ENCLOSURE 4

PROPOSED EXEMPTION FROM THE REQUIREMENTS OF 10 CFR 50.68(b)(1)

Spent Fuel Pool Dilution Analysis

45 Pages Follow

ENGINEERING ANALYSIS COVER SHEET

EA- WJB-00-01

Total Number of Sheets 56

Title Spent Fuel Pool Dilution Analysis

INITIATION AND REVIEW

Calculation Status	Preliminary ☐	Pending ☐	Final ☑	Superseded ☐

Rev #	Description	Initiated By	Initiated Date	Init Appd By	Review Method: Alt Calc	Review Method: Detail Rev'w	Review Method: Qual Test	Technically Reviewed By	Technically Reviewed Date	Rev'r Appd By	Sup'v or NMC Appd
0	**Original Issue**	WJ Beckius	1/25/01	RDR	X	X		JA Meinke	2/13/01		
1	Updated to support new storage casks and pool configurations	SF Pierce SFPierce	6-15-05	BNB		X		GTWiggins GTWiggins	6-16-05	BNB	BNB

Note:

Revision bars are provided for all technical and/or significant changes made in going from revision 0 to revision 1 of this EA. Where possible, text from the comment resolution process in revision 0 of this EA are incorporated. These changes are not considered technical changes to the EA and are therefore not provided with revision bars.

Reference/Comment

Purpose

The purpose of the original issue of this analysis is to support a Tech Spec change request to credit dissolved boron in the spent fuel pool rack criticality analysis. This Tech Spec change was implemented in T.S. Amendment 207.

The purpose of this analysis is expanded in Revision 1 to support an Exemption Request from the requirements of 10CFR SECTION 50.68(b)(1) for the Palisades Plant to support loading of NUHOMS®-32PT dry fuel storage casks.

This EA also provides approval/acceptance of Transnuclear Calculation No. 11030-01 Rev. 0, "Boron Dilution Criticality Analysis for NUHOMS®-32PT with CE 15x15 Fuel" (Attachment 1). This vendor calculation determines the minimum soluble boron concentration required to maintain subcriticality of the NUHOMS®-32PT DSC loaded with 32 CE 15x15 fuel assemblies following a boron dilution event.

Objective

The objective of this analysis is to show that a dilution accident will result in the spent fuel pool boron concentration remaining above that assumed in the criticality analysis, as reported in Reference 3, for long enough to credit operator action to terminate the event. The assumed criticality values were 850 ppm for normal storage conditions and 1350 ppm for a bundle drop or bundle misloading condition which is a double contingency event.

In support of the exemption request, the objective of this analysis is to show that a dilution accident will result in the spent fuel pool boron concentration remaining above that assumed in the criticality analysis, as reported in Reference 30, for long enough to credit operator action to terminate the event. The assumed criticality value is 1850 ppm for the NUHOMS®-32PT cask loading event.

References

1. ANS 57.2/ANSI N210-1976,"Design Objectives for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Stations."
2. Standard Review Plan (NUREG-800) Section 9.1.2
3. EA-SFP-99-02, "Spent Fuel Pool Accident and Rack Interaction Evaluation," March 2000.
4. FSAR Rev 25, Section 9.11 "Fuel Handling and Storage Systems.
5. FSAR Rev 25, Section 14.3 "Boron Dilution"

PALISADES NUCLEAR PLANT
ANALYSIS CONTINUATION SHEET

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Reference/Comment

6. DBD-2.07, Spent Fuel Pool Cooling System, Rev 37. FD-M-23 Rev B, "Bechtel Functional System Description Spent Fuel Pool Cooling System" [4383/1966]

8. SOP-27 Rev 46, System Operating Procedure, "Fuel Pool System"

9. COP-27 Rev 21, Chemistry Operating Procedure, "Spent Fuel Pool System Chemistry"

10. EA-GCP-93-01, "Review of Current Spent Fuel Pool Criticality Analysis and Bounding Conditions" Rev 0,3/22/93 [F474/0631]11. EA-GCP-91-05, "Spent Fuel Pool Cooling System FLONET Model," Rev 0, 1/16/92 [F027/1913]

