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Evaluation of Improvement Potential For Spent-Fuel-Cask Handling

A. L. Franklin

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EVALUATION OF IMPROVEMENT POTENTIAL FOR SPENT-FUEL-CASK HANDLING

A. L. Franklin

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ABSTRACT

This report describes the quantitative analysis of opportunities to improve the loading/unloading operations for spent fuel shipping casks. The improvement potential is defined as a reduction in the time for completion or worker exposure for the complete handling operations. Two casks have been chosen as representative of presently available shipping casks. These are the NAC-1/NFS-4 legal weight truck cask and the IF-300 rail cask. The handling operations for each of these casks are broken down into a series of sequential steps. The time for completion and worker exposure is described by a probability density function for each step. These step descriptions are then combined to form a base case description of the total loading/unloading operation. Potential improvement opportunities are evaluated by modifying the appropriate probability density function descriptors then recombining the steps to form a probabilistic description of the modified operation.

1.0 SUMMARY AND RECOMMENDATIONS

This report evaluates several opportunities to improve spent fuel handling operations. The areas of intended improvement are fleet or system turnaround time, facility turnaround time, and radiation exposure to workers. Two cask types were used in the study. The NAC-1/NFS-4 legal weight truck cask and the IF-300 rail cask were chosen to be representative of available spent fuel casks. Although some differences can be expected when comparing these casks with others, the recommendations proposed in this report are expected to apply generically to all existing and future spent fuel shipping casks. The handling operations for these two casks were evaluated for six potential improvements:

- increased payload
- improved head design
- improved cask surface
- automatic decontamination
- overpacks/contamination barriers
- improved crane design.

Table 1.1 presents a summary of the base case and improved system performance evaluations. The data summarized in this table represent the 50% points on the probability distribution functions that describe each case. A discussion of the use of probability distribution functions in this report can be found in Section 2.0. The actual time or exposure for each system configuration will likely be different than the values shown in the table. The actual values have, however, a 50% chance of being equal to or less than the values listed in the table. A quick examination of Table 1.1 shows an increase in cask payload as offering the greatest opportunity for improvement in the NAC/NFS cask handling operations. For the IF-300 the greatest improvement results from the use of overpacks or contamination barriers. For both casks, a reduction in worker exposure provides the primary motivation for these performance improvements. Lesser improvements are possible for facility turnaround time and fleet turnaround time.

TABLE 1.1. Summary of Potential Improvements^(a,b)

System Configuration	Fleet Turnaround		Facility Turnaround		Worker Exposure	
	Hours	Improvement	Hours	Improvement	Milli-man-rem	Improvement
NAC Cask						
Base Case	270	--	9	--	34	--
Increased Payload ^(c)	92	66%	3	66%	12	65%
Improved Head Design	269	<5%	8.5	6%	34	<5%
Improved Cask Surface	268	<5%	8	10%	24	29%
Automatic Decontamination	269	<5%	8.5	6%	22	36%
Overpacks/Contamination Barriers	269	<5%	8.5	6%	24	30%
IF-300 Cask						
Base Case	304	--	32	--	178	--
Increased Payload ^(c)	(d)	(d)	(d)	(d)	(d)	(d)
Improved Head Design	298	<5%	29	9%	163	8%
Improved Cask Surface	290	<5%	25	22%	93	48%
Automatic Decontamination	290	<5%	25	22%	93	48%
Overpacks/Contamination Barriers	288	<5%	24	25%	77	57%

(a) Based upon the 50% point on the probability distribution function curves.

(b) Significant figures are used for comparison purposes only, and are not intended as predictive values.

(c) Units are on a per fuel assembly basis.

(d) Analysis on this option was not performed, however, improvement would be approximately equal to percentage increase in payload.

Based upon potential improvement in worker radiation exposures and facility turnaround time, the following recommended priorities are made in approximate decreasing order of improvement potential:

For the legal-weight truck cask (NAC/NFS):

- increase payload
- develop automatic cask decontamination
- improve cask surface
- use overpacks/contamination barriers
- improve cask head design.

For the IF-300 rail cask:

- use overpacks/contamination barriers
- develop automatic cask decontamination
- improve cask surface
- improve head design
- increase payload.

For both casks, changes in crane design may provide some added convenience but would not substantially improve system performance.

2.0 INTRODUCTION

New reactors being built by electric utilities tend to have increased storage capacity for irradiated fuel elements. This trend is being motivated by a current Federal policy prohibiting the reprocessing of residual fissile material. If this trend continues, most reactors in the 1980s will have more than 15 years of spent fuel storage capacity (Winsor, Faletti and DeSteeese 1980). Consistent with this trend, the future condition of spent fuel will probably differ substantially from that fuel used as a design basis for the existing cask fleet. In addition, differences in demand for transportation services can be expected. These differences include the volume to be shipped, the out-of-reactor age of the fuel, the heat generation rate of the fuel, and the possibility of extensive shuttling of material between temporary storage sites.

