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<p style="text-align: center;">APPROVED FOR PUBLIC RELEASE</p> <p>7. Abstract</p> <p>This revision adds a section addressing impacts of dropping surfacing tool and rack cutter on the basin floor, and corrects typographical errors.</p> <p>The safety assessment is made for the activities for the preparation and installation of the discharge chute isolation barriers. The safety assessment includes a hazard assesment and comparisons of potential accidents/events to those addressed by the current safety basis documentation. No significant hazards were identified. An evaluation against the USQ evaluation questions was made and the determination made that the activities do not represent a USQ. Hazard categorization techniques were used to provide a basis for readiness review classifications.</p>		
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SAFETY ASSESSMENT OF
DISCHARGE CHUTE ISOLATION BARRIER
PREPARATION & INSTALLATION ACTIVITIES

REVISION 3

November 8, 1994

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SAFETY ASSESSMENT OF
DISCHARGE CHUTE ISOLATION BARRIER PREPARATION & INSTALLATION

1.0 SUMMARY

This analysis concludes that activities associated with installation of isolation barriers in the K Basins at Hanford can be performed safely. Doses to workers and to offsite personnel from the airborne releases resulting from the accidents bounded by this analysis will be minimal.

The activities involved have been reviewed for hazards. No new hazards have been identified that have not been addressed by the existing safety basis documentation. The activities described have been reviewed and do not represent an unreviewed safety question.

The dominant hazards are occupational safety related. Industrial safety hazards are primarily associated with barrier handling; they will be managed to protect workers by treating lifts as critical lifts. Industrial hygiene risks have been limited by selection of the materials used.

Radiation exposure for workers has been estimated and measures have been identified to limit the number of workers present, the radiation field, and the time for each job. Examples of such measures include remote control panels for surface preparation equipment and remote data collection equipment for testing. Further, work will be performed in the low field of KW first. Following this, before entry into the high fields of KE, a detailed critique will be held of KW operations identify and implement further measures to limit exposures in KE.

1.1 PURPOSE AND SCOPE OF THE DOCUMENT

The scope of this analysis is limited to activities at 105 KE & 105 KW Basins necessary to install isolation barriers in the entry to discharge chutes. These activities are preparatory to resolution of a USQ related to seismic integrity; these activities do not in themselves resolve the USQ.

The purpose of this analysis is to identify, analyze, and provide the basis for managing the hazards associated with activities specific to preparing the basin for installation of isolation barriers, installation of isolation barriers, and testing of isolation barriers.

1.1.1 ASSESSMENT OF THE SAFETY OF PLANNED ACTIVITIES

The approach selected for preparation of the basin and installation of the isolation barriers is based on simple, proven technology. Discipline in conduct of operations has been enhanced by providing compensatory measures for known weaknesses; examples include controlling all field work to a Master Work Plan (MWP), and verifying all operating procedures applying to these activities. Activities have been considered to determine what failures were credible, identifying measures to limit failure risk, and evaluating the need for recovery procedures. All planned activities can be performed within the safety envelope of the current SAR and with appropriately managed risk to plant personnel and to the general public.

1.1.2 ANALYSIS RELATED TO THE BASIS FOR RECOMMENDATION ON READINESS ASSESSMENT

Although DOE-STD-3006-93 states that graded readiness activities are appropriate, limited guidance on this additional grading exists. As a result WHC elected to attempt a better refinement by performing an activity specific hazard classification and determining whether planned activities not routinely performed in the past are activity specific hazard category 2. Activity specific hazard classification determined that the activity is arguably less than Category 2. This is primarily a result of the narrow range of in-basin activities planned.

The activity specific hazard category of the activity is determined in accordance with DOE-STD-1027-92, a supporting guide for DOE Order 5480.23, "Nuclear Safety Analysis Reports." This determination is based on a comparison of Threshold Quantities with the at-risk inventory consisting of the fuel, including transuranics and fission products, covered by the water in the basin. "New" activities (ie those not routinely performed previously) were evaluated. The evaluation found that there is no possible accident such as an equipment drop that could credibly impact the Category 2 threshold of 2795 canisters. Hence, the amount of inventory of fuel that is at risk of contributing to airborne dose is less than the Category 2 threshold quantities.

1.2 BACKGROUND

Dynamic seismic analysis, construction joint integrity projections and leak rate calculations for the K Fuel Storage have resulted in a post earthquake leak rate estimates in excess of the 1500 gph limit in the SAR. Expert and peer reviews have indicated that the complexity of the problem is such that a definitive value for leak rate is not possible. Estimates have been between 5000 and 25000 gph. This range, in addition to being higher than that used in the safety analysis, challenges the capability to adequately respond to the event to maintain fuel coverage.

Based on the foregoing, there is an increase in consequences of a previously evaluated event and reduced margin in OSRs. The discovery involves increase in the previously analyzed seismically induced leakage rather than a new basin malfunction, or new accident.

In response to the safety issue raised concerning a potential seismic event in the K Basins, a corrective action plan has been developed. Seismically induced leakage in the discharge chute portion of the basin could result in significant water level reductions in the basin. The corrective action plan requires installation of isolation barriers (i.e., upgraded cofferdams) to separate the discharge chute from the rest of the basin. A sketch of the isolation barrier location is included (see Figure 1).

A cleanup system will be installed to treat the discharge chute water. Piping will be added that will introduce treated water from the Ion Exchange Module (IXM) into the chute via a pump, and an overflow weir slot is provided in the isolation barrier to return water from the discharge chute back to the main basin. Water quality in the discharge chute is then expected to improve over that in the main basin.

2.0 PLANNED ACTIVITIES

Activities for installation of the isolation barriers in 105 KE & KW can be categorized into four groups: 1) inspection and evaluation activities 2) relocation of equipment and fuel to support installation of the isolation barriers, 3) cleaning and surfacing of the discharge chute to limit the source term remaining in the chute, 4) installation of the barriers, and leak rate testing of the barrier seals.

2.1 INSPECTION AND EVALUATION ACTIVITIES

Prior to installation of hardware in the basin, detailed inspection and evaluation are necessary to support and assure an adequate design. Figure 2 illustrates the isolation barrier layout, and demonstrates the need for accurate dimension verification of the discharge chute entry way. Inspection and evaluation, common to many plant modification, can normally be performed with minimal intrusion in the basins. The most intrusive activity will be verifying the discharge chute openings dimensions using a video micrometer. The video micrometer camera will be moved underwater, filming the opening and verifying the dimensions which the isolation barriers must be built to.

2.1.1 Safety Assessment Check sheet for activities.

<p align="center">GENERAL CHECK SHEET HAZARDS IDENTIFICATION & MANAGEMENT of MAJOR ACTIVITIES ASSOCIATED WITH THE BASIN INTEGRITY TASK</p>		
Operation(s)	Potential Hazards	Assessment & Controls
Detailed inspection and evaluation are necessary to support design	Industrial Safety - Evaluate for electrical safety.	Camera power supplies are routinely used in the basins.
	Industrial Safety - Evaluate for fire safety.	Minimal change in fire loading.
	Industrial Safety - Evaluate for crane operations safety.	No crane operations required.
	Industrial Safety (Hygiene) - Evaluate for activities which result in worker physical stress because the equipment or tools do not fit the worker well (ergonomics).	None.
	Industrial Safety - Evaluate for other considerations based on operator experience and knowledge of the plant.	None.
	Industrial Hygiene - Evaluate for potential toxic material exposure or release.	No toxic materials used.
	Radiation Exposure - Evaluate for potential As Low As Reasonably Achievable (ALARA) considerations.	Specific ALARA plan will be prepared for field work in each basin. Dominant exposure concerns result from activities in KE because of routine high fields.
	Radiation Exposure - Evaluate for high radiation fields unshielded inadvertent criticality or inadvertent removal of the fuel from the water.	No fuel will be moved. The equipment to be used (video cameras and associated cables) is light enough to preclude damage to fuel or movement of fuel. ALARA plans have been developed.
	Airborne material exposure - Evaluate for airborne radionuclides from radionuclides in suspension or solution in the basin water.	Suspension of radionuclides in the water is not required as part of this activity, nor is it likely. The camera motion will be clear of sludge.
	Airborne material exposure - Evaluate for airborne radionuclides from work in surface contamination zones.	Standard ALARA procedures will be used for these activities consistent with other video camera work that has recently been conducted in KE and KW basins.
	Nuclear Safety - Evaluate the activity for the possibility that it exceeds the existing SAR (basis for USQ screening).	See Table 1 - Activities bounded by existing safety basis.

2.2 RELOCATION OF EQUIPMENT AND FUEL TO SUPPORT INSTALLATION OF THE ISOLATION BARRIERS

Installation of the isolation barriers requires fuel or equipment relocation. These changes are basin specific:

- a) In 105 KW the location for installation of isolation barriers (see Figure 3) is currently close to existing occupied fuel storage. Some limited fuel relocation and storage rack modification (13 canisters in front of one opening and 11 in front of the other) will be required. Because KW basin is relatively clean and the canisters are closed, this activity is not expected to be a large contributor to air emissions. Canister integrity (lock bars holding the lid on and general condition) has been verified by a video survey.

This represents a rather limited fuel move (1 to 2 shifts of activity when done cautiously). The equipment is designed to stress simple and safe operation. Individual fuel canisters are grappled, suspended by a lifting tool designed to preclude lifting the canisters from the water, with design features, (length of tool) which protects against operator error. The worst credible accident, dropping of fuel, is analyzed by the existing criticality analysis. The fuel drop would not result in any risk of criticality.

Figure 3 - This figure is a composite of both 105 KE & 105 KW activities. It shows equipment relocation necessary in both basins.

- b) Some equipment must be relocated in the 105 KE discharge chutes to assure it does not interact with the barriers during an earthquake. This will be accomplished by moving the equipment to the center of the discharge chute, e.g., the old coffer dams currently located in the discharge chute will be moved to the center of the chute. In addition, it is prudent to move selected encapsulation equipment in KE out of the discharge chute into the main basin. Moving this equipment out of the chute will eliminate the necessity of removing the equipment from the water for reinstallation after the barriers are installed. For example, several empty canisters may be removed from the main basin storage racks and the packager relocated to storage, resting directly on the racks outside the chute. Additionally, one fuel element (inner) and portions of another are still located in the KE discharge chute. They will be removed.

All equipment will be moved underwater to minimize the air emissions. Hoisting equipment will be surveyed before, during and after the work. Decontamination or replacement of the equipment will be done based on survey results. All these

activities are similar to previously approved encapsulation activities. All activities are bounded by the existing Safety Analysis Report.

2.2.1 SAFETY ASSESSMENT CHECK SHEET FOR 105 KW ACTIVITIES.

GENERAL CHECK SHEET HAZARDS IDENTIFICATION & MANAGEMENT of MAJOR ACTIVITIES ASSOCIATED WITH THE BASIN INTEGRITY TASK		
Operation(s)	Potential Hazards	Assessment & Controls
Limited fuel relocation and storage rack modification (40 canisters) will be required. 105 KW isolation barrier sealing surface will also be modified by removing the existing inflatable seals and associated hardware. The removal of hardware in 105 KE was formerly accomplished by using an underwater "side grinder" for cutting. Use of remotely controlled side grinders and similar cutting or surfacing tools is planned in both KE and KW.	Industrial Safety - Evaluate for electrical safety.	None. No electrical modifications will be made to the facility. Existing facility outlets will be used for equipment.
	Industrial Safety - Evaluate for fire safety.	Minimal change in fire loading.
	Industrial Safety - Evaluate for crane operations safety.	Crane operations will be required for fuel movement and for storage rack modification. The worst postulated accident is a water drop of one fuel canister. See discussion below under Radiation Exposure for consequences.
	Industrial Safety (Hygiene) - Evaluate for activities which result in worker physical stress because the equipment or tools do not fit the worker well (ergonomics).	None.
	Industrial Safety - Evaluate for other considerations based on operator experience and knowledge of the plant.	None.
	Industrial Hygiene - Evaluate for potential toxic material exposure or release.	No toxic materials used.
	Radiation Exposure - Evaluate for potential As Low As Reasonably Achievable (ALARA) considerations.	Specific ALARA plan will be prepared for field work in each basin. KW fields are routinely less than 2 MREM/hr and specific controls are not anticipated.
	Radiation Exposure - Evaluate for high radiation fields unshielded inadvertent criticality or inadvertent removal of the fuel from the water.	Fuel handling has been performed annually for the past 10 years, and crane usage is considered routine. The worst case crane failure would result in dropping a canister of fuel on other fuel. Such a crane failure has been analyzed for criticality safety and will not cause an unplanned criticality.
	Airborne material exposure - Evaluate for airborne radionuclides from radionuclides in suspension or solution in the basin water.	Suspension of radionuclides in the water is not required as part of this activity, nor is it likely. Past fuel handling has resulted in no increase. Standard ALARA procedures will be updated and used for these activities. Rack removal poses even less risk than fuel movement. Equipment used in these tasks will be surveyed before, during and after the work to ensure the spread of contamination is limited.