12. EA-A-PAL-93-001, "Dilution Analysis to Support Decontamination" Rev 0, 3/8/93 [F373/1387]

13. EA-TM-94-100-01, "Fuel Pool Dilution Evaluation for Temporary Cooling Modifications TM-94-100 and TM-95-011, Rev 2. 7/7/95 [G391/0937]

14. GOP-11 Rev 37, General Operating Procedure, "Refueling Operations and Fuel Handling"

15. ONP-23.3 Rev 5, Off Normal Procedure, "Loss of Refueling Water Accident"

16. WI-RSD-R-018, Work Instruction, "Tri-Nuclear Underwater Filtration System," Rev 0, James C. Radosevich, 2/1/99 [4451/1139]

17. Engineering Work Sheet by K.D. Brienzo dated 8/10/77, "Derivation of the Feed and Bleed Equations for Borating or Diluting the Primary Coolant System or Any Other Closed System" attached to Memo WLR-35-79, W.L. Roberts to Plant Review Committee 5/23/79 [9055/2087].

18. EA-FPP-96-001 through EA-FPP-96-026, Hydraulic Analysis of the Fire Protection System Mains and Sprinklers by Vectra Engineering 7/18/96 and reviewed 8/20/97. Especially EA-FPP-96-008 Rev 0, Analysis for Diesel Generator 1-2 Room. [4399/2226] to [4400/0748]

20. FHSO-17A, Special Operating Procedure, "Multi-Assembly Basket Loading Procedure," Rev 1

21. ARP-8, Alarm and Response Procedure, "Safeguards Safety Injection and Isolation Scheme EK-13 (EC-13)," Rev 63

22. T.V. Wambach of NRC to D.P. Hoffman 2/2/1982, "SEP TOPIC III-4.A, "Tornado Missiles" - Palisades

23. K.W. Berry to NRC 10/16/86, "Expansion of Spent Fuel Pool Storage Capacity" TSCR rev 1 [3720/1492]

24. OTH013809, OE Action: EA for SFP Dilution with loaded DFS Cask. Initiated 5/26/2005.

25. EA-MOD-2003-019-04, revision 1. "Spent Fuel Pool Water Level Evaluation for NUHOMS Transfer Cask"

26. EA-SQG-04-01, revision 0. "Adjustment of Administrative Boron Concentration Limit for the Spent Fuel Pool." Cart/Frame 5710/2011. 27. Nuclear Regulatory Commission Office of Nuclear Reactor Regulation, NRC Regulatory Issue Summary (RIS) 2005-05, "Regulatory Issues Regarding Criticality Analyses For Spent Fuel Pools Regarding Criticality Analyses For Spent Fuel Pools and Independent Spent Fuel Storage Installations." 28. EOP Supplement 44, rev 0, Emergency Operating Procedure, "Alternate Injection From SFP" 29. FHS-M-39B, rev 6, Palisades Nuclear Plant Permanent Maintenance Procedure, "Fuel Loading and DSC Sealing Operations for NUHOMS®-32PT Dry Fuel Loading Operations " 30. Transnuclear Boron Dilution Criticality Analysis for the NUHOMS®-32PT with CE 15x15 Fuel. Transnuclear calc number 11030-01. 31. ARP-9, Alarm and Response Procedure, "Radwaste Panel Scheme EK-15 (C-40)," Rev 48 32. Palisades Nuclear Plant, Technical Data Book, Figure 8.2, formula sheet 5.B. "Mixing Two Tanks of Different Concentrations"	

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Assumptions (All Major)