Representatives of both industry and government have expressed concern that the transportation system for spent fuel may become inadequate during the 1980s (Winsor, Faletti and DeSteeese 1980). To address this concern, a project was carried out to identify new opportunities in the design and handling of spent nuclear fuel shipping casks (Winsor, Faletti and DeSteeese 1980). Particular emphasis was placed on approaches for reducing the turnaround time, cask handling labor, and radiation dose associated with spent fuel loading and unloading. Opportunities identified in this study were examined to determine if they were feasible for future improvement in spent fuel handling. Several recommendations appeared to provide substantial improvement opportunity and were recommended for further quantitative evaluation.

This study continues the investigation of improvement opportunities by providing a quantitative evaluation of each. The evaluation efforts discussed in this report include an examination of how loading/unloading contributes to time requirements and worker exposure. These contributions are also placed into an overall system perspective by including considerations of source/destination shipping times and administrative time considerations. Where appropriate, the discussions contain information pertaining to cask licensing.

Within this report, fleet (or system) turnaround time refers to the total amount of time required to load a spent fuel cask, ship it to an unloading point, unload the cask and return it to the point of origin ready for a second shipment. Statistical descriptions of transit times used in this report adjust for consecutive shipments that may not have the same point of origin. Facility turnaround time as used in this report refers to the time required to complete a loading or unloading of a spent fuel cask. Throughout this report, worker radiation exposure refers to the incremental increase in exposure that each crew member of a cask handling team experiences as the result of a loading or unloading operation. Due to minor differences between the loading and unloading operations, worker exposure is anticipated to be slightly less for unloading than for loading. The conservative assumption that the loading and unloading exposures are identical is made to simplify the analysis. Also, the analysis uses the dose rates from 5-year cooled fuel in calculating worker exposure.

Section 4.0 presents general descriptions of the NAC/NFS and IF-300 casks. A list of sequential loading steps is included. Following each general description the appropriate probability distribution functions are given. These show the composite loading operation from a probabilistic point of view.

Section 5.0 describes the improvement opportunities considered in this study. The quantitative impact of each innovation is discussed in the text and graphically compared to the base case descriptions.

3.0 STUDY APPROACH

A customary approach for this type of study is to identify those procedures to be investigated, itemize the sequence of events for these procedures, and assign a value (normally expected value) of time or worker exposure for each step. The total time for procedure completion or the total worker exposure for the complete operation is the direct sum of each of the individual steps. Occasionally the summation process becomes complicated when accounting for parallel procedural operations (two or more steps being carried out simultaneously).

This study has modified this approach slightly to provide a more realistic measure of the impacts of potential improvement opportunities. As before, the opportunities to be investigated were identified and each operation was divided into a sequence of operational steps. At this point, each step has a range of values estimated for time-to-complete and worker exposure. The value assignments were made in the form of a probability density function (pdf). Figure 3.1 shows the typical shape of the pdf assignments in this study. The horizontal axis is in units of time or milli-man-rems. The vertical axis is a measure of the probability of occurrence. In this manner, "a" represents the shortest amount of time or radiation exposure for an operation, the maximum

FIGURE 3-1. Typical Probability Density Function

amount of time or exposure is represented by "c" and the expected value for the operation is "b". The values of "a" and "c" were selected, based on personal observations and engineering judgment, to provide reasonable assurance that the actual time the operation takes will fall between a and c. Each procedural step in loading/unloading, inspection, and shipping was characterized in this manner. The pdf curves for each step were probabilistically combined to yield a pdf description of anticipated shipping operations. A base case was established by assigning pdf curves to the existing spent fuel handling system. Consideration of potential improvements were made by modifying the appropriate pdf curves to reflect expected changes in operation time or worker exposure. Not all changes are beneficial and one potential improvement may impact more than one procedural step.

The pdf curves provide a convenient means of displaying possible time or exposure variations of one or more procedural steps. These curves do not, however, display the information in a convenient manner for arriving at conclusions. Therefore, a second set of curves were produced for the turnaround time and total worker exposure information. These curves, produced by integrating the pdf curves, represent the probability distribution functions (PDF) for each case. The PDF curve, as shown in Figure 3.2, represents the probability of completing an operation within a given amount of time or less. For worker exposure, the interpretation is the probability of completing an operation with some amount

FIGURE 3.2. Typical Probability Distribution Function

of total exposure or less. In nearly all cases the PDF curve should approach a value of one. This implies that eventually all spent fuel handling operations are completed. In some cases, the PDF curve will not reach a value of one. This can be interpreted as the probability that the time to complete one or more of the sequence steps lays outside their pdf assignments. The value "a" on the horizontal axis of Figure 3.2 represents the 50% probability point. At this point, the probability that the operation requires less than "a" units of time is exactly equal to the probability the operation takes more than "a" units of time. This is not the same as the expected value of a function. In most cases in this analysis, the expected value (the point with the highest value on a pdf curve) was less than the 50% probability value. This is due to the non-symmetry of the pdf curves. The 50% value was used in this study as a means of quantifying the potential of each of the improvement opportunities considered. A 10% reduction in this value was considered a 10% improvement in performance. All conclusions and recommendations made in this report were based upon this parameter.