	<p>Airborne material exposure - Evaluate for airborne radionuclides from work in surface contamination zones.</p>	<p>No work will be performed in surface contamination zones. Greenhouses provided for equipment removal from basin. Local filtration provided. Work will be controlled remotely (from outside of zone) for surface preparation activities.</p>
	<p>Nuclear Safety - Evaluate the activity for the possibility that it exceeds the existing SAR (basis for USQ screening).</p>	<p>See Table 1 - Activities bounded by existing safety basis.</p>

2.2.2 SAFETY ASSESSMENT CHECK SHEET FOR 105 KE ACTIVITIES.

<p style="text-align: center;">GENERAL CHECK SHEET HAZARDS IDENTIFICATION & MANAGEMENT of MAJOR ACTIVITIES ASSOCIATED WITH THE BASIN INTEGRITY TASK</p>		
Operation(s)	Potential Hazards	Assessment & Controls
<p>Some equipment must be relocated in discharge chute to protect the barriers from damage during an earthquake. This will be accomplished by moving equipment to center of chute. Selected encapsulation eqpt moves out of the discharge chute into the main basin. A single inner fuel element and portions of another will be removed from the discharge chute.</p>	Industrial Safety - Evaluate for electrical safety.	None.
	Industrial Safety - Evaluate for fire safety.	Minimal change in fire loading.
	Industrial Safety - Evaluate for crane operations safety.	Crane operations will be considered as critical lifts as added assurance that basin structure, racks, canisters and fuel will not sustain unacceptable damage.
	Industrial Safety (Hygiene) - Evaluate for activities which result in worker physical stress because the equipment or tools do not fit the worker well (ergonomics).	None.
	Industrial Safety - Evaluate for other considerations based on operator experience and knowledge of the plant.	None.
	Industrial Hygiene - Evaluate for potential toxic material exposure or release.	No toxic materials used.
	Radiation Exposure - Evaluate for potential As Low As Reasonably Achievable (ALARA) considerations.	Specific ALARA plan will be prepared for field work in each basin. Dominant exposure concerns result from activities in the main KE Basin because of routine high fields found there. Activities will center, as much as possible, around the discharge chute in a lower field region. Work will be controlled remotely (from outside of zone) for surface preparation activities. Work will be performed in KW (low field basin) before performed in KE to assure disciplined operation with minimum time at risk (de facto training verification in KW).
	Radiation Exposure - Evaluate for high radiation fields unshielded inadvertent criticality or inadvertent removal of the fuel from the water.	None anticipated. Minimal fuel will be moved. The equipment to be used is light enough to preclude damage to fuel.

<p>Airborne material exposure - Evaluate for airborne radionuclides from radionuclides in suspension or solution in the basin water.</p>	<p>Suspension of radionuclides in the water is not required as part of this activity, nor is it likely. Several empty canisters may be removed from the main basin storage racks and the packager relocated to storage, resting on empty fuel storage racks. Dropping of equipment on canisters will be limited by avoiding moves over fuel. Damage of fuel from empty canister drops would not be significant due to low mass.</p>
<p>Airborne material exposure - Evaluate for airborne radionuclides from work in surface contamination zones.</p>	<p>Standard ALARA procedures will be used for these activities consistent with other work that has recently been conducted in KE and KW basins. No work will be performed in surface contamination zones. Greenhouses provided for equipment removal from basin. Local filtration provided.</p>
<p>Nuclear Safety - Evaluate the activity for the possibility that it exceeds the existing SAR (basis for USQ screening).</p>	<p>See Table 1 - Activities bounded by existing safety basis.</p>

2.3 CLEANING AND SURFACING OF THE DISCHARGE CHUTE TO LIMIT THE REMAINING SOURCE TERM

Cleaning of the discharge chute in 105 KE will involve depositing activated hardware, debris, and fuel from the discharge chute into canisters and moving these canisters to other underwater locations in the main basin. The underwater cleaning of sealing surfaces (of the main basin walls at the entry to the discharge chute) for the barriers in both 105 KE and 105 KW will involve cleaning with abrasive. All loose material must be displaced from these areas to ensure adequate sealing of the barriers. A basin water treatment system will be operational during these activities to minimize the levels of radionuclides present in the basin water.

Jack-strawed canisters and debris will be relocated from the front of the KE opening to clear an area for installation. In order to provide access to the work area, it will be necessary to remove a portion of the floor grating and associated handrails. The removal will be accomplished by a slow speed reciprocating saw incorporating a HEPA vacuum to collect any fines generated. Plastic sheeting will also be used to control the dispersal of metal fines not collected by the vacuum. (When the isolation door installation is completed, the grating and handrails will be restored using mechanical fasteners.)

After the area in front of the KE openings is cleared of debris, approximately 1 to 7 cm of sludge will be pumped from the cleared fuel racks. The sludge will be pumped to the "weasel pit" using the Wilton air pumps and suction headers. Remaining sludge inside the KE discharge chute will also be pumped to the "weasel pit" before the barriers are installed. This activity is being performed to a) minimize residual sludge in the discharge chute to optimize cleanup, b) remove sludge from work areas in a controlled fashion to assure it is not stirred up in an uncontrolled fashion during work, and c) allow for visibility during barrier installation.

A segment of the fuel racks will be removed from in front of the rack opening to make room for the seal preparation tool. The racks will be cut underwater by a remotely operated abrasive wheel saw. The rack saw will be precisely placed for each cut and will clamp to the rack to remain stationary. The saw will be provided with a shroud which will direct water flow through an underwater suction pump/filtration system to collect cuttings and other debris. The actual cut will be controlled remotely and monitored with an underwater camera. After cutting, the saw will be surveyed, decontaminated if necessary, and bagged in plastic for transfer to the other basin.

A subcontractor will furnish and operate equipment that will perform the following functions:

- Cutting away the existing inflatable rubber seal.
- Removing the existing steel strips bordering the inflatable seal by shearing the cap screws holding the strip.
- Cleaning the surface of the embedded angle at the corner of each opening with a paint/rust stripper and a grinding wheel.
- Spreading a bead of epoxy along the cleaned angle surface.

- Positioning a prefabricated stainless steel sealing strip against the cleaned angle surface which will be held in place by the epoxy.

An aluminum tool frame has been developed that will stand upright in the door entrance and is approximately 6.7 meter (22 feet) tall. The individual tools performing the separate operations can be mounted on a chain drive carrier which follows a designed path on the seal preparation tool frame and are controlled remotely. The frame itself is positioned by hydraulic jacks which wedge the frame into the discharge chute opening. Particles generated during these operations will be controlled by the use of an underwater suction pump/filtration system built into the tools. A portion of the wall preparation will extend two feet above the water line. For this phase of the work, the system will automatically transfer from the underwater suction pump/filtration system to HEPA filter air collection. (A hood that extends around the tools to the wall surface will minimize dispersion and enhance collection of radioactive particles, whether under or above water.) Other, smaller portable pieces of equipment have been developed that will shear bolts (above water) where necessary to remove the existing inflatable seal.

During the performance of this work, it will be necessary to remove tools and equipment from the basin for repair, replacement, adjustment or transfer between basins. Items removed will be surveyed and bagged into plastic to minimize air emissions. Small sample filters will operate in parallel with the underwater suction/filtration system. In order to characterize the filters, the sample filters will be removed from the water, bagged and sent to the lab for analysis. The large tool frame will need to be moved between basins; the frame will be decontaminated, if necessary, and encased in a custom made containment bag for the transfer.

The final product of these activities will be establishing a 7.5 cm (3") wide stainless steel sealing surface that has been attached to the wall by epoxy in the door seal area in both discharge chute openings in each basin. This will ensure a good seal is attained with the doors.

Debris (excepting sludge) collected from the work activity will be sampled, consolidated and eventually removed from the water for disposal. A estimated 62 cubic feet of waste, all expected to be low level radioactive waste, will be generated from these activities. The following conditions will be adhered to during the performance of all activities during the second and third phases of the work.

- o A greenhouse will be available in each basin.
- o In KE, at least one water treatment system will be operated during the work and shift-wise water sampling will be conducted for Cs-137 consistent with the Encapsulation Permit requirements.
- o In KW, at least one water treatment system will be operated during the work.

2.3.1 SAFETY ASSESSMENT CHECK SHEET FOR DISCHARGE CHUTE CLEANUP ACTIVITIES.

<p style="text-align: center;">GENERAL CHECK SHEET HAZARDS IDENTIFICATION & MANAGEMENT of MAJOR ACTIVITIES ASSOCIATED WITH THE BASIN INTEGRITY TASK</p>		
Operation(s)	Potential Hazards	Assessment & Controls
<p>Cleaning: 1) put activated hardware, debris and fuel from the discharge chute into canisters and moving these canisters to other underwater locations in the main basin 2) underwater cleaning of sealing surfaces</p>	Industrial Safety - Evaluate for electrical safety.	None
	industrial Safety - Evaluate for fire safety.	None
	Industrial Safety - Evaluate for crane operations safety.	Crane operations will be treated as critical lifts, if lift is over fuel or if it is over the basin and exceeds 800 pounds, to minimize damage potential to basin boundary and fuel.
	Industrial Safety (Hygiene) - Evaluate for activities which result in worker physical stress because the equipment or tools do not fit the worker well (ergonomics).	None
	Industrial Safety - Evaluate for other considerations based on operator experience and knowledge of the plant.	None
	Industrial Hygiene - Evaluate for potential toxic material exposure or release.	No toxic materials used
	Radiation Exposure - Evaluate for potential As Low As Reasonably Achievable (ALARA) considerations.	Specific ALARA plan to be prepared for field work in each basin. Dominant exposure will be from activities in the main KE Basin because of routine high fields found there.
	Radiation Exposure - Evaluate for high radiation fields unshielded inadvertent criticality or inadvertent removal of the fuel from the water .	Fuel handling has been performed annually for the past 10 years and crane usage is considered routine. Potential has been analyzed (see Table 1).
	Airborne material exposure - Evaluate for airborne radionuclides from radionuclides in suspension or solution in the basin water.	Some suspension of radionuclides in the water occur but additions are not considered to be significant.
	Airborne material exposure - Evaluate for airborne radionuclides from work in surface contamination zones.	Standard ALARA procedures to be used for these activities consistent with other work that has recently been conducted in KE and KW basins. No work will be performed in surface contamination zones.
	Nuclear Safety - Evaluate the activity for the possibility that it exceeds the existing SAR (basis for USQ screening).	See Table 1 - Activities bounded by existing safety basis.

2.4 INSTALLATION OF THE BARRIERS

The barriers will enter the basin building from the west access doors. The barriers will then be moved outside of the basin along the reactor interface wall until they are above the entry location located in the discharge chute (see Figure 4). Once there, they will be lowered into the water in the discharge chute. They will then be suspended from the crane in an upright position, and moved through the discharge chute entry openings into the main basin. They will be moved only in an area from which fuel has been removed to assure that they are never over fuel canisters. They are then installed by attaching to Z-brackets which mate with the walls inside the discharge chute portion basin. (See Figure 2) At no point will the barriers or associated equipment be located above fuel.

Figure 4 - Sketch showing path which isolation barriers will follow during installation.

During barrier installation, there is minimal opportunity for air emissions since the doors are uncontaminated. The barriers will be rigged from the plant rail system using two ton chain falls. Once the doors are in position in the discharge chute openings, then attachment of the brackets which hold the door from the back side will be made with stainless steel tie rods tightened by one inch lock nuts. At least one water treatment system in each basin will be in operation during the performance of door installation.

LEAK TEST

The leak test is the final phase of activity. The barrier installation will be verified for each basin by a leak test conducted with a differential water level between the basin and the discharge chute. The test will measure the changes in water levels in both the basin and the discharge chute versus time. The objective of the test is to establish (by extrapolation) that the doors will not leak more than the SAR basis if all water were to be removed from the discharge chute. In order to perform the test, a number of instruments and data collectors will be installed in the basin, including ultrasonic level indicators, thermocouples, and evaporation measurement devices. Only the thermocouples will enter the basin water and their surface area is relatively small, so a negligible effect on air emissions from these devices is expected.

The leak test will involve pumping water out of the discharge chute and into the main basin. The draw-down will lower the discharge chute level between 15 feet 4 inches to no lower than 14 feet 10 inches, so that approximately one foot of the discharge chute wall will be exposed. Several factors will mitigate the release of particles from the discharge chute exposed surfaces during this test, the duration of which is not expected to exceed 48 hours. The discharge chute area in KE is relatively clean compared to the main basin (as measured by dose rates) and has epoxy coated walls. The KW discharge chute is also epoxy coated which minimizes surface contamination and resulting emissions in that discharge chute area. Finally, weighted plastic drapes will be installed that cover the portion

of the wall that will be exposed (as completely as practical) to preclude emissions from the wall. In effect, the wall will remain wetted.