A. That the Spent Fuel Pool (SFP) remains at a uniform boron concentration during the dilution event. Justification for this is based on the fact that the fuel pool cooling system is circulating and mixing the water during normal operation of the pool. During both normal and accident conditions heat from the fuel and the design of the racks causes continuous thermal convection flow within the pool. Cold water flows down the cooler walls of the pool, along the floor under the racks, and upward though the relatively warmer fuel region. After heating by the fuel the water continues upward toward the pool surface due to the lower density of the hot water. Although this flow velocity is generally low, it is sufficient mixing for this analysis due to the generally slow dilution rate that is produced by the events being analyzed. For many events that require excess water to overflow the top of the pool, the uniform mixing assumption is thought to be conservative due to all lines entering near the top of the pool. At very high dilution rates, such as are available via the 6" swing elbow to the Fire System, the analysis is only a theoretical estimate of minimum boron concentration at some later time after the flow has stopped. The calculations show that only short times are available even with the theoretical mixing assumption and the calculation there-by serves its intended purpose. However, it should not be viewed as a calculation of the minimum boron concentration in the pool for any case that has less than approximately 3 hours response time (estimated by 30 minute end to end migration time and 6 pool "turnovers" to mix). This would translate to pure water dilution flows on the order of 700 gpm. In cases where the pump suction line is uncovered, a slight end to end concentration gradient might exist for a few hours and would be somewhat level dependent with low levels favoring better mixing due to higher thermal agitation.

This assumption is conservative for postulated dilution events related to dry fuel storage (DFS). The DFS cask is initially filled with SFP water that has been verified to meet the cask's minimum boron concentration requirement. Following fuel loading, mixing with bulk SFP water occurs only at the top opening of the cask. At Palisades, DFS cask loading occurs in the northeast corner of the main pool, rather than in a segregated cask loading area common at other facilities. Therefore the assumption that SFP boron concentration is uniform for the region near the cask top opening is reasonable. As the heat load of fuel placed in DFS is relatively low, thermal convection flow out of the cask is also low. Dilution of the fluid in the DFS cask would lag behind the general SFP boron concentration changes during the postulated dilution event and thus this assumption is conservative for the DFS case.

B. Volumes and flow rates will be based on nominal drawing dimensions. The nature of the other assumptions and the required margins built into the criticality analysis are such that the accuracy of the results would not be improved by extensive efforts to use As-Built dimensions.

For those cases where this analysis is expanded to support an Exemption Request from the requirements of 10CFR SECTION 50.68(b)(1) for the Palisades Plant to support loading of NUHOHMS®32PT dry fuel storage casks, the pool will be assumed to start at the 2500 ppm minimum boron concentration required for cask loading, and at a slightly reduced pool volume due to the presence of the cask and fuel basket system.

The original (Revision 0) calculation assumes that both the impact limiting pad used in the VSC-24 dry fuel storage system and the removable 11x11 fuel rack in the northeast corner of the pool are installed, thus displacing pool water volume. Both items are not currently installed in the pool, so the calculation of record is conservative. The conservative values obtained using these assumptions are retained in this revision for the baseline calculations. For loading the NUHOHMS®32PT dry fuel storage casks, both the VSC-24 impact limiting pad and the 11x11 fuel rack must be removed. Calculations related to the 10 CFR 50.68 exemption request do not assume that the impact limiting pad and the 11x11 fuel rack are installed.

C. <u>Acceptance of Vendor Calculation</u>

Transnuclear Inc, which holds the license for the NUHOMS® dry fuel storage system, was contracted to perform criticality analysis required for revision 1 of this EA. Transnuclear Calculation No. 11030-01 Rev. 0, "Boron Dilution Criticality Analysis for NUHOMS®-32PT with CE 15x15 Fuel" dated June 3, 2005 is included as Attachment 1 of this EA. The calculation was prepared in accordance with Transnuclear Inc QA program which meets the requirements of the United States Nuclear Regulatory Commission related to quality control and quality assurance including the requirements set forth in 10CFR50 Appendix B.

The effect of this calculation on Palisades is that 1850 ppm is determined as the minimum SFP boron concentration to assure subcriticality when loading a NUHOMS®-32PT DSC. The calculation uses conservative input assumptions including 3.60 wt. % U235 and optimum moderation. These two assumptions add approximately 200 ppm conservatism to the nominal 3.50 wt. % U235 and full moderation case. No burnup credit is taken in these calculations. In addition, k_{eff} is maintained at 0.99.