4.0 BASE CASE DESCRIPTIONS

This section describes the cask handling operations presently used with the IF-300 and NAC-1/NFS-4 spent fuel shipping casks. For convenience, consideration of existing cask designs has been limited to these two casks. Observations made in this report are expected to apply to other viable spent fuel shipping casks. This is because in general all existing and anticipated future casks have basically the same functional parts. Lifting mechanisms, radiation shields, and heat rejection surfaces are all customary features of spent fuel casks. The pdf curves used to describe the handling operations are expected to account for broad differences between these two cask types and others not discussed in this report. The pdf curves also adjust for differences in handling procedures from one location to another. The effects of some innovations are sufficiently small that they cannot be readily observed when the pdf curves are generalized to cover in broad range of cask types. In these cases, the estimates will be constrained to IF-300 and NAC/NFS casks and some differences can be expected when transferring the concepts to other casks.

Exposure estimates are made by considering each person involved in the loading/unloading operation to be at a particular location around the cask. The exposure estimates for some of the operational steps account for significant personnel movement around the cask. Statistical estimates of exposure for the complete operation will be arrived at by probabilistically combining the exposure estimates of the individual steps. Background exposure is not included in the exposure estimates.

4.1 NAC-1/NFS-4 CASK

The NFS-4 cask, illustrated in Figure 4.1 has a cavity 4.52 meters long and 0.34 meters in diameter (Winsor, Faletti and DeSteele 1980). Interchangeable fuel baskets provide a capacity of 1 PWR or 2 BWR fuel assemblies. The primary cask cavity consists of an 8-mm stainless steel pressure shell surrounded by a 168-mm thick lead gamma shield and a 32-mm thick compartmentized neutron

FIGURE 4.1. NFS-4 Spent Fuel Shipping Cask

shield tank. The shield tank contains a borated water antifreeze solution. An expansion chamber for the shield tank is included to accommodate temperature changes of the solution.

The cask lid that seals and shields the cask cavity is solid stainless steel and is attached to the cask by 6 high-strength bolts. The cavity is sealed by two O-rings.

Balsa wood impact limiters, encased in stainless steel, are located on the ends of the cask to provide impact protection. The lower impact limiter also serves as an expanded base for stability when the cask is vertical. A removable lid impact limiter is used to protect the cask head. This limiter is removed and stored on the transport trailer during the normal loading/

unloading operation. Necessary connections to the primary cavity (i.e., vent and drain valves, pressure test connections, and relief valves) are protected by the lid and upper impact limiter.

Two sets of trunnions are used for cask handling and transport tie-down purposes. The upper set, attached to the upper impact limiter, is used for lifting the cask. The lower trunnions are offset to provide a pivot from the vertical loading position into the horizontal transport mode.

A generalized handling procedure for this cask is listed in Table 4.1.

TABLE 4.1. NAC-1/NFS-4 Handling Procedures

1. Initial inspection, monitoring, and removal from vehicle
 - a. Receive cask, radiation survey, and obtain surface smears
 - b. Release forward and rear tie-downs, remove lid impact limiter
 - c. Attach yoke and lift from trailer
 - d. Transport cask to the decontamination area
2. Cask cleaning
 - a. Cask washdown
3. Casks preparation for placement in spent fuel pool
 - a. Remove head bolts
 - b. Monitor cask cavity
4. Storage pool operations
 - a. Place cask in loading/unloading pool and remove head
 - b. Load/unload fuel
 - c. Replace head, reconnect yoke, and return cask to decontamination pool
5. Loaded cask preparation and checks
 - a. Secure head
 - b. Flush cavity
 - c. Confirm fuel bundle integrity
6. Cask decontamination
7. Vehicle loading
 - a. Transport cask to trailer
 - b. Load cask onto trailer and secure tie downs and impact limiter
 - c. Survey cask and obtain release documents

The probability density function estimates for these steps are given in Appendix A. For each step there is a pdf for completion time and worker exposure. Observation of a NAC/NFS loading made possible the additional detail shown in Table 4.1. A later description of the IF-300 handling procedure is greatly simplified. This does not imply the IF-300 loading is more simple than that for the NAC/NFS cask.