A CAM will be operational over the discharge chute at all times during the leak test. Emissions resulting from the one or two tests required in each basin are expected to be below the NOC limits established for KE encapsulation above water activities. As with all activities in the seismic barrier installation, the KW activities are scheduled to occur before the KE activities. The experience gained at KW will be taken into consideration before performing activities in the more contaminated KE basin.

Water quality will be maintained in the discharge chute by continuous flow through the region. Piping will be provided to return treated water (less than 200 gpm) from the IXM to the chute. The water level will be allowed to rise several inches higher inside the discharge chute than in the main basin; it will overflow a weir (slot cut into the barrier) and return to the main basin. This system will be shut off during barrier installation to prevent difficulty in installing barriers across the entries, but will routinely operate there after.

2.4.1 SAFETY ASSESSMENT CHECK SHEET FOR BARRIER INSTALLATION ACTIVITIES.

<p style="text-align: center;">GENERAL CHECK SHEET HAZARDS IDENTIFICATION & MANAGEMENT of MAJOR ACTIVITIES ASSOCIATED WITH THE BASIN INTEGRITY TASK</p>		
Operation(s)	Potential Hazards	Assessment & Controls
<p>1) Barriers moved near the basin until they are at entry location. Then lowered into the water and installed by attaching to brackets.</p> <p>2) Piping installed to return water from the IXM to the chute.</p> <p>3) Leak test establish head between main basin</p>	Industrial Safety - Evaluate for electrical safety.	None. No electrical modifications will be made to the facility. Existing outlets will be used for equipment.
	Industrial Safety - Evaluate for fire safety.	Minimal change in fire loading
	Industrial Safety - Evaluate for crane operations safety.	Crane operations required and will be treated as critical lifts, to minimize damage potential to basin boundary and fuel.
	Industrial Safety (Hygiene) - Evaluate for activities which result in worker physical stress because the equipment or tools do not fit the worker well (ergonomics).	None
	Industrial Safety - Evaluate for other considerations based on operator experience and knowledge of the plant.	A water safety protection program will be provided.
	Industrial Hygiene - Evaluate for potential toxic material exposure or release.	None
	Radiation Exposure - Evaluate for potential As Low As Reasonably Achievable (ALARA) considerations.	Specific ALARA plan to be prepared for field work in each basin. Dominant exposure will be from activities in the main KE Basin because of routine high fields found there. Some increase in field when discharge chute level is lowered, due to "bath-tub ring" unshielding.
	Radiation Exposure - Evaluate for high radiation fields unshielded inadvertent criticality or inadvertent removal of the fuel from the water.	None, no fuel to be moved.
	Airborne material exposure - Evaluate for airborne radionuclides from radionuclides in suspension or solution in the basin water.	Because dropping of equipment on fuel canisters could damage fuel, fuel will be removed from the working areas prior to barrier installation. Additional airborne activity risk is not significant.
		Standard ALARA procedures to be used for these activities consistent with other work that has recently been conducted in KE and KW basins. No work will be performed in surface contamination zones.
	Nuclear Safety - Evaluate the activity for the possibility that it exceeds the existing SAR (basis for USQ screening).	See Table 1 - Activities bounded by existing safety basis.

3.0 SAFETY ASSESSMENT

The activities involved with installation of discharge chute isolation barriers to mitigate the seismic induced leakage from basin-reactor building construction joint have been reviewed for hazards to identify the inventory at risk. The identified hazards are controlled or mitigated by the existing systems or procedures or will be mitigated or controlled by implementation of existing administrative practices. No new hazards have been identified that have not been addressed by the existing safety basis documentation.

Three classes of events have been identified for which determinations are necessary, sludge movement, mechanical damage resulting in fuel failure, and criticality. These are developed below.

3.1 SLUDGE

An evaluation of the implications of sludge on all activities planned at the basins can be found in Attachment I. Sludge is a significant issue in KE, because it is present throughout the basin, and in KW because it may be present in closed canisters. All criticality analyses are routinely performed assuming sludge is present.

Routine operations associated with isolation barrier installation in KE which should consider sludge are well bounded by existing analyses. The most significant activity planned is moving sludge away from the discharge chute opening prior to installation of the isolation barriers. This consists of pumping of sludge to the "weasel pit", an activity which is also covered by criticality safety analysis¹. Relocation of sludge to this area does not pose a criticality risk.

Accidents which may involve significant sludge movement can be bounded by accidents which cause rapid-uncontrolled water movement, which suspends sludge and moves it. Only one accident has been identified which could lead to this consequence, dropping of an isolation barrier. As the barrier falls, the majority of its potential energy is expected to be converted to water movement.

Material of the particle size distribution and density of sludge is easily disturbed by the turbulent flow associated with a barrier drop. Once disturbed, it remains in suspension in water for extended periods (hours to days). Experience with pumping sludge shows that the suspended material will be rapidly distributed through large volumes of water by convection and diffusion. The sludge then settles out as the turbulence of the water decreases, covering large areas of the basin with an additional thin roughly uniform layer. Because of the properties of the sludge, attempts to accumulate sludge using engineered systems (induce settling in a local area) have been unsuccessful to date. Accumulating a layer of sludge of optimum density to cause criticality concerns is not credible (see Attachment I).

Although significant sludge accumulation is not a credible result of an accident, other factors would mitigate it, if it were. The actual composition of sludge is significantly less reactive than that analyzed, and the settled out sludge is not

¹ 1993, MCNP Calculations of K-infinity for 100 KE Basin Sludge Samples, WHC-SD-NR-CSER-008. Rev 1, W.D. Wittekind.

optimally moderated. For optimally moderated uranium oxide accumulations to 90 cm (35.4 in) outside canisters containing Mark IV fuel (the only fuel allowed in KE) the calculated k_{inf} remained below 0.98 for both stainless steel and aluminum canisters. Since such an accumulation is not credible as the result of a door fall, criticality can be ruled out², even with postulated fuel relocation as discussed in Attachment II.

3.2 MECHANICAL DAMAGE OF FUEL

Fuel damage may be bounded by considering the drop of a large mechanical object on fuel. A drop of a barrier (See Attachment II) is selected because it represents by far the most massive component to be moved in the vicinity of the fuel.

The activities for the preparation for and installation of the barriers do not require removal of fuel, fuel pieces, or sludge from the basin. Therefore the form of the material is fuel with at least 3 meters (9.5 feet) of water coverage. Further, for all accidents identified, 4 meters (13 feet) of coverage exists.

Research on decontamination factors associated with pool scrubbing of fuel and corrosion product particulate has been conducted since the 1960's and represents a mature nuclear reactor safety technology. Radioactive material released under water will be reduced by the scrubbing action of the water. The amount released to the air is reduced by a decontamination factor (DF) due to this scrubbing. The DF for a particle passing through 4 meters of water is 10^8 ; through 3 meters of water it is 10^6 . A regulatory case is best built when insensitive to variation, hence a conservative factor of only 10^4 was selected for this analysis. The threshold values used to evaluate hazard categories for the barrier installation activities were reduced by a DF of 10^4 .³

Appendix A documents the calculation which determines the number of elements of canisters necessary to exceed the Category 3 and Category 2 thresholds. These values are conservative since they are based on MK IV elements, which are 30% heavier than the MK 1A fuel, and represent the most massive fuel available in the basin. The 105 KW basin contains only MK 1A fuel. Appendix A shows that an inventory of 17 canisters is required to reach the Category 3 threshold and 2795 canisters would be required to reach the Category 2 threshold based on radiological inventory.

A barrier represents the largest component to be moved in the vicinity of the fuel. The barrier is brought into the basin through the discharge chute, and does not move over the fuel. It moves nearest the fuel when it is upright and moved out of the discharge chute entry. A worst case scenario, dropping the door while moving it into final position, would result in it moving down approximately 0.6 meter (2 feet), at which point the door would pivot about the point in contact with the basin floor.

The falling barrier would pivot down either on edge or flat. If it drops "flat", hydraulic drag will tend to absorb the energy of the fall. The mechanical damage

² 1994, *Criticality Safety Evaluation K Basin Storage Rack Seismic Qualification*, WHC-SD-NR-CSER-009, Rev. 0.

³ WHC-SD-SNF-SARR-001; Pool Scrubbing of fuel and Corrosion Product Particulate; M.G. Plys, H.K. Fauske & Associates, 1994.

to the fuel resulting from the barrier fall can be estimated based on the total energy available and the strength of the canisters and fuel (See Attachment II). For a bounding argument, however, it is arguable that even in the unlikely event all 10 canisters potentially involved as the door came down in an "edge first" trajectory totally failed (crushed), this would remain below the category 3 threshold. Although arguments in Attachment II demonstrate that a "flat" door fall is highly unlikely to damage fuel and will only cause limited canister damage, the barrier profile may come into contact with more than 40 canisters (and possibly up to 80 canisters). Hence the total number of canisters involved may exceed the Category 3 threshold, but remains below the category 2 threshold.

Factors which would mitigate such damage include treatment of all door lifts as critical lifts (whether in the vicinity of the fuel or not), removal of 24 canisters of fuel in the vicinity of the KW openings (11 in front of one and 13 in front of the other), and limitations on the total energy available for damage.

As allowed by DOE-STD-1027-92, the threshold values applied for existing facilities can be modified to reflect the form and amount of radioactive material. The threshold values of DOE-STD-1027-92 are based on the assumption that the fraction of releasable material for solids is 1/100 and for other solids is 1/1000. Noble gas and halogen release fractions are not relevant in K Basin fuel; the quantities of these materials are negligible due to decay.

The threshold values were established by backfitting airborne dose calculations to determine the threshold release value by isotope. Practically, by remaining within the Category 2 threshold for total number of canisters involved, one has assured that the 100 meter dose from such an accident remains below 1 Rem and below Category 3 implies that there is no significant impact, even if all the inventory were totally involved in the accident. Because the detailed discussion in Attachment II indicates that actual fuel involvement will be extremely limited, no appreciable dose is expected on or off site.

3.3 CRITICALITY

Criticality has been a significant consideration in the basins throughout their operating history. A number of safety analyses and criticality analyses have been developed over the years to assure that adequate margins are maintained. The current fuel moves (listed in the table below) are bounded by existing analyses and are within the current safety envelope for K Basins, as documented in Criticality Safety Evaluation Reports^{4, 5, & 6}.

⁴ 1992, WHC-SD-NR-CSER-001 Rev. 0, *K Basin Criticality Evaluation for Irradiated Fuel Canisters in Sludge*, W.D. Wittekind.

⁵ 1991, WHC-SD-NR-CSER Rev 0, *Criticality Safety Evaluation Report N Reactor Fuel Support - KE Basin Fuel Repackaging*, A.L. Doherty & C.L. Gesh.

⁶ WHC-SD-NR-CSER-007 Rev 1, *Criticality Safety Evaluation Report, 105-KE Basin Fuel Encapsulation*, K.N. Schwinkendorf.

As discussed in Attachment I, the presence of sludge has been extensively considered in the existing analyses^{7&8}.

3.4 ACTIVITY SPECIFIC HAZARD CATEGORIZATION

Appendix A documents the calculation which determines the number of elements or canisters necessary to exceed the Category 3 and Category 2 thresholds. These values are conservative since they are based on MK IV elements, which are 30% heavier than the MK 1A fuel, and represent the most massive fuel available in the basin. The 105 KW basin contains only MK 1A fuel. Appendix A shows that an inventory of 17 canisters is required to reach the Category 3 threshold and 2795 canisters would be required to reach the Category 2 threshold based on radiological inventory.

Segregation of activities, as allowed in DOE Standard 1027, requires separation of the radionuclides to demonstrate that an accident in one area can not credibly propagate to another. Typically this can be best accomplished by physical separation. Appendix A shows that an inventory of 2795 canisters is required to reach the Category 2 threshold. The maximum number of canisters postulated to be involved in any mechanistic accident, 80, is significantly less than 2795.

Further confidence in segregation can be gained. Each basin contains on the order of 3600 canisters, subdivided into three bays by concrete walls. Each bay contains approximately 1200 canisters. This is substantially below the 2795 canisters required to reach the Category 2 threshold. Hence, segregation may be argued to be credible.

⁷ 1993, *MCNP Calculations of K-infinity for 100 KE Basin Sludge Samples*, WHC-SD-NR-CSER-008. Rev 1, W.D. Wittekind.

⁸ 1992, *K Basin Criticality Evaluation for Irradiated Fuel Canisters in Sludge*, WHC-SD-NR-CSER-001 Rev 0, Wittekind, W. D.