Description of the Spent Fuel Pool

Physical Description of the Area.

The Palisades Plant is built into the side of a sand dune. The ground to the east of the auxiliary building is at elevation 625' while the ground (Lake Michigan beach) to the west and north sides is at Elv. 590'. To the south is the 3' thick post tension reinforced concrete containment extending from Elv. 570 (20' below grade) to Elv. 782 (192' above grade). The fuel pool enclosure roof is 86' below this at Elv. 696.

The Spent Fuel Pool (SFP) is located in the plant Auxiliary Building at the highest normal operating level which is elevation 649 (see Bechtel Drawings M-3 through M-7 normally found in the front of the P&ID book). It is immediately adjacent to containment. The south end of the pool enclosure is formed by the Equipment Hatch section of the containment wall. The refueling deck of containment is also at Elv. 649 so that with the equipment hatch open there is direct visual communication possible to both ends of the fuel transfer tube. Due to typical noise levels in the area audio communication requires radio or telephone assistance although it is only about 70 feet away.

The Auxiliary Building structure at and below the pool deck is reinforced concrete with walls in excess of a foot thick for radiation shielding and missile protection purposes. Above the actual pool deck, the remaining sides of the enclosure at elevation 649 and above are steel construction with light siding attached with rivet type joints. Under internal pressure such as might be caused by the low pressure inside the eye of a tornado the siding is designed to blow outward and thereby keep the roof from lifting and falling back into the fuel pool.

The Safety Injection and Refueling Water Tank (SIRWT) base is on elevation 644 and is less than 10 feet outside the west wall of the pool enclosure. The tank has 24 foot sidewalls and during normal operation is kept essentially full (water level near Elv. 668). Tech Spec, no margin, minimum actual water surface is ~Elv. 664 which is 17 feet above the normal fuel pool level. The plant control room at Elv. 626 is directly below the SIRWT with the east wall of the viewing gallery and stair well being part of the fuel pool shielding concrete associated with the west fuel pool and tilt pit wall.

On the 649' fuel pool deck just 11 feet north of the pool is a large, crane accessible, floor hatch going to the track alley which is at Elv. 626' and just north of the fuel pool. This provides the main freight path for all material and equipment going into either the fuel pool or containment. The east wall of the track alley is a roll up door large enough to accommodate a railroad car. The north wall is steel and siding construction similar to that above the fuel pool.

The widest crane hook accessible path between the track alley hatch and the containment hatch, that is not over the fuel pool or tilt pits, is about 5 feet wide. Heavy Loads administrative controls are utilized in the area, and the L-3 main hoist crane is rated as NUREG-612 and NUREG-0554 single failure proof. During refueling the rigging and movement of all material and equipment transiting this area going into and out of containment is handled and supervised by non-resident refueling contractor personnel. The fuel pool crane rail is at elevation 676'-8" and the crane is seismically rated with wheel retention hardware to keep the bridge and trolley from coming off the tracks. The bridge at 44'-8" span is also too large to fall into the 15' wide pool by any credible means.

The Plant has a Dry Cask fuel storage program that periodically loads fuel into storage cask liners and transports them to track alley with a heavy shielding cask. There the transfer cask is mated to the storage cask and a dry transfer of the liner takes place.

Fuel Pool Design

The main fuel storage pool is a 38'-9" long by 14'-8" wide rectangle. The top of the pool is at Elv. 649 and the nominal bottom is at Elv. 611 making the nominal depth of the physical structure 38 feet. There is s 6" high by 6" wide curb around the entire fuel pool and tilt pit system. A 9' by 9' section of the north east corner of the pool floor is suppressed 3'-6" into the 6' thick floor shielding concrete to facilitate cask set down at Elv 607'-6" and thereby allow the fuel transfer machinery to clear its lip. Presently, this suppression area contains a transfer cask stand that replaced the previous foam filled impact limiting pad. The pool water volume is adjusted in revision 1 of this EA to compensate for removal of the impact limiting pad and insertion of the new transfer cask stand. The pool volume is further corrected for removal of the 11x11 rack from the pool's north east corner, and its associated fuel. Fuel displaced volume is revised slightly. Revision 0 of this EA assumed the11x11 rack and its full fuel load were present. Removal of these items will more closely represent current and likely future pool configurations. The cask stand is removable but resides in the pool on a semi-permanent basis to ease dry cask loading schedules and avoid repeated decontamination.

