (person-mrem)	Dose from Cask (person-mrem)	Total Dose (person-mrem)
1. Enter station to Crane Enclosure	0.0	0.0	0.0
2. Horizontal lift of cask and cradle	0.6	0.0	0.6
3. Upend cask, lift cask to North Bay	2.0	0.0	2.0
4. Remove lids, inspect, replace seals	13.3	0.0	13.3
5. Attach primary lid to hoist and lift	0.2	0.0	0.2
6. Attach lift yoke to cask and lift	1.3	0.0	1.3
7. Move cask to fuel building	6.3	0.0	6.3
8. Lower top of cask to pool surface, fill	8.0	0.0	8.0
9. Set cask on pool bottom, remove yoke	4.7	0.0	4.7
10. Load cask with assemblies	37.5	0.0	37.5
11. Install primary lid	33.8	0.0	33.8
12. Attach yoke, lift to surface, install bolts	15.0	15.0	30.0
13. Drain cask	19.6	55.0	74.6
14. Move cask to work area	4.9	16.2	21.1
15. Torque primary lid, vacuum dry	5.6	50.1	55.7
16. Backfill cavity with helium	2.3	14.2	16.5
17. Install secondary lid	5.2	33.3	38.5
18. Install seal monitoring instrument	1.4	7.9	9.3
19. Attach lift yoke and lift cask	1.0	3.0	4.0
20. Place on surface in Crane Enclosure	0.5	5.7	6.2
21. Transport cask to on-site storage area	1.1	25.8	26.9
Total	164.3	226.2	390.5

TABLE 3.3. Occupational Dose by Area in Which the Dose is Incurred

Location	Background Dose (person-mrem)	Cask Dose (person-mrem)	Total Dose (person-mrem)
Crane Enclosure (Empty)	1		1
North Bay (Empty)	16		16
Fuel Building	128	82	210
North Bay (Loaded)	18	112	130
Crane Enclosure (Loaded)	2	26	28
Storage Pad	0	5	5
Total	165	225	390

TABLE 3.4. Occupational Dose by Job Category

Category	Personnel	Average Dose/ Job Category (person-mrem)
Operations	1 Shift Supervisor	9
	4 Operators	172
Quality Control	1 Inspector (part-time)	2
Health Physics	1 Assistant Supervisor	9
	1-3 Technicians (part-time)	83
	1-2 Decontamination Technicians (part-time)	111
Engineering	1 Engineer (part-time)	3
Security	1-6 Officers (part-time)	1
Maintenance	1 Technician (part-time)	0
Contractor	2 Drivers (part-time)	0
Total		390

It should be noted that these dose estimates are based on spent fuel with an average burnup of 21,960 MWd/MTU and 11.3 years of cooling. Other fuel loadings may result in substantially different personnel dose levels.

3.3 DOSE REDUCTION SUGGESTIONS BASED ON HANDLING EXPERIENCE

Personnel dose reduction actions at the Surry Power Station target both area background dose rates and dose rates from the loaded storage casks. Techniques that can be used to reduce occupational dose include, but are not limited to, the following:

1. Placing low-source assemblies around the periphery of the cask basket. Longer cooled and lower burnup assemblies can have much lower radiation rates, especially for neutrons.

2. Providing low-dose waiting areas through the use of portable shielding.

3. Placing portable shields over the primary lid during drying and testing operations in the North Bay.

The first dose reduction technique targets the dose from the cask, which represents 60% of the occupational dose received during cask handling operations. The second dose reduction technique attempts to deal with the 40% of occupational dose due to background area dose. The third technique is designed to reduce the dose around the head of the cask, which accounts for approximately 175 mrems of exposure from the cask (about 45% of total occupational dose).

Dose reductions achieved through use of these suggestions will vary from reactor site to reactor site, depending upon the specifics of the site handling procedures and equipment utilization.

4.0 REFERENCES

GNS. 1983. Topical Safety Analysis Report for the CASTOR V Cask - Independent Spent Fuel Storage Installation (Dry Storage). Gesellschaft fur Nuklear-service mbh (General Nuclear Systems Inc.), Federal Republic of Germany.