Figure 4.2 presents a PDF curve of the handling time for the entire NAC-1/NFS-4 loading operation. This curve represents a description of the amount of time a cask loading might require. For the remainder of this report the term "facility turnaround time" will be used interchangeably with cask loading or unloading times. Facility turnaround time does not account for transit times between source and destination. The "fleet" or "system" turnaround time shown in Figure 4.3 accounts for two-way transit time in addition to both loading and unloading time. Transit times for the loaded shipment and empty return are assumed to be identical. These times are based upon a shipping distance of 1000 miles.

FIGURE 4.2. Probability Distribution Function for NAC-1/NFS-4 Facility Turnaround Time, Base Case

FIGURE 4.3. Probability Distribution Function for NAC-1/NFS-4 Fleet Turnaround Time, Base Case

Figure 4.4 presents a description of the radiation exposure to workers for a loading operation. This information accounts for exposure to the loading/unloading crew. Differences in the loading and unloading operations should make the unloading exposure slightly less. An example of these differences would be in the cask decontamination operation. Workers decontaminating the cask following a loading will receive substantially more exposure than those decontaminating the empty cask following the unloading. This difference will be partially compensated for by a reversal of the situation during the cask preparation process prior to placing the cask in the fuel storage pool. Other minor differences can be identified between the loading and unloading operations. The net result of these differences should be a slightly smaller exposure for an unloading operation than for a loading operation. In this study, however, unloading exposures are conservatively assumed to be the same as loading exposures.

FIGURE 4.4. Probability Distribution Function for Radiation Exposure for Loading a NAC-1/NFS-4 Cask, Base Case

The information presented in Figure 4.4 represents the incremental increase in worker exposure due to the loading operation. It does not include occupational background exposure or the exposure to the truck drivers during transit.

As mentioned earlier, the PDF curves predict a range of possible values for completion time or radiation exposure for loading/unloading operations. The range determined in this study appears consistent with values predicted in similar studies (Anderson 1978).

4.2 IF-300 CASK

The General Electric IF-300 spent fuel shipping cask, illustrated in Figures 4.5 and 4.6, is designed to ship 18 BWR elements or 7 PWR fuel elements irradiated to design exposures. When loaded, the cask weighs between

FIGURE 4.5. IF-300 Cask

FIGURE 4.6. IF-300 Irradiated Fuel Shipping Cask
(Shown in Normal Rail Transport Configuration)

61,700 and 63,500 kgs, depending on the particular type of fuel being shipped. The skid and cooling system weigh approximately 20,400 kgs. (GEI-92817 1973)

The cask is mounted on a skid in a horizontal position during transport. Transportation is primarily by rail, although the skid is designed to accept wheel assemblies for short-haul, special permit trucking. This dual-mode shipping configuration permits the use of the IF-300 cask at those reactor sites that have no direct rail access. The short-haul capability is used to move the cask to the nearest convenient railhead, where it will be transferred to its primary mode of transportation using roll-on/roll-off techniques.

The cask is supported on the skid by a saddle at the head end and a cradle at the bottom end. The cradle forms the pivot about which the cask is rotated to a vertical position for removal from the skid. There is one pickup position on the cask body just below the closure flange. The support saddle engages the cask at this section. The lifting trunnions are removed during transport.

The cask is lifted by a special yoke. This yoke accepts the normal reactor building crane hook in its upper end and engages the cask lifting trunnions with two hooks on its lower end. The same yoke is used for both cask rotation and cask lifting. Once the cask is in the spent fuel pool the cask head is removed using two steel cables attached to the lifting yoke.

All external and internal surfaces of the cask are stainless steel. The inner and outer shells are Type 317 stainless steel, and the flanges and fins are ANSI-300 stainless steel Type 304. The fuel baskets also are made of stainless steel. Gamma and fast neutron shielding are provided by water in the cask cavity, depleted uranium metal within the cask shell, and an exterior water-filled enclosure. The exterior shielding water enclosure is fabricated from thin-walled stainless steel, and is corrugated to increase the heat transfer area. The corrugations also significantly increase the strength of the outer jacket and its resistance to damage. This cylindrical containment is attached to the cask body and masks the active fuel zone.

The closure head is sealed with a metallic gasket. The maximum normal operating pressure for the cask cavity is 1380 kPa. However, the design

working pressure is 2760 kPa at a material temperature of 435°C. Overpressure for the valve is 2400 kPa. The valve is set for a maximum steam or gas blow-down of 5% and a liquid blowdown of 10%. The cask cavity is equipped with two nuclear service valves, one in each of two valve boxes for filling, draining, venting and sampling. These valves have quick disconnect fittings for ease in servicing. Both valve handles are secured during transit to prevent tampering. A pressure gauge with quick disconnect fittings is provided with the cask tool kit. The shielding water containment is protected from overpressure by a 1380 kPa relief valve. It is also serviced by fill and drain valves located in two valve boxes. Four tanks have been fitted to each cask to contain the shielding water during thermal expansion.