The pool was provided with 2 tilt pits in anticipation of a second Nuclear Plant unit to be built north of the existing fuel pool enclosure. The pits are 21' long by 5' wide and extend downward to Elv. 610'. The floors of the tilt pits slope toward the floor drains at 1/8" per foot so the floor drain is 2 to 3" below 610'. The Tilt Pits are attached to the main pool by a 4' long by 2'-6" wide corridor which extends downward to Elv. 625. There is a gate on the pool end of this corridor and a 1'-2" section in the center of the corridor is widened to 3'-6" to accommodate interlocking shielding blocks. The shield blocks are not used in lieu of procedural restrictions on fuel movement past the gate. The floor of the gate corridor at 625 feet insures that approximately one foot of water remains above the fuel in the event of gate failure with the transfer tube open. This also limits the consequences of refueling pool seal failure or steam generator dam failure during refueling.

Since the second unit was never built the north tilt pit was converted to extra fuel storage space. Its floor drain has been cut and capped at the ceiling of the fuel pool heat exchanger room where it exits the embedding concrete. The north gate is never used because it blocks the path of water circulation to the fuel racks in the north pit thereby interfering with convective cooling. If the gate is installed, vertical convection, boil off and conduction to the fuel pool concrete would still be available to this area where only well decayed fuel is stored. A local, locked closed, manual valve is available to make up any boil off from the fuel pool cooling system. Since boil off leaves almost all of the boron, make up from non-borated demineralized water hose bibs in the area is also a viable option which involves no significant dilution.

The entire fuel pool and tilt pit system is lined with 3/16" thick Type 304 stainless steel plate [Drawing C-90 Rev 12 Note #2]. The liner sheets are welded together at leak chase channels embedded in the concrete. This facilitates welding heat transfer, insures no hydrostatic pressure exists behind the plates to bulge them on drain down, and also provides some indication of the location and severity of any leaks in the liner plate.

Fuel Pool Cooling System.

The fuel pool cooling system is located in the fuel pool heat exchanger room at Elv 590 of the auxiliary building just below and to the west of the fuel pool and directly under the cable spreading room, just below the 2400 volt 1-D safety bus. It is protected from external flooding by the water tight door on the component cooling room across the hall from it.

The pool cooling system main circulation path contains 2 half capacity low head pumps (40 Hp rated for 1700 gpm each at 64 feet of head) and one heat exchanger. The pumps take suction via a 14" line that penetrates the south end of the pool with centerline at Elv. 645-0" (per drawing C-91). This is only 2 feet below pool normal water level of 647' (range is 647-9"[SOP-27 step 7.2.1.a.2] to 646'-9"[SOP-27 step 7.1.1.a]). The low level alarm is set at Elv. 646 (ARP-8 annunciator 9 via LS-0924) and at this point, by actual operating experience, there is already considerable air induction due to a suction vortex that exists at the pool surface.

The heat exchanger is 2 shells E-53A and E-53B permanently plumbed in series-counter flow "U" configuration without isolation or bypass lines to allow use of only one at a time. Butterfly valve SFP-107 at the outlet of the heat exchanger must be throttled [SOP-27 step 7.1.1.g] to avoid spurious trip of the pump low discharge pressure alarm which is set at 30 psig.(ARP-8 annunciator 8 and PS-0926).