APPENDIX

CASTOR V/21 HANDLING TIME, MOTION, AND DOSE DETAILS

TABLE A.1. CASTOR V/21 Cask Handling - Time and Motion Form - Revision 0, 06/29/87

Activity	Work Area	Crew Members	Time in Area (min)	Average Distance from Cask (ft)	Dose Rate from Cask (mR/hr)	General Area Dose Rate (mR/hr)	Cask Dose (mR)	General Area Dose (mR)	Personnel Time (man-hr)
A. AT SHIP DOCK									
1. Cask removed from ocean vessel	DK	4	30	25	0.00	0.00	0.00	0.00	2.0
2. Cask moved to barge dock crane	DK	2	15	25	0.00	0.00	0.00	0.00	0.5
3. Raise Cask from wood cradle	DK	8	80	5	0.00	0.00	0.00	0.00	10.7
4. Lower Cask to metal cradle on transport unit on barge	DK	8	20	5	0.00	0.00	0.00	0.00	2.7
5. Secure Cask to cradle	DK	2	15	2	0.00	0.00	0.00	0.00	0.5
6. Barge leaves dock	DK	5	15	100	0.00	0.00	0.00	0.00	1.3
			175				0.00	0.00	17.7

Activity	Work Area	Crew Members	Time in Area (min)	Average Distance from Cask (ft)	Dose Rate from Cask (mR/hr)	General Area Dose Rate (mR/hr)	Cask Dose (mR)	General Area Dose (mR)	Personnel Time (man-hr)
B. TRANSPORT TO STATION									
1. Barge travels up James River		5	230	100	0.00	0.00	0.00	0.00	19.2
2. Barge, tug, transport unit arrive at dock	DK	6	25	100	0.00	0.00	0.00	0.00	2.5
3. Blocking and bracing removed from transport unit	DK	2	15	5	0.00	0.00	0.00	0.00	0.5
4. Protective cover removed from Cask		4	20	2	0.00	0.00	0.00	0.00	1.3
5. Transport unit drives off barge	DK	3	5	25	0.00	0.00	0.00	0.00	0.3
6. Transport unit travels along access road 2 miles to receiving area		3	10	25	0.00	0.00	0.00	0.00	0.5
7. Transport unit proceeds to Station gate, 100 yards		3	2	25	0.00	0.00	0.00	0.00	0.1
			307				0.00	0.00	24.4
8. Security search		1	45	10	0.00	0.00	0.00	0.00	0.8
9. Transport unit proceeds to Crane Enclosure		3	2	25	0.00	0.00	0.00	0.00	0.1
			47				0.00	0.00	0.9
10. Horizontal lift of cask and cradle from transport unit	C/E	4	30	15	0.00	0.25	0.00	0.50	2.0
11. Cask and cradle lowered to floor of Crane Enclosure	C/E	4	5	15	0.00	0.25	0.00	0.08	0.3
			35				0.00	0.00	2.3
			389				0.00	0.58	27.6

TABLE A.1. (contd)