The fuel assemblies are contained within a removable, slotted, stainless steel basket: one designed to accommodate BWR assemblies and one for the PWR assemblies. Criticality control is achieved by using B_4C -filled, stainless steel tubes welded to the basket. Fuel elements are restrained axially by spacers mounted on the inside of the closure head. The basket is centered within the cask cavity by disc spacers. Nine such spacers are mounted along the fuel basket length. Fuel elements are inserted and removed from the basket using standard grapples. The basket is removed only when the cask is to be used for the shipment of another fuel type.

The outer surface of the cask body is finned for impact protection. These fins are stainless steel and are welded to the cask surface. The cask ends and valve boxes are also finned for impact protection. The external water jacket is constructed of thin-walled material and does not contribute to the impact protection of the cask.

A generalized handling procedure for this cask is listed in Table 4.2. The probability density function estimates for these seven steps can be found in Appendix A. For each step there is a pdf curve for completion time and worker exposure. The radiation exposure curves for those steps that contribute significant amounts to the worker exposures are also presented in Appendix A.

TABLE 4.2. IF-300 Handling Procedures

<u>Step</u>	<u>Procedure</u>
1	Initial inspection, radiation monitoring, and removal from vehicle
2	Cask cleaning
3	Cask preparation for placement in spent fuel pool
4	Storage pool operations
5	Loaded cask preparation and checks
6	Cask decontamination
7	Vehicle loading

The facility turnaround time for an IF-300 loading is displayed in Figure 4.7. The fleet turnaround time is presented in Figure 4.8. The incremental increase in worker exposure due to an IF-300 loading operation is shown in Figure 4.9. As with the NAC cask, these curves appear consistent with previous studies of this type (Anderson 1978).

FIGURE 4.7. Probability Distribution Function for IF-300 Facility Turnaround Time, Base Case

FIGURE 4.8. Probability Distribution Function for IF-300 Fleet Turnaround Time, Base Case

FIGURE 4.9. Probability Distribution Function for Radiation Exposure for Loading an IF-300 Cask, Base Case

5.0 IMPROVEMENT EVALUATIONS

The following section describes several potential improvements in spent fuel handling. Each potential improvement is discussed as it pertains to the NAC-1/NFS-4 or IF-300 shipping casks. Subjects discussed for each innovation will be the impact on fleet turnaround time, facility turnaround time and worker exposure. The discussion uses probability distribution functions to graphically demonstrate the predicted improvement potential of each concept. Quantification of improvement (i.e., percent improvement) is based on the 50% points on the PDF curves as discussed in Sections 3.0, 4.1 and 4.2.

5.1 INCREASED CASK PAYLOAD

Lower radioactivity levels in long-cooled fuel will make possible an increase in cask payload without increasing surface dose rates from the cask. To accomplish this, extensive cask redesign would be necessary. Shielding requirements would need to be re-evaluated and perhaps adjusted to maintain acceptable exposure levels and cask weight limitations. Reasonable opportunity appears to exist for increasing the payload of a legal-weight truck cask. This would have a direct impact on fleet productivity by reducing the number of shipments necessary to complete a shipment campaign. Presently the NAC/NFS cask can accommodate 1 PWR and 2 BWR fuel assemblies. If possible a new cask design would triple that amount, the fleet productivity would improve approximately 66% per fuel assembly as shown in Figure 5.1.

The facility turnaround time will increase slightly for each loading because of the additional fuel assemblies. However, as with the fleet turnaround time, the turnaround time per fuel assembly will decrease approximately 66%. The same reduction is expected for radiation exposure to workers.

The IF-300 is already a multiple fuel assembly cask. The opportunity for increasing the payload of this cask is somewhat less than the NAC cask. If significant increases could be made in the payload, the estimated improvement in handling would be approximately equal to the percentage increase in payload. This improvement estimate applies to facility turnaround time, fleet turnaround time and worker radiation exposure.

FIGURE 5.1. Probability Distribution Function for Fleet Turnaround Time for NAC Cask; Increased Payload and Base Case

5.2 CASK HEAD DESIGN

Several aspects of head closure systems for both the IF-300 and NAC/NFS casks are candidates for potential improvement. The IF-300 cask head is secured with 32 head bolts that are torqued to 950 N-m. The time involved in unbolting and bolting the cask head is a significant fraction of the loading/unloading time. Dimensional tolerances for the cask head are sufficiently small that head alignment can be difficult. Not only must the head bolts and holes be aligned correctly, but also the head must remain level with respect to the cask. This is necessary to reduce the chance of jamming the head.