LIST OF FUEL WHICH WILL BE MOVED FROM THE ENTRY OF THE DISCHARGE CHUTES IN 105 KW
 The canister in location 1204 has eight 21 inch assemblies and 6 19.5 inch assemblies, and
 is listed as two separate canisters to account for differing factor weights.

105 K West Fuel Movement Data									
Cubicle	Key	Length	No. of	Energy	Outer Mass	Inner Mass	Ass'y U-235	Canister U	Canister U
Location		Inches	Assy's	MWD	pounds	pounds	pounds	pounds	kg
1101	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
1102	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
1103	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
1104	2823	21	14	749.06	24.43	12.12	0.42	5.88	2.67
1105	2823	21	14	749.06	24.43	12.12	0.42	5.88	2.67
1201	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
1202	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
1203	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
1204a	3650	21	8	445.59	24.43	12.12	0.42	3.36	1.52
1204b	3650	19.5	6	326.55	22.88	11.34	0.39	2.36	1.07
1205	3650	19.5	14	326.55	22.88	11.34	0.39	5.51	2.50
1301	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
1302	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
1303	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
3501	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
3502	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67

3504	350	19.5	14	494.33	22.88	11.34	0.39	5.51	2.50
3505	385	21	14	546.33	24.43	12.12	0.42	5.88	2.67
3601	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
3602	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
3603	1449	21	14	760.68	24.43	12.12	0.42	5.88	2.67
3604	2127	15	7	276.05	17.29	8.57	0.30	2.08	0.94
3605	2127	21	14	845.18	24.43	12.12	0.42	5.88	2.67
3704	832	19.5	14	649.78	22.88	11.34	0.39	5.51	2.50
3705	832	19.5	14	649.78	22.88	11.34	0.39	5.51	2.50
Totals			329		595.86	295.55	10.25	135.71	61.56

Note: The canister in location 1204 has eight 21 inch assemblies and 6 19.5 inch assemblies.

Listed as two separate canisters to account for differing factor weights.

4.0 CONDUCT OF OPERATIONS

Discipline in conduct of operations has been enhanced by providing compensatory measures for known weaknesses. All barrier related plant work is now being controlled to an approved schedule. All field work for barrier installation will be controlled to a Master Work Plan (MWP), which will be maintained by operations. All operating procedures invoked by the MWP and applicable to these activities will be verified prior to use; where inadequacies are identified, the procedures have been or will be revised. Detailed procedures have been developed for work done by others (e.g. ICF Kaiser Hanford crane operations) and approved by plant management. Field supervision will be required for all critical activities (e.g., fuel handling).

Activities have been considered to determine what failures were credible, identify measures to limit failure risk, and evaluate the need for recovery procedures. As an example, past experience shows that drop of a fuel canister is unlikely, but possible. As a result the operating procedure for fuel handling has been revised to require that the operator verify proper engagement of the hook on the canister lifting bail after lifting the canister 50 to 80 mm (2 to 3 inches). The canister covers have been examined, documented on video footage, to verify that lock bars are in the locked position and that the lock bar condition is satisfactory. The canisters themselves have been examined for signs of corrosion which may indicate structural weakness (considered precautionary, no record of such a failure exists). All fuel transfers will be performed only with a supervisor present. Previous practice had allowed continued fuel handling after dropping up to 3 canisters; the upgraded requirement now requires full work stoppage until the problem causing the drop is evaluated and a problem specific recovery plan is developed.

A set of sub-systems has been identified as required to be operational to assure the safety of the planned activity. They are:

- System 05 - The installed radiation monitoring system including alarm and annunciation components is required to be in-service for all fuel movement.
- System 07 - Fuel Handling Equipment - Necessary equipment includes all components necessary to preclude an accidental fuel drop. Also the modification of the fuel storage racks shall be performed to an approved Engineering Change Notice (documenting the completed USQ screening) and a detailed procedure to assure conformance of the process to requirements for modification to a Safety Class I component.
- System 14 - Cranes and Hoists - The cranes and hoist designated for use in the subject fuel handling evolution and door rigging will be covered.
- System 43 - Water Sampling and Analysis - Those elements required to satisfy protection of personnel and the conditions of the WDOH air permit will be covered.
- System 50 - Environmental Monitoring - Those elements required to provide protection of personnel and to satisfy conditions of the WDOH air permit will be covered.

Plant readiness will be verified following the detailed guidance of the "Plant Readiness Plan to Move Fuel to Support Isolation Barrier Installation", which will be submitted for DOE approval following DOE approval of the readiness level. This plant readiness plan (PRP) defines the actions required to assure the Basins readiness to support isolation barrier installation. The purpose of this plan is to provide a comprehensive methodology to assure basin readiness to perform the activity while ensuring the safety of the workers, the public and the environment, and that applicable requirements and regulations are met. When completed and documented, the actions prescribed in this plan will provide a high degree of confidence in the ability of the K Basin personnel to successfully complete the fuel movement and other activities. This objective will be achieved by confirming that required management systems and documentation are in place, that a qualified staff is assigned and trained, procedures are in place, and that systems and equipment are ready for operation within the approved safety envelope.

5.0 CONTINGENCY MANAGEMENT

It is expected that some changes to the above will be necessary as the work progresses. Such changes will be reviewed for impact to assess whether a) a major change in scope of work is involved, b) radioactive contaminants are being disturbed, c) the amount of hardware being inserted into or removed from the basin is affected, and d) to determine whether the activity change poses an Unreviewed Safety Question (USQ). For a major change in work scope (including major changes in the hardware entering or leaving the basins), this safety assessment will be revised. In the event radioactive contaminants are potentially disturbed, the Radiation Work Procedures (RWPs) will be revised. If the activity is determined to pose an USQ, the activity will be reviewed and prior DOE approval will be obtained before performing the proposed work.

6.0 SAFETY EVALUATION

The general check sheets identify general hazards resulting from identified activities. Table 1 identifies the accident/events addressed by the existing safety documentation, determines whether the accident/event is applicable to operations for described activities, and provides the basis for the determination that it is bounded by the existing safety basis. Table 2 provides the response to the Unreviewed Safety Question screening questions.

The hazard category of the activity is determined in accordance with DOE-STD-1027-92, a supporting guide for DOE Order 5480.23, "Nuclear Safety Analysis Reports." This determination is based on a comparison of Threshold Quantities with the at-risk inventory consisting of the fuel, including transuranics and fission products, covered by the water in the basin. This form is used because all activities involving fuel or events/accidents on fuel are underwater. A conservative decontamination factor (DF) of 10^4 is assumed. As allowed by DOE-STD-1027-92, the threshold quantities provided by the standard can be divided by this value. The amount of fuel to reach the Category 3 threshold is then calculated. The Category 3 threshold quantity is 243 fuel assemblies (17 canisters). Appendix A provides the calculations for this determination.

In addition there is no possible equipment drop that could be likely to impact 17 canisters significantly. Hence, it could be argued that the amount of inventory of fuel that is at risk of contributing to airborne dose is less than the Category 3 Threshold Quantities. Further, no accident is postulated which involves more than 80 canisters total, which is well below the category 2 threshold of 2795 canisters.

7.0 CONCLUSION

The hazard category of the activity has been developed as specified in DOE-STD-1027-92, a supporting guide for DOE Order 5480.23, "Nuclear Safety Analysis Reports" is Category 3. Implicit in this categorization determination is the conclusion that doses to workers and to offsite personnel from the airborne releases resulting from the accidents bounded by this analysis will be minimal.

The activities involved with installation of discharge chute isolation barriers to mitigate the seismic induced leakage from basin-reactor building construction joint have been reviewed for hazards. The identified hazards are controlled or mitigated by the existing systems or procedures or will be mitigated or controlled by implementation of existing administrative practices. No new hazards have been identified that have not been addressed by the existing safety basis documentation.

All activities, including fuel handling, are bounded by existing safety analyses. The activities described, therefore, present no undo risk and also do not represent an unreviewed safety question.

The dominant hazards are occupational safety related. Industrial safety hazards are primarily associated with barrier handling; they will be managed to protect workers by treating lifts as critical lifts. Industrial hygiene risks have been limited by selection of the materials used.

Radiation exposure for workers has been estimated, and measures have been identified to limit the number of workers present, the field, and the time for each job. Examples of such measures include remote control panels for surfacing equipment and remote data collection equipment for test data. Further, work will be performed in the low field of KW first. Following this, before entry into the high fields of KE, a detailed critique will be held of KW operations to limit exposures in KE.

TABLE 1
SAFETY EVALUATION OF ACTIVITIES VS SAFETY BASES EVENTS/ACCIDENTS

Accident/Event (1)	Assumptions	Probability	Consequences (Remarks)	INVOLVES FUEL MOVE/BARRIER INSTALLATION (2)
1. Rail Car Fuel Spill - Criticality (SAR 8.1.1)	Contents of 3 casks spill and form a hemispherical configuration with optimal moderation and reflection.	10^{-4} to 10^{-6} "Not expected to occur during the lifetime of the facilities."	No criticality. Less than the necessary 169 elements for a criticality.	NO - FUEL NOT HANDLED OUT OF BASIN
2. Cask Fuel Spill - Criticality (SAR 8.1.2)	Contents of one cask spill into an optimally moderated and reflected hemisphere.	10^{-2} to 10^{-4} "Infrequent"	No criticality. Less than the minimum critical mass (169 elements).	NO - NO CASKS BEING USED
3. Canister Drop - Criticality (SAR 8.1.3)	1 over 3 storage configuration.	10^{-2} to 10^{-4} "Infrequent"	Spike fuel - Keff remains below 0.822. No criticality.	YES a canister drop is possible (for fuel movement only) - NO CHANGE (i.e. this activity is bounded by SAR basis accident).
4. Broken Fuel Elements - Criticality (SAR 8.1.4)	Estimated 5% of total fuel is broken and 1% of the fuel has gone into solution immediately surrounding the fuel elements.	1 to 10^{-2} "Anticipated"	No criticality.	Yes, fuel is moved; this activity represents no change from SAR basis activity.
5. Water Loss and Partial Moderation - Criticality (SAR 8.1.5)	Loss of coolant water. Reduction in density of the cooling water.	10^{-4} to 10^{-6} "Not expected to occur during the lifetime of the facilities."	No criticality. The Keff for a partially moderated array is less than for a fully moderated array.	Yes, fuel is moved; this activity represents no change from SAR basis activity.
6. Loss of Storage Array Geometry - Criticality (SAR 8.1.6)	Maximum storage array is 1 over 3. No storage of unirradiated fuel. No storage of Mark IA fuel in the west bays and no hanging fuel in the west bays.	10^{-4} to 10^{-6} "Not expected to occur during the lifetime of the facilities."	No criticality. The storage restrictions prevent a critical mass configuration.	No - NO HANGING FUEL
7. Well Car Drop Into the Fuel Storage Basin - Criticality (SAR 8.1.7)	Derailers, railstops and bumpers are utilized. Locomotive speed limited to 2 mph. No Mark IA and no hanging fuel in west bays.	$< 10^{-6}$ "Incredible"	No criticality. Measures noted in the Assumptions prevent critical mass formation.	NO - NO TRAIN AND WELL CAR REQUIRED, NO FUEL MOVEMENT OUT OF BASIN
8. Loss of Monitoring Instrumentation (SAR 8.2.1)	Annunciation of instrument loss in the Control Room	1 to 10^{-2} "Anticipated"	No significant consequences. Immediate response procedures in place.	YES, this is relevant to fuel moves - no change in evaluation or SAR basis, work may need to stop as dictated by response procedures.
9. Liquid Waste Car Accident (SAR 8.2.2)	Spill from tank car loaded with low level waste water in transit to the 200 Area.	1 to 10^{-6} From "Anticipated to Extremely Unlikely."	For low level waste release of a small quantity the consequences are minimal. For total release of a shipment, the consequences could be great. Not quantified.	NO - NO LIQUID WASTE GENERATED BY ACTIVITY

TABLE 1
SAFETY EVALUATION OF ACTIVITIES VS SAFETY BASES EVENTS/ACCIDENTS

10. Crane Failure and Cask Dropped Into the Fuel Loadout Pit (SAR 8.2.3)	Fully loaded cask. Drop pulverizes the concrete beneath the cask. Percolation through the concrete slab and the soil are equal.	10^{-2} to 10^{-4} "Infrequent"	Leak of 2 gal. per min. to the soil. Environmental release is minimal due to under basin membrane and tile field.	YES - For lifts of equipment and barrier, the SAR documented cask event is bounding. (3)
11. Crane Failure and Cask Dropped Onto the Floor of Transfer Area (SAR 8.2.4)	Fully loaded cask (42 elements) drops 15 feet or more and overturns. The lid comes off and fuel spills out. Three broken elements per cask with break at a 45° angle. Fuel has been stored 150 days. 100% of the noble gases and 50% of the iodines are released as the only source term.	10^{-2} to 10^{-4} "Infrequent"	Site boundary dose: 7×10^{-6} mrem whole body and 1.5×10^{-3} mrem thyroid. (On-site dose - 16 mrem EDE 286 mrem limiting organ) (Off-site dose - 21 mrem EDE 386 mrem limiting organ)	NO - No fuel handling will occur out of basin.
11A. Crane Failure and Cask Dropped Onto the Floor of Transfer Area (Maximum Credible Accident) (SAR 8.2.4)	Cask fully loaded with broken fuel elements drops at least 15 feet, overturns and spills fuel out. Fuel is 150 days old. Only 100% noble gases and 50% iodines are released.	10^{-4} to 10^{-6} "Not expected to occur during the lifetime of the facility"	Offsite population exposure of 2×10^{-5} mrem whole body and 4.5×10^{-2} mrem thyroid doses. SEE ITEM 17 BELOW FOR A REANALYSIS OF THIS ACCIDENT.	
12. Loaded Canister Dropped from a Lifting Hoist to the Pool Floor (SAR 8.2.5)	Fully loaded canister dropped 3.5 feet.	10^{-2} to 10^{-4} (Not defined in SAR)	No leakage. There is no fracture of the cement slab.	YES (FOR FUEL HANDLING ONLY) - This represents NO CHANGE from the SAR baseline. Canister handling will be the same as documented in SAR baseline.
13. Fire and Explosion Hazard (SAR 8.2.6)	Noncombustible facilities. Adequate fire water supply. No ion exchange material regeneration.	None	None to very minimal. Hydrogen hazard in IXC and IXM being evaluated.	YES, some limited flammable materials may be brought in. This represents no change, from the SAR baseline, no unusual explosives or combustibles will be used.