Water returns to the pool via a 12" line that enters the pool with centerline at Elv. 648'-0" on the north end. The line is supplied with a 1 and 1/2" siphon breaker that terminates at Elv. 647'-6" which is near and frequently above the water surface. The line originally went to the bottom of the pool but was cut off by FC-375 [DBD-2.07] above Elv 645'. This was done during the first pool expansion reracking in association with removal of the control rod rack. Since the line itself terminates above the invert of the suction line [Vendor Print C-94 Sh2 = NUS 5097M2000 Rev 11 says at 645'] the siphon breaker is no longer required. With this "dip tube" cut off, convection must now be relied upon to deliver cold water to the bottom of the racks. Although quite low these natural convection velocities have demonstrated their adequacy for heat removal, however, water clarity cleanup can be delayed and visibility can suffer from "heat waves".

The spent fuel pool filter originally installed in the plant is retired in place. The spent fuel pool and refueling cavity water is now filtered with portable locally immersed Tri-Nuc Filters with suction and discharge both on the small unit itself which sits on the pool floor. Portable non-floating versions also exist that can be hooked up to local flanges in the fuel pool cooling system. Finally a discharge hose can be hooked up to filter and be used to transfer pool water to other points in the plant such as the radwaste system.
During the Dry Cask Storage canister loading process a local skid containing water and vacuum pumps is used to move pool water into and out of the canister. During this evolution pool boron concentration must be above 2550 ppm by procedure and 2500 ppm by Tech Spec. as a matter of criticality safety within the fully, and later partially, flooded liner.

A demineralizer is available to process a small fraction of the cooling flow. A small 15 HP higher head (160 GPM at 160 feet of head) booster pump takes suction via a 3" tee at the heat exchanger outlet and supplies the necessary pressure to drive flow through the demineralizer. The demineralizer is rated 150 gpm at 20 psi differential pressure. The 150 gpm demineralizer loop will turn over 1.5 pool volumes per day.

Fuel Pool Fill and Drain Provisions

The spent fuel pool contains the following penetrations or available temporary water sources all of which could possibly be potential dilution source:

Size inch	Elevation Centerline	Use	Normal fluid	Potential Dilution Mechanism
36	617'-6"	South Tilt Pit Fuel Transfer Tube	Pool Water and Refueling Cavity water	dilution of Refueling cavity by CCW via Shutdown Cooling Hx tube leak, accidental safety injection actuation during refueling, refueling cavity decontamination efforts

Size inch	Elevation Centerline	Use	Normal fluid	Potential Dilution Mechanism
14	645'-0"	SFP cooling out of the pool	Pool Water	hot spot removal & pipe decon activities, fire system elbow installed, Hx tube leak, demineralizer sluice water not isolated
12	648'-0"	SFP cooling in to the pool	Pool Water	same as above
6	610'-0"	S. Tilt Pit Drain	Pool Water	same as above
6*	648'-6"	NW overflow	Empty	All 4 overflows go to Equipment Drain Tank which could backup due to extensive interconnections with many other plant systems. Due to the dominant height of the pool other systems such as waste gas tend to flood much earlier, however.
6*	648'-6"	SW overflow	Empty	See Above
6*	648'-6"	N tilt pit overfl.	Empty	See Above
6*	648'-6"	S tilt pit overfl.	Empty	See Above
4	645'-0"	N tilt pit fill	Pool Water	See SFP Cooling (Table lines 2,3, & 4)
4	645'-0"	N tilt pit fill	Pool Water	See SFP Cooling (Table lines 2,3, & 4)
2	610, 611	leak chase drains for main pool and both tilt pits	Empty	there are multiple lines which go to funnels and then to Dirty Waste Tank
3	Over Top	Fire Hose	L. Michigan	Emergency Pool refill to restore cooling or shielding
3/4	Over Top	Fill pool via Red Rubber Hose	Demin water	Decontamination and evaporation makeup from either Primary Makeup Tank T-90 or Utility Water Tank T-91
3/4	Over Top	Fill pool via Red Rubber Hose	Concentrated Boric Acid	Borate the pool above SIRWT levels to facilitate Dry Cask loading from the Recycled Boric Acid Tank T-96 (ReBAT)
None	Portable Unit floats on pool surface	Filter pool water for visibility improvement	Spent fuel pool water	System uses a floating skimmer skirt for suction of the pump which floats in the pool below the surface and discharges outward several feet below the surface. No tubing or hose connections are possible for the skimmer.