Activity	Work Area	Crew Members	Time in Area (min)	Average Distance from Cask (ft)	Dose Rate from Cask (mR/hr)	General Area Dose Rate (mR/hr)	Cask Dose (mR)	General Area Dose (mR)	Personnel Time (man-hr)
C. PREPARATION FOR LOADING									
1. Attach 125T crane to lift yoke	C/E	4	15	N/A	0.00	0.25	0.00	0.25	1.0
2. Attach lift yoke to Cask	C/E	4	5	5	0.00	0.25	0.00	0.08	0.3
3. Tilt Cask, raise 4 feet	C/E	4	5	25	0.00	0.25	0.00	0.08	0.3
4. Attach upper impact limiter to Cask	C/E	4	5	5	0.00	0.25	0.00	0.08	0.3
5. Lift, move Cask to Decon Bldg	C/E	2	10	25	0.00	0.25	0.00	0.08	0.3
6. Lower Cask into North Bay	D/B	4	10	15	0.00	1.00	0.00	0.68	0.7
7. Disengage lift yoke	D/B	3	10	5	0.00	1.00	0.00	0.50	0.5
8. Attach hoist, lower impact limiter	C/E	4	10	N/A	0.00	0.25	0.00	0.17	0.7
9. Move LIL to Decon Bldg roof	C/E	4	5	N/A	0.00	0.25	0.00	0.08	0.3
			75				0.00	2.00	4.4
10. Remove 3 secondary lid (SL) bolts	D/B	2	3	2	0.00	1.00	0.00	0.10	0.1
11. Install 3 SL alignment studs	D/B	2	3	2	0.00	1.00	0.00	0.10	0.1
12. Remove remaining 43 SL bolts	D/B	2	30	2	0.00	1.00	0.00	1.00	1.0
13. Attach lifting head to SL	D/B	3	5	2	0.00	1.00	0.00	0.25	0.3
14. Attach lifting tool to 10T hoist	D/B	2	10	N/A	0.00	1.00	0.00	0.33	0.3
15. Engage lifting tool to lifting head	D/B	2	5	4	0.00	1.00	0.00	0.17	0.2
16. Lift SL, move to storage	D/B	4	15	N/A	0.00	1.00	0.00	1.00	1.0
17. Disengage lifting tool	D/B	2	5	N/A	0.00	1.00	0.00	0.17	0.2
18. Clean SL sealing surface	D/B	2	10	N/A	0.00	1.00	0.00	0.33	0.3
19. Install SL seal protector	D/B	2	10	2	0.00	1.00	0.00	0.33	0.3
20. Remove 3 primary lid (PL) bolts	D/B	2	3	2	0.00	1.00	0.00	0.10	0.1
21. Install 3 PL alignment studs	D/B	2	3	2	0.00	1.00	0.00	0.10	0.1
22. Remove remaining 41 PL bolts	D/B	2	30	2	0.00	1.00	0.00	1.00	1.0
23. Attach lifting tool to 10T hoist	D/B	2	5	N/A	0.00	1.00	0.00	0.17	0.2
24. Attach lifting head to PL	D/B	2	5	2	0.00	1.00	0.00	0.17	0.2
25. Engage lifting tool to lifting head	D/B	2	5	N/A	0.00	1.00	0.00	0.17	0.2
26. Lift PL, move to storage	D/B	4	15	N/A	0.00	1.00	0.00	1.00	1.0
27. Disengage lifting tool	D/B	2	5	N/A	0.00	1.00	0.00	0.17	0.2
28. Clean PL sealing surface	D/B	2	10	2	0.00	1.00	0.00	0.33	0.3
29. Install PL seal protector	D/B	2	5	2	0.00	1.00	0.00	0.17	0.2
30. Tie nylon ropes to protector	D/B	2	5	2	0.00	1.00	0.00	0.17	0.2
31. Inspect fuel channels in basket	D/B	3	10	0	0.00	1.00	0.00	0.50	0.5
32. Replace PN metallic seal	D/B	5	30	N/A	0.00	1.00	0.00	2.50	2.5
33. Remove PL vent cover and fitting	D/B	2	5	N/A	0.00	1.00	0.00	0.17	0.2
34. Remove drain outer and inner covers	D/B	2	5	N/A	0.00	1.00	0.00	0.17	0.2
35. Replace SL metallic seal	D/B	5	30	N/A	0.00	1.00	0.00	2.50	2.5
36. Cover SL and PL	D/B	2	5	N/A	0.00	1.00	0.00	0.17	0.2
			272				0.00	13.34	13.6
			347				0.00	15.34	18.0

TABLE A.1. (contd)