TABLE 1
SAFETY EVALUATION OF ACTIVITIES VS SAFETY BASES EVENTS/ACCIDENTS

14. Loss of Pool Coolant (SAR 8.2.7)	Total loss of pool water. Maximum of 5% of total fuel is damaged.	$< 10^{-6}$ "Incredible"	Release is less than 200 times that of the cask drop. (On-site dose - 3.1 mrem EDE 57.1 mrem limiting organ) (Off-site dose - 3.6 mrem EDE 77.1 mrem limiting organ)	YES, this is related to barrier installation, but it represents NO CHANGE because barrier installation does not increase the probability of loss of coolant.
15. Uncontrolled Railroad Train (SAR 8.2.8)	Runaway train enters pool causing floor damage and leak of pool water. Derailers, railstops and bumpers in place and functional. Train speed controlled.	$< 10^{-6}$ "Incredible"	None since event is incredible. If credible, the leak would cause water loss and release of material.	YES, vehicles for delivery must be considered. The planned activity is bounded by the existing SAR. Equipment delivery will be by vehicles much lighter than train and cask, and entry to the basin is limited to routes which would not allow runaway vehicles to enter the basin.
16. Sludge Criticality (SER 3.1.8)	0.95 fuel only stored in KE.	$< 10^{-6}$ "Cannot Occur"	Homogeneous sludge cannot become critical.	YES, sludge will be disturbed by this activity. However, this activity represents NO CHANGE from the existing baseline.
17. Crane Failure and Cask Dropped Onto the Floor of Transfer Area (Maximum Credible Accident) (SER 3.2.4 replaces SAR 8.2.4)	Cask contains 3 canisters (42 elements) of all broken fuel. Fuel is 10 years old and is 12% Pu fuel. On-site exposure is for 2 hours and the off-site exposure is 8 hours.	Maximum of 10^{-4} "Not expected during plant lifetime."	On-site dose - 220 mrem EDE 4 rem limiting organ Off-site dose - 290 mrem EDE 5.4 rem limiting organ	NO - NO FUEL MOVEMENT OUT OF BASIN
17A. Cask Drop with 3 Canisters of Sludge	Sludge escapes ruptured canisters, dries and release radioactive materials. Sludge source term is 1985 sludge decayed 6 years.		On-site dose - 250 mrem EDE 4.7 rem limiting organ Off-site dose - 83 mrem EDE 1.6 rem limiting organ	
18. Loss of Off-site Power (SER 3.3.1 - SAR 5.3.3)	Total loss of power from offsite. Fuel handling operations cease with the power outage.	1 to 10^{-4} "Infrequent to Anticipated"	Heating up of pool due to loss of cooling. Maximum temperature is 130°F after 60 hours. (Being re-evaluated for current fuel age)	YES, loss of offsite power may occur during fuel handling or barrier installation activities. However, these activities represent NO CHANGE from the SAR baseline.

TABLE 1
SAFETY EVALUATION OF ACTIVITIES VS SAFETY BASES EVENTS/ACCIDENTS

19. Loss of Pool Cooling (SER 3.3.2 - SAR 5.3.3)	Loss of cooling with maximum heat load and no natural phenomena cooling. Initial temperature of 100°F and a maximum of 1.45 MW heat load.	1 to 10 ⁻⁴ "Infrequent to Anticipated"	Heating up of pool to a maximum of 130°F after 60 hours. (Being re-evaluated for current fuel age)	YES, loss of pool cooling may occur during fuel handling or barrier installation activities. However, these activities represent NO CHANGE from the SAR baseline.
20. Design Basis Earthquake (SER 3.3.3 - SAR 2.5)	Maximum horizontal acceleration of 0.25 g with simultaneous vertical acceleration of 0.17 g.	2.0 X 10 ⁻⁴	Basin leakage from either cracks in basin walls or at the construction joint between the basin and the reactor. Water loss is less than total. (See Item 44)	YES, rack cutting must be considered for change in facility seismic capability. The ECN USQ screening and analysis show that cutting of racks will not compromise seismic capability. (4)
21. Tornado (SER 3.3.4 - SAR 2.6)	Maximum wind speed of 175 mph.	6.82 X 10 ⁻⁶	Failure of wall and roof panels. Steel frame remains intact.	YES, a tornado could occur during these activities. This represents NO CHANGE from the existing SAR baseline.
22. Floods (Probable Maximum Flood) (SER 3.3.5 - SAR 4.3)	Reaches 423 feet above mean sea level.	(SDC 4.1 Design Basis Flood)	Loss of raw water (pumps submerged).	YES, flooding could occur during planned activities. This represents NO CHANGE from the existing SAR baseline.
23. Ashfall (SER 3.3.6 - SAR 4.6)	Maximum depth of 6 inches followed by heavy rain.	1 to 10 ⁻⁴ "Infrequent to Anticipated"	Roof loading of 25 lb/ft ²	YES, volcanic ashfall could occur during this activity. This represents no change from the existing SAR baseline.
24. Low/No Flow of Service Water (SER 3.4.1)	Pipe break causes basin overflow at KE. Flow is 2000 gpm to the basin. 8 hours to respond.	Low probability	Discharge of 90,900 gal. to the river via 1908-K outfall and formation of a 5.4 acre shallow (3 in. deep) lake at KE. Total off-site dose of 4.1 E-1 mrem/yr. and 3.4 mrem/yr on-site dose at 100 meters.	YES, loss of service water could occur during these activities. This represents no change from the existing SAR baseline.
25. Fuel Storage Basin Water Level Low (SER 3.4.2)	See items 5 and 14.	10 ⁻⁴ to 10 ⁻⁶	See item #s 5 and 14	YES, water level management will be required during this activity, as always. This activity represents no change from the existing SAR baseline.
26. Fuel Storage Basin Water Level Very Low or None; Fuel Storage Basin Leakage Catastrophic (SER 3.4.3)	See items 5, 14, 18, 19 and 20.	10 ⁻⁴ to 10 ⁻⁶	See item #s 5, 14, 18, 19 and 20.	YES, as in 25 above. This represents no change from the existing SAR baseline.

TABLE 1
SAFETY EVALUATION OF ACTIVITIES VS SAFETY BASES EVENTS/ACCIDENTS

27. Fuel Storage Basin Temperature Very High (SER 3.4.4)	See items 18 and 19.	10^{-2} to 10^{-4}	See item #s 18 and 19.	YES, high temperature alarms may occur during these activities. This represents no change from the existing SAR baseline.
28. Fuel Storage Basin Leakage (SER 3.4.5)	See items 5 and 14	10^{-4} to 10^{-6}	See item #s 5 and 14.	NO CHANGE TO 5 OR 14
29. Contaminated Building Atmosphere (SER 3.4.6)	Canister removed from basin with unnoticed fuel assembly. Hoist fails in "on" position. Evacuation of the basin and impacted areas.	$< 10^{-6}$ "Not expected to occur during the life of the facility."	On-site dose: 5 mrem EDE 90 mrem limiting organ Off-site dose: 7 mrem EDE 130 mrem limiting organ	Yes, radioactivity will be monitored. This represents no change from the existing SAR baseline.
30. Confinement of Gaseous Radiolysis Products (SER 3.4.7)	Radiolysis of sludge in basin and of canister contents.	Sludge $< 10^{-6}$ "Incredible" Canister-Not Defined	No consequences for sludge since it is incredible. Canister seal will leak at 100 psi and release gases.	Yes This represents no change from the existing SAR baseline.
31. Nitrogen Cylinder Rupture (SER 3.4.8)	Rupture of cylinder and formation of missile impacting fuel.	$< 10^{-6}$ "Incredible"	No longer credible. Bottles have been moved out of basin.	No - No pressurized gases required
32. Oxidation of Uranium Hydrides - Failure to Add Corrosion Inhibitor (SER 3.4.9)	Corrosion inhibitor not added to canister. Hydration of uranium has occurred.	existing analysis indicates $< 10^{-6}$ "Incredible"	None, the event is incredible.	The activity planned would not change the amount of corrosion inhibitor. This represents no change from the existing SAR baseline.
33. Release of Chlorine (SER 3.5.1)	Chlorine released from KE Water Treatment Facility.	None from planned activity.	Being re-evaluated due to modification and upgrade of chlorine system.	Yes, chlorine release is possible coincident with the planned activities. This represents no change from the existing SAR baseline.
34. Release of Sulfuric Acid/Sodium Hydroxide (SER 3.5.2)		$< 10^{-6}$ "Incredible"	None. Sources have been removed.	No - No acids/bases required
35. Sulfuric Acid or Sodium Hydroxide Solution Sent Directly to Basin (SER 3.5.3)		$< 10^{-6}$ "Incredible"	None. Sources have been removed.	No - No acids/bases required
36. OSR Fissile Mass Limits - Addition of Sludge to Open Canisters (SER 3.6.1)	Sludge canister spill into a loaded fuel canister.	10^{-2} to 10^{-4} "Infrequent"	Reduces reactivity.	NO - KW HAS CLOSED CANISTERS, NO FUEL CANISTER MOVEMENT AT KE.
37. Keff 0.98 vs 0.95 (SER 3.6.2)	NA	NA	Non concern. Evaluation and resolution sent to Tiger Team.	No -Issue resolved

TABLE 1
SAFETY EVALUATION OF ACTIVITIES VS SAFETY BASES EVENTS/ACCIDENTS

38. DBE Basin Water Level (SER 3.6.3)	See item #s 14 and 20.	2×10^{-4}	See item #s 14 and 20.	Yes - Evaluated by #14 & # 20
39. Spent Ion Exchange Shipment for Burial (SER 3.6.4)	NA	NA	Tiger Team item - resolution submitted.	Yes, this activity will generate additional ion column loading. This represents no change from the existing SAR baseline.
40. Basin Leakage Monitoring (SER 3.6.5)	NA	NA	Tiger Team item - resolution submitted.	Yes, basin leakage would need to be evaluated following an isolation barrier drop. This represents no change from the existing SAR baseline.
41. Release of Ion Exchange Medium (SER 3.6.6)	Drop of one IXM from crane or drop of two IXC's from crane. Release of 1% of the radioactive inventory from the resin.	10^{-2} to 10^{-4} "Unlikely Event"	Being re-evaluated with revised source terms. Previous analysis had results of: On-site does: 1.9 mrem EDE 28 mrem limiting organ Off-site dose: 0.92 mrem EDE 8.6 mrem limiting organ	Yes, this activity may require accelerated change of an ion column. This represents no change from the existing SAR baseline.
42. Clearwell Integrity During DBE (SER 3.6.7)	Loss of clearwell due to DBE.	2×10^{-4}	Loss of coolant makeup water. No significant basin impact. (Credit no longer taken)	No - No credit for integrity of Clearwell during DBE
43. Ventilation Stack Failure (SER 3.6.8)	Stack failure due to aircraft striking it.	$< 10^{-7}$ "Incredible"	Upper part of stack impacts basin.	No - No affect on stack
44. Unsupported Basin Construction Joint (SER 3.6.9)	No rebar or doweling across joint.	2×10^{-4}	Leak rate less than the ability to makeup. Leak rate from failure of 17 sq. ft. area of the basin floor is 2 gpm. (Being re-evaluated in conjunction with DBE review.)	Yes - Until isolation barrier installed no change in potential affect on basin water level.