Aligning and securing the head of the NAC/NFS cask is not as difficult as with the IF-300. Head jamming can, however, still occur if the head becomes tilted with respect to the cask. In addition, a complicating factor to NAC/NFS head alignment is the O-ring seals. During the alignment procedures the O-ring seals on the head have a tendency to come loose and fall away from the head.

It was found that a redesign of the cask head, head alignment, and head-securing mechanisms will not appreciably improve the turnaround time or reduce the worker exposure for the NAC/NFS cask. A 5% reduction in facility turnaround time is indicated by the curves in Figure 5.2. This improvement would be due to a reduction in time for cask preparation prior to entering the storage pool and a reduction in the amount of time to reposition the head following the loading operation. Any reduction in time required to secure the head following the loading operation is masked by operations carried out simultaneously with securing the head. These activities include flushing the cavity and decontaminating the cask.

FIGURE 5.2. Probability Distribution Function for Facility Turnaround Time; Improved NAC/NFS Cask Head Design and Base Case

No measurable reduction in worker exposure is anticipated for a redesigned NAC/NFS head because reductions in handling time occur during low-exposure operations (i.e., empty cask preparation and head alignment within spent fuel pool).

A head redesign for the IF-300 cask could result in significant savings in facility turnaround time. A reduction in the number of head-securing bolts and an increase in the dimensional tolerances could substantially shorten the time for cask preparation and head alignment. Before these changes can be made in the IF-300 design, a different cask sealing method would be needed. The present tolerances and number of head bolts are necessary to maintain adequate seals for all design conditions. Figure 5.3 shows the range of potential facility turnaround improvement for a redesigned cask head. This represents approximately a 9% decrease in facility turnaround time.

FIGURE 5.3. Probability Distribution Function for IF-300; Turnaround Time for New Head Design and Base Case

The estimated improvement in worker exposure resulting from an improved IF-300 cask head design is 8%. This is shown graphically in Figure 5.4. The reductions in exposure are the direct result of shorter handling times.

5.3 CASK SURFACE

Future casks may be carrying fuel cooled longer than that used as a design basis for existing casks. If so, the lower heat flux from long-cooled fuel may

FIGURE 5.4. Probability Distribution Function for IF-300; Exposure Reduction for New Head Design and Base Case

eliminate the need for heat dissipation fins or corrugations. The elimination of these surface irregularities will reduce the casks' tendency to retain contamination. It will also allow for easier surface access where decontamination is needed.

Contamination rejection might be further enhanced by using a coating that is radiation resistant and permanently applied to the cask surface. An epoxy based paint may be one possibility. Such a coating might make the removal of residual contamination easier and faster, in addition to reducing the amount of contamination involved.

An ideal cask surface, using one or more of these ideas, is expected to result in the facility turnaround improvement shown in Figure 5.5 for the NAC/NFS cask. The improvement potential for the IF-300 is shown in Figure 5.6. These two figures depict a 10% and 22% improvement respectively.

The opportunity to realize these improvements in facility turnaround time will be limited somewhat by fuel integrity checks. During a cask loading operation, it is not unusual to perform fuel integrity checks simultaneously

FIGURE 5.5. Probability Distribution Function for Facility Turnaround Time; Improved NAC Cask Surface and Base Case

FIGURE 5.6. Probability Distribution Function for Turnaround Time; Improved IF-300 Cask Surface and Base Case

with cask decontamination. Presently, for the NAC/NFS cask, the decontamination and integrity checks require approximately the same amount of time to complete. Full realization of cask surface improvements may require complimentary changes in fuel integrity confirmation methods.

The potential for worker exposure reduction by way of improved cask surface is 30% for the NAC/NFS cask and 45% for the IF-300. These reductions are shown graphically in Figures 5.7 and 5.8.

Unlike turnaround time, personnel exposure to radiation is not sensitive to fuel integrity confirmation. If, however, special coatings are used on the cask surface, special handling requirements may be necessary to prevent damage to the coating. Depending upon the nature of the coating and the required adjustments in handling procedures, a portion of the radiation exposure may be transferred to another step in the loading/unloading process rather than actually being removed from the operation.

FIGURE 5.7. Probability Distribution Function for Radiation Exposure; Improved Cask Surface and Base Case for NAC/NFS Cask

FIGURE 5.8. Probability Distribution Function for Radiation Exposure; Improved Cask Surface and Base Case for IF-300 Cask

5.4 AUTOMATIC DECONTAMINATION

Cask decontamination contributes significantly to overall facility turnaround time. Also, a majority of the worker exposure experienced during the loading operations can be attributed to cask decontamination. Automation of the decontamination process may result in significant improvement in both of these areas. Reduction in turnaround time may also be affected by required fuel integrity checks as discussed earlier.

There are at least three approaches to automating the decontamination process. The first and most apparent would be a mechanized work station capable of removing surface contamination. In this approach, the cask would be placed in the decontamination area immediately upon removal from the storage pool. Mechanically controlled scrubbing devices would then remove the surface contamination in much the same manner as is presently done with manual labor. A decontamination area of this type could also be used to clean incoming casks and casks contaminated during dry handling operations.