Size Inch	Elevation Centerline	Use	Normal fluid	Potential Dilution Mechanism
2 or 3	Portable Unit sits on pool floor or north tilt pit pass through. (600gpm unit has 3" hose)	Filter pool water for visibility improvement	Spent fuel pool water	System uses optional suction or discharge hoses of various lengths designed to control the fraction of the pool volume involved in the recirc path. A hose could be rigged to discharge outside the pool for temporary water movement or sampling. A suction hose can also be attached to the pump for use as a vacuuming device.
3/4	Hose Over Top	Dry Cask Canister fill and pump down skid.	Spent fuel pool water at 2500 ppm or greater	Used to prefill liner before it is immersed in the pool and to pump down and then vacuum evacuate the liner after it is seal welded. Flushing and skid checkout could result in some pool dilution.

* These overflows attach to HC-4-4" pipe and go to the Equipment Drain Tank (520 gallons rated at 50 psig) located at Elv. 579 in East Safeguards room [ref: P&ID M-221 Sh 2 and AMMS]. The system can be aligned to automatically pump T-80 to a 50,000 Gallon Clean Waste Receiver Tank via P-75A or B and a 2" line by action of LIC-1008.

The transfer tube is actually suspended within a 4' diameter pipe which is welded to the Tilt Pit liner plate. The 3' pipe is sealed to the 4' pipe with a bellows located in the Tilt Pit. The containment penetration anchors to the 3' pipe via a 54" pipe collar arrangement at the containment liner plate inside containment. The containment integrity boundary is at a double O-ring seal on the blind flange in the refueling cavity Tilt Pit. The entire 70'-3" length is a containment boundary with the inside of the tube being outside containment. The space between the tubes can store pool leakage and render it undetectable. A 36" gate valve is installed on the Spent Fuel Pool Tilt Pit end of the transfer tube, however, it has been inoperable in the open position for many years.

The fuel pool gates are rated at full hydrostatic pressure of the full pool. The gates use a double tube inflatable seal supplied by plant Nitrogen at about 30 psi [Vender Print C-93 Sh. 1 rev 4]. There is also a local backup nitrogen system. During normal plant operation the south gate is installed and the tilt pit is dry at least to the bottom of the transfer tube. The north tilt pit gate is always open. The threshold of the gate at 625 elev. protects against total drain down of the main pool, however, radiation levels would be very high and likely preclude entry into the pool area under these conditions.

Fuel Pool Cooling System Interconnections.

The below table lists lines that penetrate the Spent Fuel Pooling Cooling System at or near Elevation 590. The system is pressurized by 57 feet of water (~25 psig) at that point. Leakage out of the system especially during refueling with the SIRWT nearly empty can cause the need for emergency makeup with non-borated water. The system also contains equipment vent and drain lines that go directly to atmosphere. Leakage from those lines wet the floors and fill the Auxiliary building sump via the floor drains where they are noticed by operators on shiftly or hourly rounds of plant equipment. These lines are not dilution hazards due to the air gaps in the lines which prevent any backup.

Size	Location	Use	Normal Fluid	Potential Dilution Mechanism
6	P-51B suction	fill pool from SIRWT (T-58) via MV-ES-3263	refueling water 1720 ppm minimum	Can dilute pool from 2500 ppm used during dry cask loading. Due to 2500 ppm maximum for the SIRW set by Tech Spec there is a potential DFS criticality problem. The valve is locked closed.
6	P-51B discharge and refueling cavity fill and recirc	return Spent Fuel Pool or Refueling Cavity water to SIRWT via MV-SFP-126 or MV-SFP-127	refueling water 1720 ppm minimum	This line also fills pool by gravity due to being connected to the only tank that is at higher elevation than pool. This line has caused pool overflow numerous times in the past. The valves are locked closed. Boron at 1720 ppm minimum insures there is no SFP rack criticality hazard. Due to 2500 ppm maximum for the SIRW set by Tech Spec there is a potential DFS criticality problem.
8	P-51A and B suction	Shutdown Cooling System Cross-Tie via MV-SFP-131	Cold Shutdown boron concentration	Drop line to Shutdown cooling used as SFP Hx backup. Line is blind flanged with a spool piece and valve is locked closed. Late in core life Cold Shutdown Concentration is about 600 ppm. Use only allowed at cold SD since SDC Hx is part of ECCS System.
8	SFP Hx (E-53A,B) discharge.	Shutdown Cooling System Cross-Tie via MV-SFP-132	Cold Shutdown boron concentration	Return line from SD Cooling. Line is blind flanged with a spool piece and valve is locked closed. Late in core life Cold Shutdown Concentration is about 600 ppm.