- (1) SAR - Safety Analysis Report Irradiated N Reactor Fuel, WHC-SD-WM-SAR-062 REV 1.

SER - Safety Evaluation of Fuel Encapsulation in the 105-KE Storage Basin, WHC-SD-TA-020 REV 0. Also contained in Addendum 1 of SAR.

N.N.N - Refers to section of SAR or SER.

- (2) Applicability is for all activities unless otherwise noted.

- (3) The existing accident analysis reference by the SAR, UNI-287, "Extreme Load Analysis of the 100K Fuel Storage Basins and Clearwells", evaluated the consequences of dropping a fully loaded fuel canister, 728 lbs, on the 2 ft thick basin floor from a height of 3.5 ft. The energy of the falling canister, just before impact, would be about 2290 ft-lb, allowing for buoyancy effects. The maximum impacting force would be 68,500 lb which is less than the punching shear resistance of the concrete of 291,320 lb. For this drop no damage to basin is sustained.

A 25 foot drop of a transfer cask which weighs 48,000 lb will result in fracture of the basin floor, however leakage would be limited such that water make up can be effected before there is significant reduction in water level.

For the activities involving isolation barrier installation the maximum weight object would be the gate portion of the barrier with a weight of less than 2700 lbs. Using the same velocity values as for the fuel canister the impacting force would be 0.87 of the resistance. The drop height of the gate could be higher but because of its shape would likely sustain deformation which would reduce the impact force. Therefore damage to fuel basin is not likely to be sustained by equipment drops and in any case any damage would be much less than that of a cask drop. In addition such lifts will be handled as critical lifts which makes the probability of drops very small.

Drops on the fuel in racks will damage fuel but would be limited to a few canisters. Such damage could result in additional spread of radioactive materials to the water. Because the corrosion rates are slow the amount added would not be significant to that already in the water. The additional airborne radioactivity would thus also not be significant.

- (4) Refer to ECN 610292/610293, Prepare Isolation Barrier Location for Doors KE/KW.

TABLE 2
USQ EVALUATION

1	Does the proposed activity increase the probability of occurrence of an accident previously evaluated in the safety basis?	NO
	Basis: The handling of the fuel is the same as was done in the past so there should be no difference in probability of canister drop or lifting of fuel to basin surface. The activity involving other equipment with the potential for damage to safety structures are one limited activities with special lift requirements such that the probability of drop should be small. For other applicable accidents identified in Table 1 there is no change in operation thus no change in probability.	
2	Does the proposed change increase the consequences of an accident previously evaluated in the safety basis?	NO
	Basis: The drop accidents are all bounded by the existing safety basis as indicated in Table 1. For other applicable accidents there is no change.	
3	Does the proposed activity increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the safety basis?	NO
	Basis: The only potential malfunctions are to the basin structure and fuel racks that would be caused by drops. These were addressed by 1 above.	
4	Does the proposed activity increase the consequences of a malfunction of equipment important to safety previously evaluated in the safety basis?	NO
	Basis: The only potential malfunctions are to the basin structure and fuel racks that would be caused by drops. These were addressed by 2 above.	
5	Does the proposed activity create the possibility of an accident of a different type than any previously evaluated in the safety basis?	NO
	Basis: The general check sheets for hazard identification did not identify any different accidents.	
6	Does the proposed activity create the possibility of a malfunction of equipment important to safety previously evaluated in the safety basis?	NO
	Basis: Only mechanical damage to basin structure and fuel racks was identified and these are addressed by existing safety basis.	
7	Does the proposed activity reduce the margin of safety as defined in the basis for any Technical Safety Requirement?	NO
	Basis: No technical safety requirement(OSR) is impacted by the described activities.	

EVALUATION OF MINIMUM AMOUNT OF FUEL TO EXCEED HAZARD CATEGORY 2 OR 3 THRESHOLDS
WITH WATER SCRUBBING OF 10,000

PREPARED BY 1211 March
DATE 9/21/94
CHECKED BY C. S. [Signature]
DATE 9/21/94

[illegible]

SUMMARY ASSESSMENT OF SLUDGE ISSUES ASSOCIATED WITH ISOLATION BARRIER INSTALLATION IN 105 KE

INTRODUCTION

N Reactor irradiated fuel is currently stored in the K East (KE) reactor storage basin in canisters. There is an accumulation of sludge, containing uranium oxide of variable composition and density around these irradiated-fuel storage canisters. For isolation barrier installation, no planned operations or postulated accidents will increase the sludge in the vicinity of the discharge chute beyond the current 7 cm (2.75 in.) maximum. The following summary provides current insight on the character of the sludge and provides the safety basis for managing sludge during these operations.

CHARACTERIZATION OF SLUDGE

Traditional analyses with KE sludge have been performed using highly conservative assumptions about the sludge composition and depth. A series of measurements of depth of sludge in the 105-K East Basin was recently completed by Surveillance Systems Engineering and K Basin Engineering staff. This provided two important forms of data:

1. Physical measures of sludge depth in the basin, pits, and a sampling of canisters.
2. Video tapes documenting measurements.

The sludge depths in the main 105-K East basin are 7 cm (2.75 in.) or less. Other locations outside the main basin report deeper collections. The deepest accumulation found outside the main basin was next to the screen in the Weasel Pit where the depth was approximated to be 99 cm (39 in.). This is expected, since sludge is pumped to this location when it is removed from the main basin.

Data specific to the region around the discharge chute has been collected (1994/10). These sludge measurements report depths in position 1201 (immediately outside East discharge chute opening) of 1 cm (0.4 inch) and in position 3603 (immediately outside West discharge chute opening) of 7 cm (2.75 inch). The observed sludge gradient is gradually decreasing away from the West opening (a few centimeters per meter). This gradient is consistent with past sludge movement. The discharge chute sludge was cleaned out by jetting it into the main basin through the West opening; sludge settled preferentially immediately outside of the opening.

Table 1 provides a summary of the 105-K East sludge properties.

Table 1. Typical Character of Sludge.

Characteristic	Range or Type
<ul style="list-style-type: none"> Particle size distribution <ul style="list-style-type: none"> - Median of volume distribution (μ) - 90% of volume (μ) 	32 to 44 4 to 120
<ul style="list-style-type: none"> Density <ul style="list-style-type: none"> - Settled-with water (g/ml) - Particle density-dried (g/ml) 	1.13 to 1.54 3.0 to 3.3
<ul style="list-style-type: none"> Percent solids 	17.5 to 52.6
<ul style="list-style-type: none"> Percent non-dissolvable solids 	4.3 to 6.2%
<ul style="list-style-type: none"> Chemical composition of dissolvable portions 	Fe>U>Al>Ca>Si>Cr>Zn>Mg
<ul style="list-style-type: none"> Fissile content <ul style="list-style-type: none"> - U (%) - Pu 	3.5 to 10.9 (~1/400 of U)
<ul style="list-style-type: none"> Radiation level (mR/hr/g of B/γ) 	3.3 to 11.4

CRITICALITY ISSUES ASSOCIATED WITH SLUDGE

An analysis has been made (1992) of the criticality considerations associated with encapsulation related sludge containing broken fuel pieces and the associated fuel storage canisters. As a limiting case model, the sludge was modeled as wet uranium oxide of different densities between about 3 g/cm³ and 6 g/cm³ uranium oxide to determine the optimally moderated case. Both MCNP and WIMS-E computer code calculations were made for the case of 0.947 wt% ²³⁵U uranium oxide around the Mark IV fuel canisters in the uranium oxide sludge. Unirradiated uranium (no credit taken for ²³⁵U depletion) was used in the analysis as a conservative assumption. For most scenarios k_{inf} was computed for configurations containing stainless steel and aluminum canisters. These configurations represent the limiting case for reactivity increase due to sludge accumulation; calculations were also performed for a realistic sludge composition derived from analytical measurements.

Two types of calculations were performed for comparison to benchmark experiments - one involving documented Mark IA subcritical tests (1982) and the other involving homogenous mixtures of UO₃-H₂O. These two benchmarks are considered closely related systems, and because adequate calculational techniques exist for relatively small extrapolation from these data; the k_{eff} limit of 0.98 is justified according to Company policy (WHC-CM-4-29).

There is nothing to indicate a potential criticality hazard involved with disturbed sludge or sludge accumulation in the KE fuel storage basin. Specific results from the 1992 analysis include:

- The sludge minimum slab thickness is 125.36 cm (49.35 in.) for k_{eff} of 0.98.
- For optimally moderated uranium oxide accumulations to 90 cm (35.4 in) outside canisters containing Mark IV (the only fuel allowed in KE) fuel or canisters containing fuel rods in uranium oxide the MCNP calculated k_{inf} remained below 0.98 for both stainless steel and aluminum canisters.

More recent analyses (1994) also considered sludge as present for assessment of criticality safety margins. Sludge was modeled as wet UO₂ powder at an optimum moderation density of 3 grams UO₂/cm³ (significantly higher than the observed 0.17 grams UO₂/cm³) and uranium enrichment of 0.947 wt% ²³⁵U, giving H/U atomic ratio = 7.26 in this wet UO₂ powder. The UO₂ was assumed to be at 10.96 g/cm³ theoretical density with the void space filled with H₂O.

The criticality evaluations consider normal operation and a series of credible off-normal situations without the storage racks. The off-normals include a series of losses of canister spacing in KE and KW basins. Calculations also considered accidental maximum possible buildup of uranium oxide outside the canisters.

In all the analyses the racks were assumed to be absent allowing for canister movement into more reactive configurations. Both canisters made from aluminum and stainless steel were considered. Different scenarios were investigated.

These include all spacing controls removed and all canisters tipped and stacked on their sides. Some accidents considered canister spills with additional fuel placed between canisters in space the canister storage racks presently occupy.

The analyses were performed with the MCNP code. Results from these calculations are:

- o If the racks are removed and canisters stay in place, no reactivity change is observed.
- o If canisters are moved together, reactivity increases. However, for MKIV and MKIA fuel assemblies in stainless steel canisters or aluminum canisters, with or without uranium oxide buildup, the criticality limit ($k_{eff} + 2 \sigma < 0.98$) is not exceeded.
- o If canisters are broken apart and close packed in a hexagonal geometry, the reactivity increases. For MKIV fuel assemblies in stainless steel canisters, or in aluminum canisters, this does not exceed the criticality limit ($k_{eff} + 2 \sigma < 0.98$).
- o If canisters are tipped, the k_{eff} is less than for standing canisters. The tipped configuration is critically safe for both types of fuel and for both canister materials.
- o Single canister fuel spill off-normal assumed fuel elements around existing canisters. The calculations for spilling all the fuel out of a single canister indicate that for MKIV fuel in stainless steel or aluminum canisters, the criticality limit ($k_{eff} + 2 \sigma < 0.98$) is not exceeded under any condition.
- o Multiple canister fuel spill off-normal assumed one canister of fuel elements around each existing canister. The calculations for a large number of canister drops indicate that for MKIV fuel in stainless steel or aluminum canisters, the criticality limit ($k_{eff} + 2 \sigma < 0.98$) is not exceeded.

OPERATIONS AND ACCIDENTS ASSOCIATED WITH ISOLATION BARRIER INSTALLATION

Routine operations associated with isolation barrier installation in KE which should consider sludge are well bounded by existing analyses. The most significant activity planned is moving sludge away from the discharge chute opening prior to installation of the isolation barriers. This consists of pumping of sludge to the "weasel pit", an activity which is also covered by criticality safety analysis (1993). Relocation of sludge to this area does not pose a criticality risk.

Accidents which may involve significant sludge movement can be bounded by accidents which cause rapid-uncontrolled water movement, which suspends sludge and moves it. Only one accident has been identified which could lead to this consequence, dropping of an isolation barrier. As the barrier falls, the

majority of it's potential energy is expected to be converted to water movement.

Material of the particle size distribution and density of sludge is easily disturbed by the turbulent flow associated with a barrier drop. Once disturbed, it remains in suspension in water for extended periods (hours to days). Experience with pumping sludge shows that the suspended material will be rapidly distributed through large volumes of water by convection and diffusion. The sludge then settles out as the turbulence of the water decreases, covering large areas of the basin with an additional thin roughly uniform layer. Because of the properties of the sludge, attempts to accumulate sludge using engineered systems (induce settling in a local area) has been unsuccessful to date. Accumulating a 90 cm layer of sludge is not credible.

Although sludge accumulation is not a credible result of an accident, other factors would mitigate it, if it were. The actual composition of sludge is significantly less reactive than that analyzed, and the settled out sludge is not optimally moderated. For optimally moderated uranium oxide accumulations to 90 cm (35.4 in) outside canisters containing Mark IV fuel (the only fuel allowed in KE) the MCNP calculated k_{inf} remained below 0.98 for both stainless steel and aluminum canisters. Since such an accumulation is not credible as the result of a door fall, criticality can be ruled out.