A second approach would be to use ultrasound as a scrubbing mechanism. The ultrasound approach would require a liquid medium for the ultrasound to be effective. This implies a wet handling operation. The ultrasonic devices would be installed in the storage pool (similar to present day spray rings) or in a separate decontamination chamber.

A third approach to automatic decontamination would be the application of a temporary coating to the exterior of the cask. This could have an adhesive affect on radioactive particles, binding them to the coating. Following the loading/unloading operation the coating would be "peeled" off the cask, removing any contamination picked up in the storage pool and perhaps some residual contamination that was on the cask when the coating was applied. It is possible that such a coating could reduce the preparation time necessary before putting the cask into the storage pool. Presently it is common to clean the cask before placing it in the storage pool. This is to remove dirt and grime picked up during transit. The adhesive coating might be sprayed over the road dirt and then be used to remove the dirt at the same time as the normal cask decontamination. Such a coating would need to be compatible with the storage-pool water chemistry and tolerant of radiation exposure for short periods of time.

The potential facility turnaround time improvement for the NAC/NFS and IF-300 casks were determined to be 6% and 22%, respectively. This information is shown graphically in Figures 5.9 and 5.10. The exposure reductions for these two casks were determined to be 36% and 45% as shown in Figures 5.11 and 5.12. These estimates are based on a mechanized work station for decontamination. The ultrasonic cleaning and temporary coating concepts were included in the discussion for completeness. However, no quantitative analysis was performed for the concepts because of the lack of detailed information.

5.5 OVERPACKS/CONTAMINATION BARRIERS

Overpacks and contamination barriers are another way of attempting to reduce the time and exposure involved with cask decontamination. The function of contamination barriers is to prevent loose radioactive material from ever coming in

FIGURE 5.9. Probability Distribution Function for Facility Turnaround Time; Automatic Decontamination and Base Case for the NAC Cask

FIGURE 5.10. Probability Distribution Function for Facility Turnaround Time; Automatic Decontamination and Base Case for the IF-300 Cask

FIGURE 5.11. Probability Distribution Function for Radiation Exposure; Automatic Decontamination and Base Case for the NAC Cask

FIGURE 5.12. Probability Distribution Function for Radiation Exposure; Automatic Decontamination and Base Case for the IF-300 Cask

contact with the cask, thus eliminating the need for decontamination. Generally, contamination barriers protect only a portion of the cask and contribute significant time and worker exposure to the loading/unloading operation while being installed on the cask.

Overpacks approach the decontamination problem from a different aspect than contamination barriers. They are intended to reduce the amount of decontamination necessary from a conventional loading/unloading operation. The overpack would serve as a barrier between higher cask surface contamination levels and the environment. Periodic decontamination would be necessary to maintain reasonable activity levels on the interior of the overpack. As before, there will be some time and exposure investment in installing and removing the overpacks. Also, since the overpack would become a part of the shipping system, there are questions regarding the required licensing of the overpack. It may be possible to consider the overpack a Type A package since it is intended to contain the small amounts of surface contamination.

The estimated impact from the use of overpacks and contamination barriers on facility turnaround time is 6% for the NAC/NFS cask and 25% for the IF-300. These estimates are shown in Figures 5.13 and 5.14. The reductions in worker exposure for the NAC/NFS and IF-300 casks were determined to be 30% and 55%, respectively, as shown in Figures 5.15 and 5.16.

5.6 CRANE DESIGN

Several aspects of the crane design at the loading/unloading facility can influence the time required to load/unload a spent fuel cask. At some facilities the crane is restricted in the number of directions it can move. This requires that the vehicle carrying the cask be positioned in exactly the correct location. The time investment in this precise vehicle positioning generally decreases with practice. Additional degrees of freedom for the crane can easily alleviate this problem.

At some facilities, plant layout forces indirect transfer means from the vehicle to the cask preparation area. These situations should be avoided when possible.

FIGURE 5.13. Probability Distribution Function for Facility Turnaround Time; Application of Overpack/Contamination Barrier and Base Case for the NAC Cask

FIGURE 5.14. Probability Distribution Function for Facility Turnaround Time; Application of Overpack/Contamination Barrier and Base Case for the IF-300 Cask

FIGURE 5.15. Probability Distribution Function for Radiation Exposure; Application for Overpack/Contamination Barrier and Base Case for the NAC/NFS Cask

FIGURE 5.16. Probability Distribution Function for Radiation Exposure; Application of Overpack/Contamination Barrier and Base Case for the IF-300 Cask

One additional consideration should be made when designing crane facilities. The crane operator should be positioned so he can observe the cask and crane hook position at all times.