Activity	Work Area	Crew Members	Time in Area (min)	Average Distance from Cask (ft)	Dose Rate from Cask (mR/hr)	General Area Dose Rate (mR/hr)	Cask Dose (mR)	General Area Dose (mR)	Personnel Time (man-hr)
D. LOADING									
1. Attach lifting head to PL	C/E	2	5	N/A	0.00	0.25	0.00	0.04	0.2
2. Engage lifting tool to lifting head	C/E	2	5	N/A	0.00	0.25	0.00	0.04	0.2
3. Lift PL with 10T hoist	C/E	3	5	N/A	0.00	0.25	0.00	0.06	0.3
			15				0.00	0.14	0.7
4. Attach crane to lift yoke	D/B	2	15	N/A	0.00	1.00	0.00	0.50	0.5
5. Attach lift yoke to Cask	D/B	2	10	2	0.00	1.00	0.00	0.33	0.3
6. Remove SL seal, protector	D/B	2	5	2	0.00	1.00	0.00	0.17	0.2
7. Raise Cask	D/B	2	10	10	0.00	1.00	0.00	0.33	0.3
			40				0.00	1.33	1.3
8. Attach lower, upper impact limiters	F/B	5	5	5	0.00	3.00	0.00	1.25	0.4
9. Move Cask to Fuel Pool	F/B	5	2	15	0.00	3.00	0.00	0.50	0.2
10. Release impactor limiters from Cask	F/B	6	15	5	0.00	3.00	0.00	4.50	1.5
			22				0.00	6.25	2.1
11. Lower top of Cask to pool surface	F/B	6	7	25	0.00	5.00	0.00	3.50	0.7
12. Fill Cask with water	F/B	6	15	5	0.00	3.00	0.00	4.50	1.5
			22				0.00	8.00	2.2
13. Lower Cask to bottom of Fuel Pool	F/B	4	5	25	0.00	5.00	0.00	1.67	0.3
14. Disengage lift yoke	F/B	6	2	25	0.00	5.00	0.00	1.00	0.2
15. Raise lift yoke, rinse with water	F/B	4	10	25	0.00	3.00	0.00	2.00	0.7
16. Move lift yoke to C/E	C/E	2	2	N/A	0.00	0.25	0.00	0.02	0.1
			19				0.00	4.69	1.3
17. Load 21 fuel assemblies in basket	F/B	3	150	25	0.00	5.00	0.00	37.50	7.5
18. Remove PL seal protector using rope	F/B	5	2	25	0.00	5.00	0.00	0.83	0.2
19. Bring PL from C/E	F/B	2	5	N/A	0.00	3.00	0.00	0.50	0.2
20. Attach chain fall below 10T hook	F/B	3	30	N/A	0.00	5.00	0.00	7.50	1.5
21. Lower PL onto Cask	F/B	6	30	25	0.00	5.00	0.00	15.00	3.0
22. Verify PL seated using CCTV	F/B	6	15	25	0.00	5.00	0.00	7.50	1.5
23. Disengage lifting tool from PL	F/B	6	5	25	0.00	3.00	0.00	1.50	0.5
24. Raise lifting tool, rinse	F/B	4	5	N/A	0.00	3.00	0.00	1.00	0.3
			92				0.00	33.83	7.2

TABLE A.1. (contd)

Activity	Work Area	Crew Members	Time in Area (min)	Average Distance from Cask (ft)	Dose Rate from Cask (mR/hr)	General Area Dose Rate (mR/hr)	Cask Dose (mR)	General Area Dose (mR)	Personnel Time (man-hr)
D. LOADING (contd)									
25. Position lift yoke over Cask	F/B	6	10	25	0.00	3.00	0.00	3.00	1.0
26. Lower to Cask, engage	F/B	6	10	25	0.00	5.00	0.00	5.00	1.0
27. Raise top of Cask to surface	F/B	4	10	10	0.00	3.00	0.00	2.00	0.7
28. Install 6 PL bolts	F/B	6	10	2	15.00	5.00	15.00	5.00	1.0
			40				15.00	15.00	3.7
29. Install Cask drain pipe through PL	F/B	6	15	5	10.00	5.00	15.00	7.50	1.5
30. Pump Cask dry	F/B	3	75	5	10.00	3.00	37.50	11.25	3.8
31. Secure from pumping	F/B	2	5	2	15.00	5.00	2.50	0.83	0.2
			95				55.00	19.58	5.5
32. Raise Cask from Fuel Pool, rinse	F/B	6	5	10	5.00	3.00	2.50	1.50	0.5
33. Move Cask over impact limiters	F/B	5	5	5	10.00	3.00	4.17	1.25	0.4
34. Attach impact limiters	F/B	6	5	5	10.00	3.00	5.00	1.50	0.5
35. Move Cask to Decon Bldg	F/B	2	5	15	2.00	0.25	0.33	0.04	0.2
36. Disconnect lower impact limiter	D/B	4	5	5	10.00	1.00	3.33	0.33	0.3
37. Lower Cask into North Bay	D/B	2	5	10	5.00	1.00	0.83	0.17	0.2
38. Disengage lift yoke, store	C/E	2	10	N/A	0.00	0.25	0.00	0.00	0.3
			40				16.17	4.88	2.4
			535				86.17	131.20	33.9

TABLE A.1. (contd)