CONCLUSION

Routine operations and accidents which may occur during isolation barrier installation will not result in sludge movements which pose criticality safety problems in the basin.

References

1994/10, *Sludge Measurement Results for 105 KE Basin*, Draft OA with projected release 10/31/94, WHC-SD-WM-ANAL-037, T.A. Meling.

1994, *Criticality Safety Evaluation K Basin Storage Rack Seismic Qualification*, WHC-SD-NR-CSER-009, Rev. 0.

1993, *MCNP Calculations of K-infinity for 100 KE Basin Sludge Samples*, WHC-SD-NR-CSER-008. Rev. 1, W.D. Wittekind.

1992, *K Basin Criticality Evaluation for Irradiated Fuel Canisters in Sludge*, WHC-SD-NR-CSER-001 Rev 0, Wittekind, W. D.

1982, *Nuclear Criticality Safety Analysis and Technical Basis for Contingent Fuel Storage in 105-KE/KW Basins*, UNI-1779, Toffer, H., and J. H. Eaves.

WHC-CM-4-29, *Criticality Safety Manual*.

Analyses of Falling Objects Within the Basin

1.0 INTRODUCTION

The fall of objects into the basin has the potential to damage fuel or to damage the basin floor. An analysis of these events is presented below.

The most limiting object to be handled is the isolation barrier, which can be treated as a plate. This plate, 5.5 meter high (18 feet) and 1.1 meter (43 inches) wide, is to be used as an isolation barrier in the water filled K-East basin. The plate is nominally 1.3 cm (0.5 inch) thick, but with various seals and attachments, weighs 1091 kg under water. This is equivalent to a solid steel plate which is 2.7 cm (1.1 inch) thick. This assessment examines the consequences if this plate were to fall over on the irradiated reactor fuel storage canisters which are located in racks at the bottom of the basin, and considers the impact of the plate on the basin floor.

The assessment is divided into four primary parts. The first considers the impact velocity and energy of the plate when it reaches the bottom. The second part estimates the amount of damage to the canisters. The third part assesses the potential for damage to the basin from an isolation barrier impacting directly on concrete or from an isolation barrier's energy being transmitted via impact through canisters which sit on the basin floor. The fourth part evaluates the criticality implications of a plate drop. The assessment also concludes that other drops are bounded by the plate drop.

2.0 MODELING OF PLATE FALL

2.1 Small Scale Experiments

Small scale experiments using plates in water with the correct height to width (aspect ratio) show that if the standing plate is released from a vertical position, it will hinge along the bottom edge (the "flat" trajectory shown in Figure 1). If the bottom edge is initially at a horizontal corner, the plate will flop down in a simple and direct manner. If the plate bottom edge is not firmly in the corner, there may be some sideways rotation (i.e. shifting side to side) during the downward travel. It is very small and the bottom corners of the plate provide a restoring moment which prevents significant sideways rotation. If the plate is released while standing away from the basin sides, midway through the downward motion, the bottom edge moves backward and a sideways rotation may develop, sometimes as much as 180° or more. However, it is significant that the plate always falls by hinging about the bottom edge. Any tendency to tip sideways is overcome by the interaction of the plate bottom corners with the pool bottom which provides a restoring moment. Also, the plate always lands flat on the tank bottom. However if the plate is released as falling on a sideways edge, it will continue like that all the way

to the bottom (referred to in Figure 1 as "edge first" trajectory).

Another observation is that the plate falling velocity is controlled by the drag resistance of the water. A heavy steel plate falls much faster than a lighter aluminum plate with the same height and width. This is expected of course and, as will be shown later, the terminal velocity causes drag forces which are in equilibrium with the weight.

2.2 Modeling

There is some uncertainty in the drag coefficient. A flat plate of infinite length is estimated to have a value near 2. However, for finite lengths, the value ranges from 1.1 to 1.5. Since a smaller drag coefficient means higher plate velocities, a conservative value of 1.0 was selected to this study.

A computer model was constructed for the falling plate with the bottom edge as the hinge. Gravitation forces accelerate the plate during its rotation and drag forces by the water retard this motion. It was soon noticed that the predicted terminal velocity could be calculated by considering the plate to be horizontal and summing moments about the bottom edge. The accelerating moment is caused by the plate weight acting at the center of gravity. The resisting moment is obtained by integrating the drag forces over the plate. The inertia of the plate is included in the model but does not play a role.

These concepts are shown in Equation 1

$$\Sigma M = 0$$

$$\frac{WL}{2} - \frac{1}{2} \rho_w C_D \frac{S}{L^2} V_{\max}^2 \int_0^L r^3 dr = 0 \quad (1)$$

where W = Plate weight under water
L = Plate length
 ρ_w = Density of water
 C_D = Drag coefficient
S = Plate width
 $V_{\max}$ = Velocity at plate tip

Figure 1 - Sketch showing the trajectories for two modes of isolation barrier falls in the event that the support fails during movement into the basin.

Solving Equation 1 for $V_{\max}$ yields a velocity of 2.7 m/s (8.8 ft/sec) with a kinetic energy of 1540 J. (The falling time is over 5 seconds). This may be contrasted with a case without water drag. Here the falling time is about 2.7 seconds, final tip velocity is 11.3 m/s, and the kinetic energy is 3×10^4 J. The presence of water reduces the plate kinetic energy by a factor of 20. However the case without water drag can be used to conservatively approximate an unlikely edge drop case for a bounding accident¹.

3.0 DAMAGE TO FUEL STORAGE CANISTERS FROM BARRIER FALL

3.1 General Overview of Isolation Barrier Falls in Basin

Isolation barriers [5.5 meters (18 feet high), 1.1 meter (43 inches) wide and 10 centimeters (4 inches) thick (1/2" steel plate with 3 1/2 inch tube steel stiffeners)] are initially inserted into the discharge chute by suspending them horizontally above the discharge chute and lowering, in a controlled fashion, the bottom edge until the barrier is upright and from 0.15 meters (0.5 foot) to 0.6 meters (2 foot) above the basin floor. Isolation barriers are brought into the main basin by moving them, in the upright position, from the discharge chute into the main basin. Isolation barriers are never moved directly over fuel.

Two separate falls will be considered in the overall analysis. The first, considered here, is the impact of a barrier when dropped on fuel. It will be developed for both the probable "flat" trajectories (Section 3.2) and the less probable "edge first" trajectory (Section 3.3). The second, considered in Section 4.0 below, evaluates the impact of a barrier drop onto unprotected concrete; this case is of significance since concrete damage could lead to basin leakage.

¹ WHC-SD-SNF-SARR-004, Revision 0, Results of Falling Barrier Analyses, G. L. Fox, 11/94.

3.2 "Flat" Trajectory Falls

Although barriers will not be moved above fuel, they will be moved in the vicinity of fuel. If a barrier lifting tackle were to fail and the barrier to be dropped, it would come into contact with fuel. Figure 2 provides a postulated typical side perspective (to scale), as seen immediately before a falling barrier strikes fuel. In this figure, the barrier is assumed to fall in the dominant "face first" mode.

Canisters are nominally 740 mm X 460 mm X 230 mm (29" X 18" X 9"), and are placed in racks in the basin. The individual rack sections (described in WHC-SD-WM-SAR-062 Rev 1, Section 5.2.1) are two canisters wide [1070 mm (42")] and vary in length with a length of 10 or more canisters for an array of 20 or more canisters per individual rack. The racks are interlocked to limit motion of any rack with respect to its neighbors. They stand 430 mm (1' 5") nominal above the basin floor and provide lateral separation only (canisters sit directly on the basin floor). Canisters are separated by members ranging from 1-1/4" Schedule 40 pipe to doubled 6" channel.

Note that the maximum fuel involved, assuming the barrier were to fall totally onto fuel canisters, can be bounded by the area of the barrier as laid down across a set of canisters (see Figure 3). An isolation barrier is approximately 2 racked canisters wide and approximately 20 canisters long, for a total of 40 canister equivalents which could be covered by a worst case fall. If the barrier was assumed to bounce or move sideways due to rotational momentum, one could postulate up to double this number, for a total of 80 canisters involved.

As developed above, the maximum kinetic energy of a "flat" fall is 1540 J. (The falling time is over 5 seconds). The presence of water reduces the plate kinetic energy by a factor of 20.

Figure 2 - Possible fall of barrier. Note barrier is 18 feet long and nearest fuel is approximately 5 feet from the barrier. Upon loss of support, the barrier will fall freely until it hits the basin floor. It then rotates around the "hinge point" in contact with the floor until it comes into contact with the nearest fuel canisters.

3.3 "Edge First" Trajectory Falls

Although the fall of a barrier so that it impacts edge first is unlikely, an "edge first" fall results in the highest kinetic energy available to do damage. This case, without water drag, can be used to conservatively approximate an unlikely edge drop case for a bounding accident. Here the falling time is about 2.7 seconds, final tip (top of barrier) velocity is 11.3 m/s, and the kinetic energy is 3×10^4 Joules.

The edge first fall results in a leading edge which is 100 mm (4") wide and 5500 mm (18') long impacting canisters, yielding the highest impact loading possible. The footprint of such a fall would cover up to 20 canister barrels for a 10 canister equivalent impact zone.

Figure 3 - Sketch showing the footprint of an isolation barrier fallen across fuel canisters in racks in K Basin.

3.4 Barrier Interaction with Fuel Canisters

This section will examine potential interactions of a falling barrier with fuel canisters. The potential for canister damage will be broken into damage from direct "flat" impact (Section 3.4.1), damage from direct "edge first" impact (Section 3.4.2), and the potential for barrier impact moving the fuel (section 3.4.3).

Data has been developed for canister compression to support the design of equipment to dispose of canisters by crushing them (canister crushers). This data focused on the maximum forces the equipment must be designed to provide. It does provide useful data for analysis of accidental crushes resulting from drop of equipment on canisters in the basin.

The basic crush data was collected for empty canisters. Both Aluminum and Steel canisters were crushed. The actual crush behavior can be visualized as similar to the crush of a thick wall soda can; it proceeds by localized indentations of the canister (usually symmetrically located on opposing sides of the canister). The resistance of the canister remains high until the initial buckling (first set of indentations) occurs; it then drops for a period until the first set of dents are fully collapsed. Once the dents are fully collapsed, the resistance rises until another set of indentations appears. This behavior results in fluctuations in the resistance to crushing, as can be seen from the graph below (typical actual performance). Representative data has not been formally reported, but is summarized below, based on logs, discussions with the PNL lead engineer and review of video footage of the tests. Formal test reports will not be developed because independently performed calculations analytically predict the crush forces to be consistent with those actually observed.

3.4.1 Canister Damage from Direct "Flat" Impact

The failure of the canister could be expected to appear as indentations of the canister above the fuel, as shown in Figure 3. Note that the fuel, located in the lower portion of the canister, would act as a constraint, preventing the canister from buckling inward at locations where fuel is present. The fuel elements range from 380 mm (14.9") to 690 mm (26.9") in length. Hence, if canister failure occurs, the probable failure is buckling by indentations in the gas plenum above the fuel.

The energy available for buckling the canisters limits the total number of canister which can be seriously deformed. Compression of a single canister through the first 150 mm (6 inches) at a minimum 8.9×10^4 Newtons (2×10^4 pounds) resistance would absorb 1.4×10^4 Joules (1×10^4 foot-lbs) of energy [93 Joules/mm]. The maximum energy available from an isolation barrier drop,

Force to Compress Canisters

in the "flat" case is 1.54×10^3 Joules. In the "flat" case, this energy can easily be absorbed by deformation of a single canister less than 18 mm (0.7"). Since the actual point of initial contact of the barrier with the fuel is 1.5 m (5') from the bottom end of the barrier, and the barrier is 5.5 m (18') long, only a fraction of this energy (280 Joules) is available to do work on the lead canister. This energy is sufficient to damage one canister by 3 mm (0.1"). Hence, since the actual damage would be spread among several canisters, none are seriously compressed by the barrier impact. Even accounting for the oblique nature of the impact, damage to canisters will be limited.

3.4.2 Damage from Direct "Edge First" Impact

An "edge first" impact is judged to be highly unlikely. Small scale experiments using plates in water with the correct height to width (aspect ratio) show that if the standing plate is released from a vertical position, it will "hinge" along the bottom edge. Attempts to initiate an "edge first"

fall with a plate suspended from the top were not successful; when the leading edge strikes the bottom, the plate rotates to the lower energy state which corresponds to the plate bottom totally in contact and "hinging" on the floor. Further, although impact with the wall was postulated as an initiator of an "edge first" fall, attempts to cause an "edge first" fall by wall contact resulted in either a "flat" fall or the plate coming to rest propped against the wall. "Edge first" falls were only achieved by suspending the plate over an obstacle on the bottom and dropping it; this configuration is unlikely to exist during handling in the basin.