None of these suggestions is expected to appreciably impact facility turnaround time or worker exposure. This is because it would be rare to find a facility with all three problems. Each condition by itself is not significant. However, adequate consideration of these items during the design of a new facility would be appropriate for minimizing turnaround time and exposure during spent fuel handling.

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APPENDIX A

PROBABILITY DENSITY FUNCTIONS FOR
NAC-1/NFS-4 AND IF-300 HANDLING OPERATIONS

APPENDIX A

PROBABILITY DENSITY FUNCTIONS FOR NAC-1/NFS-4 AND IF-300 HANDLING OPERATIONS

This section shows the probability density function estimates. Figures A.1 - A.28 pertain to the NAC/NFS spent fuel shipping cask. Figures A.29 - A.42 pertain to the IF-300 cask. Caution should be used when reviewing these figures. The scales used in these figures were chosen for maximum visibility and are not consistent from one figure to the next. The reader should check the scales before comparing one figure to the next.

The completion time figures have the units of probability of x versus hours. The probability of x (hours) is plotted on the vertical scale and hours are plotted on the horizontal scale. The personnel exposure figures have the units of probability of x versus milli-man-rems. Again, the probability of x (milli-man-rems) is plotted on the vertical scale and milli-man-rems is plotted on the horizontal scale.

FIGURE A.1. Step 1a. Completion Time for NAC/NFS Cask

FIGURE A.2. Step 1a. Personnel Exposure for NAC/NFS Cask

FIGURE A.3. Step 1b.Completion Time for NAC/NFS Cask

FIGURE A.4. Step 1b.Personnel Exposure for NAC/NFS Cask

FIGURE A.5. Step 1c. Completion Time for NAC/NFS Cask

FIGURE A.6. Step 1c. Personnel Exposure for NAC/NFS Cask

FIGURE A.7. Step 1d. Completion Time for NAC/NFS Cask

FIGURE A.8. Step 1d. Personnel Exposure for NAC/NFS Cask

FIGURE A.9. Steps 2 Plus 3. Completion Time for NAC/NFS Cask

FIGURE A.10. Steps 2 Plus 3. Personnel Exposure for NAC/NFS Cask

FIGURE A.11. Step 4a. Completion Time for NAC/NFS Cask

FIGURE A.12. Step 4a. Personnel Exposure for NAC/NFS Cask

FIGURE A.13. Step 4b. Completion Time for NAC/NFS Cask

FIGURE A.14. Step 4b. Personnel Exposure for NAC/NFS Cask

FIGURE A.15. Step 4c. Completion Time for NAC/NFS Cask

FIGURE A.16. Step 4c. Personnel Exposure for NAC/NFS Cask

FIGURE A.17. Step 5a. Completion Time for NAC/NFS Cask

FIGURE A.18. Step 5a. Personnel Exposure for NAC/NFS Cask

FIGURE A.19. Step 5b. Completion Time for NAC/NFS Cask

FIGURE A.20. Step 5b. Personnel Exposure for NAC/NFS Cask

FIGURE A.21. Steps 5c Plus 6. Completion Time for NAC/NFS Cask

FIGURE A.22. Steps 5c Plus 6. Personnel Exposure for NAC/NFS Cask

FIGURE A.23. Step 7a. Completion Time for NAC/NFS Cask

FIGURE A.24. Step 7a. Personnel Exposure for NAC/NFS Cask

FIGURE A.25. Step 7b. Completion Time for NAC/NFS Cask

FIGURE A.26. Step 7b. Personnel Exposure for NAC/NFS Cask

FIGURE A.27. Step 7c. Completion Time for NAC/NFS Cask

FIGURE A.28. Step 7c. Personnel Exposure for NAC/NFS Cask

FIGURE A.29. Step 1. Completion Time for IF-300 Cask

FIGURE A.30. Step 1. Personnel Exposure for IF-300 Cask

FIGURE A.31. Step 2. Completion Time for IF-300 Cask

FIGURE A.32. Step 2. Personnel Exposure for IF-300 Cask

FIGURE A.33. Step 3. Completion Time for IF-300 Cask

FIGURE A.34. Step 3. Personnel Exposure for IF-300 Cask

FIGURE A.35. Step 4. Completion Time for IF-300 Cask

FIGURE A.36. Step 4. Personnel Exposure for IF-300 Cask

FIGURE A.37. Step 5. Completion Time for IF-300 Cask

FIGURE A.38. Step 5. Personnel Exposure for IF-300 Cask

FIGURE A.39. Step 6. Completion Time for IF-300 Cask

FIGURE A.40. Step 6. Personnel Exposure for IF-300 Cask

FIGURE A.41. Step 7. Completion Time for IF-300 Cask

FIGURE A.42. Step 7. Personnel Exposure for IF-300 Cask

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