Activity	Work Area	Crew Members	Time in Area (min)	Average Distance from Cask (ft)	Dose Rate from Cask (mR/hr)	General Area Dose Rate (mR/hr)	Cask Dose (mR)	General Area Dose (mR)	Personnel Time (man-hr)
E. DRYING AND TESTING									
1. Install SL seal protector	D/B	4	2	2	10.00	1.00	1.33	0.13	0.1
2. Remove lifting head from PL	D/B	3	10	2	10.00	1.00	5.00	0.50	0.5
3. Install vent plate adaptor	D/B	4	5	2	10.00	1.00	3.33	0.33	0.3
4. Install valve holder to adaptor	D/B	4	5	2	10.00	1.00	3.33	0.33	0.3
5. Set up Vacuum Drying System (VDS)	D/B	2	5	5	5.00	1.00	0.83	0.17	0.2
6. Remove PL alignment pins	D/B	4	5	2	10.00	1.00	3.33	0.33	0.3
7. Dry & clean PL bolt holes	D/B	4	15	2	10.00	1.00	10.00	1.00	1.0
8. Install PL bolts, torque	D/B	2	30	2	10.00	1.00	10.00	1.00	1.0
9. Vacuum dry fuel cavity	D/B	0	600	5	5.00	1.00	0.00	0.00	0.0
10. Test cavity dryness	D/B	4	10	5	5.00	1.00	3.33	0.67	0.7
11. Partially fill cavity with He	D/B	3	5	5	5.00	1.00	1.25	0.25	0.3
12. Test lid seals for tightness	D/B	3	10	2	10.00	1.00	5.00	0.50	0.5
13. Install leak test penetration plug	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
14. Remove PL vent hardware	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
			712				50.07	5.55	5.6
15. Install vent quick connect	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
16. Evacuate cavity to 1 mbar	D/B	2	30	5	5.00	1.00	5.00	1.00	1.0
17. Backfill cavity w/ He to 800 mbar	D/B	2	5	5	5.00	1.00	0.83	0.17	0.2
18. Install vent cover	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
19. Test vent cover for leak rate	D/B	2	10	5	5.00	1.00	1.67	0.33	0.3
20. Install drain outer cover	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
21. Test drain cover for leak rate	D/B	2	10	5	5.00	1.00	1.67	0.33	0.3
			70				14.18	2.34	2.4
22. Remove SL seal protector	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
23. Attach lifting tool to 10T hoist	D/B	4	5	N/A	0.00	1.00	0.00	0.33	0.3
24. Engage lifting tool to lifting head	D/B	4	5	N/A	0.00	1.00	0.00	0.33	0.3
25. Raise SL from storage	D/B	4	5	N/A	0.00	1.00	0.00	0.33	0.3
26. Lower SL onto cask	D/B	4	10	5	5.00	1.00	3.33	0.67	0.7
27. Disengage lifting tool	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
28. Remove lifting head	D/B	2	5	5	5.00	1.00	0.83	0.17	0.2
29. Remove lid alignment pins	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
30. Dry and clean SL bolt holes	D/B	2	15	2	10.00	1.00	5.00	0.50	0.5
31. Install SL bolts, torque	D/B	2	15	2	10.00	1.00	5.00	0.50	0.5
32. Install seal test instrument in SL	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
33. Evacuate interlid space to 1 mbar	D/B	2	5	5	5.00	1.00	0.83	0.17	0.2
34. Backfill space with He to 1000 mbar	D/B	2	5	5	5.00	1.00	0.83	0.17	0.2
35. Remove seal test plug	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2

TABLE A.1. (contd)

Activity	Work Area	Crew Members	Time in Area (min)	Average Distance from Cask (ft)	Dose Rate from Cask (mR/hr)	General Area Dose Rate (mR/hr)	Cask Dose (mR)	General Area Dose (mR)	Personnel Time (man-hr)
E. DRYING AND TESTING (contd)									
36. Install He leak detector	D/B	3	5	2	10.00	1.00	2.50	0.25	0.3
37. Test lid seals for leak rate	D/B	3	10	5	5.00	1.00	2.50	0.50	0.5
38. Remove He leak rate	D/B	3	5	2	10.00	1.00	2.50	0.25	0.3
39. Install seal test plug	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
			120				33.34	5.19	5.5
40. Fill space with He to 7000 mbar	D/B	2	15	5	5.00	1.00	2.50	0.50	0.5
41. Test seal monitoring instrument	D/B	3	5	5	5.00	1.00	1.25	0.25	0.3
42. Install quick connect cover	D/B	2	5	2	10.00	1.00	1.67	0.17	0.2
43. Test quick connect cover seal	D/B	3	10	5	5.00	1.00	2.50	0.50	0.5
			35				7.92	1.42	1.5
			937				105.51	14.50	15.0