Figure 3 - Canister on the left shows anticipated failure following impact of massive object such as isolation barrier.

Although considered unlikely (and possibly not physically achievable), it is prudent to develop the "edge first" case as a bounding case. The maximum kinetic energy available from the "edge first" isolation barrier drop is 3×10^4 Joules. This kinetic energy, if totally available to do damage would be sufficient to compress 4 canisters 80 mm (3"). Since the actual point of initial contact of the barrier with the fuel is 0.9 m to 1.5 m (3' to 5') from the bottom of the barrier, and the barrier is 5.5 m (18') long, only a fraction of the kinetic energy would be available to do work on the lead canisters. Hence, it is likely that this damage will be distributed among the row of canisters with which the edge impacts. Up to 10 canister equivalents may see some damage. The damage will be limited to canister deformation and possibly up to four canisters crushed to the point of contact with the fuel and possible fuel deformation. The fuel will act as a stiffener for the canister, resisting further collapse. Because the resistance of the canister barrel would increase when fuel is contacted, damage (crushing) of intact fuel in the canisters would be limited.

3.4.3 Potential for Barrier Impact Moving the Fuel

Movement of canisters and fuel can be bounded by building on the arguments developed above. When the barrier falls, it will tend to pivot around the point of initial impact with the fuel unless something constrains pivoting. For a solid enough constraint to move fuel, the basin wall would have to serve as the constraint; this will only occur during a "flat" fall since a high wall impact is necessary to rotate the door for an "edge first" fall. For this scenario, the barrier will hit fuel at 1.5 m (5') distance from the edge of the wall when the barrier impact point is 740 mm (29") off the basin floor. If no deformation occurs and the door does not slip with respect to the point

of impact on the canister while sliding up the wall (highly unlikely), we could develop the maximum canister movement. This results as the bottom of the barrier slides up the wall, moving the tops of canisters outward. The maximum displacement, established by simple geometric relationships, is 170 mm (6.7"). This would be insufficient to significantly change the fuel geometry.

The canister barrels are nominally 230 mm (9") in diameter and the racks separate canisters by 270 mm (10.625") from center to center using Schedule 40 1-1/4" pipe. Hence the first canister will not come into contact with the second canister until it has tipped enough to move the top 40 mm (1.5"). Applying the same argument for subsequent canisters implies that the 170 mm (6.7") movement of the first canister may result in a 130 mm (5.2") movement of the second, a 70 mm (2.7") movement of the third, a 30 mm (1.2") movement for the fourth, and none for the fifth. Since the barrier may initially come into contact with 2 or parts of three separate canisters, up to 3 X 4 or 12 canisters may be rotated as the barrier comes into contact with canisters. It is reasonable to expect that, due to rack geometry constraints, none of the canisters will overturn.

Figure showing fuel shifting as driven out by falling isolation barrier. Note that fuel canisters shift is constrained by the racks.

4.0 POTENTIAL FOR DAMAGE TO THE BASIN

Damage to the basin can be evaluated by considering four options. Section 4.1 will consider the force on the basin floor resulting from the impact of a falling door as transmitted by a canister. Section 4.2 covers the consequences of impact on the basin floor when the door is dropped while suspended upright. Section 4.3 will evaluate the potential for damage to the basin floor from a direct impact during door initial entry into the discharge chute. Section 4.4 addresses general equipment drops.

4.1 Transmitted Impact of Barrier through Canister to Floor

If a barrier impacts a canister or canisters while falling, one must also evaluate the potential for basin damage. A simple model, considering only the ability of canisters to transmit this force, demonstrates that canisters will fail before the basin floor. This simplified model, conservatively neglecting inertial effects, the compression of concrete, and compression of soil below the concrete, yields confidence that the transmitted force of a barrier drop will not fail concrete.

The maximum force a canister can transmit to the basin floor is 3.6×10^5 Newtons (8.0×10^4 lbs), as seen from canister crushing data. The punching shear stress resistance of the basin floor (a reinforced concrete slab which is greater than 510 mm (20 inches) thick) as developed in the safety analysis report discussion of a loaded canister drop, is 1.3×10^6 Newtons (2.9×10^5 lbs).² Hence, there is a factor of 3.5 margin assuring the canister will buckle before the force is sufficient to fail the concrete. Regardless of the accident, the canisters will provide an effective buffer to protect the basin floor from damage. As the initial canister crushes, other canisters will be contacted by the falling barrier, distributing the load over a larger area and absorbing additional energy.

4.2 Upright Barrier Impact on Basin Floor

During installation, from initial uprighting until connection of tie rods, the barriers are supported by a single lifting bail located on the top of the barrier (the door is supported so that the 43" side is parallel to the bottom). This occurs both in the discharge chute and in the main basin. The barrier is upright and from 150 mm (0.5 foot) to 600 mm (2 feet) above the basin floor.

If the barrier drops from the maximum height of 600 mm, the energy at impact is 6600 Joules. The barrier will probably hit on the bottom and distribute the impact across a surface which is 4" X 43" for an area of 1.1×10^5 mm² (172 inch²). This can be compared with the 330 kg (728 lbs) canister drop from 1 meter (3.5') in the basin which yields an energy of 3300 Joules which is absorbed over an area of 6.5×10^4 mm² (100 inch²) with a factor of 4.2 margin to impact failure (neglecting inelastic effects). Hence, although the margin would be reduced slightly, failure of the basin due to impact is not a likely consequence of a barrier drop from 0.6 meters. However, surface damage to the concrete of up to 17 mm (0.7 inch) penetration was predicted.

If the barrier rotates while falling, a corner impact may occur. Such rotation is unlikely, because of the balanced single point support which must be postulated to fail. Analyses performed on the impact of a rotated door with only 650 mm² (1 inch²) impact area indicates penetration of up to 100 mm (3.8 inch) is possible. A conservative assumption in determining the magnitude of penetration was assuming the surface impacted remains 650 mm²; even the worst credible rotation would increase the effective impact area several times. An additional conservative assumption was that the total energy of the door is transmitted to concrete through this 650 mm²; rotation of the door more than 0.1 radian would bring the center of mass outside of the point of impact. Hence the impact would rotate the door, reducing the energy available at the impact point for concrete damage.

² WHC-SD-WM-SAR-062 Rev 1

Neglecting these effects, the damage resulting from this fall can be conservatively computed. Assuming the impact point remained 650 mm² and the energy was transmitted through this point, an estimate was made to determine whether spalling or scabbing (punching a conical segment from the bottom of the concrete basin floor) were credible. Even neglecting soil resistance, the most conservative model indicated that scabbing was highly unlikely. Hence, significant leakage is not likely³.

However, if basin failure did occur, it would be bounded by the analysis in the existing Safety Analysis Report⁴ for K Basins. The specific bounding analysis is drop of a loaded shipping cask (mass exceeds that of door) from above the water (significantly greater than 0.6 meters) with a larger footprint and large damage projected, resulting in a leakrate of 5500 liters per hour (1500 gph).

4.3 Impact of Rigging Failure During Initial Entry of Barrier into Water

Barriers enter the water in the discharge chute. There they are supported by two lifting bails located on the middle of the top and bottom of the barrier (the door is supported so that the 110 cm (43") and 5.5 m (18') sides are both parallel to the bottom). One end is slowly lowered until the barrier is upright and from 0.15 meters (0.5 foot) to 0.6 meters (2 foot) above the basin floor.

If the rigging attached to one of the lifting bails should fail (unlikely since this is being treated as a critical lift), the barrier would still be supported by one end, and would swing down through the water. The swing would be "flat" since the remaining lifting bail's support is 300 mm (12") above the centerline and would serve to prevent rotation to an "edge first" fall. As in the "flat" fall, the barrier would reach a terminal velocity which limits the total kinetic energy at the bottom of the swing to 1540 Joules. This energy would be further damped as the door continued to swing, until it came to rest, supported above the floor.

If the barrier does not clear the floor because the remaining support has been lowered by mistake, it will impact concrete. Because it is still supported from a single point, and the motion is damped, the maximum energy available is 1540 Joules and the impact to the basin bottom would be a glancing blow. The degree to which the blow is glancing depends on the height of the remaining support; if the remaining support is 5.5 m (18') above the floor, virtually no

³ Memo, B.V. Winkel to J.C. Wiborg, Isolation Door Drop concern, October 19, 1994.

⁴ WHC-SD-WM-SAR-062 Rev 1

contact will be made while a support only 4.9 m (16') above the floor results in greater impact.

Since the failure of one support point with a corresponding error leaving the remaining support at less than 5.5 m (18') is unlikely, the argument will be analytically developed in a limited fashion. Inspection of the margin available for the case discussed in 4.2 above, combined with the additional mitigating factors, supports a case that this accident will not fail the basin floor. Additional mitigating factors include: a) glancing blows require less force to deflect, and reduce the component of downward force the basin must withstand, b) the energy available to do damage is significantly less than a direct drop and c) the impact point with one support would be the nominal 4" X 4" tubing welded as stiffening to the barrier providing for energy absorption from plastic deformation of the tube steel. Finally, using the table developed in Section 4.4 below, the door could be dropped 4.6 meters (15 feet) from an initially vertical configuration and, if the impact area exceeds 1290 mm² (2 inch²), a factor of 1.5 margin remains to basin floor perforation; the energy available from any partially supported fall is less than that of a 4.6 meters (15 foot) free fall.

4.4 Impact of General Rigging Failures Resulting in Drops into Water

Drops of objects other than the isolation barriers must also be considered. An analysis, the results of which are summarized in the table below, was performed to establish a relationship between the mass of objects and the height at which, if they fall, failure of the basin by penetration, scabbing, and spalling leading to basin failure by perforation is not credible⁵. A limited impact area is conservatively applied; the larger the impact area, the more limited the likelihood of perforation will be. This analysis also neglects the mitigating effects of buoyancy resulting from displacement of water and of hydraulic drag; hence it represents an initial screening tool which may be supplemented.

This table can be applied for a routine screening of equipment moved into the basin in support of isolation barrier installation. As an example, the next most massive component used in isolation barrier installation is the surfacing equipment which has a mass of 360 Kg (800 lbs). It could be dropped from a height in excess of 9100 mm (30 feet) without failing the basin floor. Further, since it is constructed of Aluminum, it has a water displacement corrected mass of 235 Kg (520 lbs) which could be dropped from in excess of 30 feet (i.e., higher than it can be raised) without damaging the basin floor sufficiently to yield perforation. A similar analysis, applied to other lighter components indicates that the risk of damage from dropped equipment resulting in leakage is minimal.

⁵ Letter, B.V. Winkel to J. C. Wiborg, K BASIN HARDWARE DROP CONCERNS, BVW-8D429-008, November 9, 1994.

Projectile mass (weight) for an object hitting on an impact area of 1290 mm² (2 inch²) which can be dropped from various heights while maintaining a safety factor of 1.5 to an impact resulting in perforation of the basin floor.

Height of object above basin floor upon drop	Mass/Weight of Missile which will not perforate basin floor if it impacts on an area of 1290 mm ² (2 inch ²)
305 mm [1 foot]	7.2×10^3 Kg [1.6×10^4 lb]
609 mm [2 feet]	4.4×10^3 Kg [9.8×10^3 lb]
914 mm [3 feet]	3.3×10^3 Kg [7.2×10^3 lb]
1220 mm [4 feet]	2.6×10^3 Kg [5.8×10^3 lb]
1524 mm [5 feet]	2.2×10^3 Kg [4.9×10^3 lb]
3050 mm [10 feet]	1.3×10^3 Kg [2.9×10^3 lb]
4570 mm [15 feet]	1×10^3 Kg [2.2×10^3 lb]
6100 mm [20 feet]	7.7×10^2 Kg [1.7×10^3 lb]
9100 mm [30 feet]	5.4×10^2 Kg [1.2×10^3 lb]

5.0 CRITICALITY IMPLICATIONS OF A PLATE DROP

The most significant fuel movement, as discussed in section 3.4.3, results in no change in the areal density of the fuel. Other consequences such as partial crushing of canisters yields no change in areal density. The event does not result in spreading fuel over or among canisters. The configuration (fuel geometry) it creates is bounded by existing Criticality Safety Evaluation Reports. Hence, the margin to accidental criticality is not reduced significantly by any of these postulated scenarios.⁶

6.0 CONCLUSION

The drop of an isolation barrier during installation is highly undesirable. A number of approaches will be taken to limit the potential for drop, including treating lifts as critical lifts, removing fuel in the immediate vicinity and limiting the height of barriers during handling in the basin. In the event a drop did occur, the damage would be limited to partial crushing of a limited number of canisters. No mechanism for radionuclide release to the atmosphere was identified. Criticality risk is not increased.

⁶ 1994, Criticality Safety Evaluation K Basin Rack Seismic Qualification, WHC-SD-NR-CSER-009, Rev. 0.