Activity	Work Area	Crew Members	Time in Area (min)	Average Distance from Cask (ft)	Dose Rate from Cask (mR/hr)	General Area Dose Rate (mR/hr)	Cask Dose (mR)	General Area Dose (mR)	Personnel Time (man-hr)
F. TRANSPORT FOR STORAGE									
1. Attach 125T crane to lift yoke	C/E	6	10	N/A	0.00	0.25	0.00	0.25	1.0
2. Attach lift yoke to Cask	D/B	3	10	5	5.00	1.00	2.50	0.50	0.5
3. Lift Cask from North Bay	D/B	3	5	10	2.00	1.00	0.50	0.25	0.3
			25				3.00	1.00	1.8
4. Move Cask to Crane Enclosure	C/E	2	5	25	0.00	0.25	0.00	0.04	0.2
5. Lower cask to LIL on C/E floor	C/E	2	5	10	2.00	0.25	0.33	0.04	0.2
6. Disengage impact limiter from Cask	C/E	4	5	5	5.00	0.25	1.67	0.08	0.3
7. Lower Cask to floor	C/E	2	5	10	2.00	0.25	0.33	0.04	0.2
8. Disengage lift yoke from Cask	C/E	4	10	5	5.00	0.25	3.33	0.17	0.7
9. Disengage crane from yoke, store	C/E	4	10	N/A	0.00	0.25	0.00	0.17	0.7
			40				5.66	0.54	2.3
10. Lubricate load bearing surfaces	C/E	2	7	2	10.00	0.25	2.33	0.06	0.2
11. Remove lag vehicle spreader bar	C/E	3	5	5	5.00	0.25	1.25	0.06	0.3
12. Position transporter over cask	C/E	5	15	10	2.00	0.25	2.50	0.31	1.3
13. Extend lift arms to cask trunnions	C/E	3	5	15	0.00	0.25	0.00	0.06	0.3
14. Attach arms to trunnions	C/E	4	10	5	5.00	0.25	3.33	0.17	0.7
15. Retract arms lifting cask	C/E	4	5	10	2.00	0.25	0.67	0.08	0.3
16. Check lift hydraulic system	C/E	2	15	15	0.00	0.25	0.00	0.13	0.5
17. Raise cask to travel height	C/E	4	3	5	5.00	0.25	1.00	0.05	0.2

TABLE A.1. (contd)

Activity	Work Area	Crew Members	Time in Area (min)	Average Distance from Cask (ft)	Dose Rate from Cask (mR/hr)	General Area Dose Rate (mR/hr)	Cask Dose (mR)	General Area Dose (mR)	Personnel Time (man-hr)
F. TRANSPORT FOR STORAGE (contd)									
18. Attach restraint sling	C/E	2	5	5	5.00	0.25	0.83	0.04	0.2
19. Attach lag vehicle spreader bar	C/E	3	10	5	5.00	0.25	2.50	0.13	0.5
20. Change power to diesel	C/E	1	2	15	0.00	0.25	0.00	0.01	.0
21. Proceed to ISFSI	RD	10	15	15	0.00	0.00	0.00	0.00	2.5
22. Complete security badging at ISFSI	PAD	10	15	15	0.00	0.00	0.00	0.00	2.5
23. Remove lag spreader beam	PAD	3	5	5	5.00	0.00	1.25	0.00	0.3
24. Position cask at ISFSI	PAD	6	30	10	2.00	0.00	6.00	0.00	3.0
25. Remove restraint sling	PAD	2	5	5	5.00	0.00	0.83	0.00	0.2
26. Lower cask to pad	PAD	6	5	5	5.00	0.00	2.50	0.00	0.5
27. Detach lift arms	PAD	2	5	5	5.00	0.00	0.83	0.00	0.2
28. Attach lag spreader beam	PAD	3	5	15	0.00	0.00	0.00	0.00	0.3
29. Remove transporter	PAD	6	15	N/A	0.00	0.00	0.00	0.00	1.5
			182				25.82	1.10	15.5
			247				34.49	2.64	19.6

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