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Size	Location	Use	Normal Fluid	Potential Dilution Mechanism
6	Pool Cooling Return line HC-4-12"	Connection to the Fire System via MV-SFP-133	Lake Michigan water	Emergency Spent Fuel Pool fill line. Line is blind flanged with a swing elbow. Valve is locked closed. SOP-27 allows use of this line by System Operating Procedure with Shift Manager permission.
3	Clean Resin Transfer to T-50 Demin	via MV-SFP-136	Demin water	Resin transfer mis-valving and line unplugging efforts.
3	Spent Resin transfer from T-50 Demin	via MV-SFP-135	Demin water	Resin transfer mis-valving and line unplugging efforts.
2	bed lifting air for Demin T-50	via CK-SFP-403, MV-SFP-139 and MV-SFP-134 all in series	plant service air	Service air occasionally contains moisture.
3	Transfer Hose attachment in P-51B discharge line	via MV-SFP-140	Hose bib.	Drainage and hot spot flushing
6	hot spot removal in cavity and tilt pit drain lines	Spool piece between MV-ES-3263, MV-SFP-123, and MV-SFP-118	Tri-Nuc filter and flushing water	Spool piece is isolated by normally closed, locked closed valves and is normally kept bolted in place. Used to splice in portable Tri-Nuc unit during draining of the fuel transfer path to avoid hot spots and in conjunction with at least 4 separate blind flanged tees for hot spot flushing while piping is isolated from the SFP.
8	P-51B suction from Refueling Cavity	Refueling Cavity draining or cooling or cleanup via MV-SFP-117	SIRWT water 1720 ppm minimum	Flushing and decon efforts use limited demin water during Cavity drain down. Valves are locked closed as containment isolation valves during normal operation.
6	SFP Hx outlet	Refueling cavity fill or cleaning or cooling return via MV-SFP-121	SIRWT water 1720 ppm minimum	Used only during refueling. Valves are locked closed as containment isolation valves during normal operation.

Fuel pool temperature limits

The fuel pool is operated between the temperature limits of 68 and 150 degrees F. When it contains fuel the pool the administrative limits are greater than 75 and less than 125 degrees F. During maintenance activities the upper limit can be raised to 140 degrees providing the Demineralizer is bypassed before reaching 125 F, the high temperature alarm is declared inoperable after reaching its normal alarm point of 125 F, and a heatup rate has been determined so that cooling is re-established before reaching 140 F. (SOP-27 section 4.1)

Loss of cooling due to low pool level with attendant and excessive heatup rate including temperatures approaching boiling are the most probable reasons for refilling the pool with non-borated water. This trades a dilution event for an overheating event which is preferable if the margin to criticality is available.

Normal refueling sequence for flood up

During normal operation the Spent Fuel Pool is a nearly passive operation. Refueling operations pose a greater threat because the normal makeup source for the pool is not available. At this time the SIRWT is pumped into the cavity and the pool is interconnected with the cavity. Thus the higher probability of leakage (due to RV to Rx Cavity seal installation and SG Nozzle Dam use) corresponds with the same time period where greatly reduced makeup capability and greatly complicated water management simultaneously exist. For this reason it is important that the transition to refueling mode be done very carefully. GOP 11 and GCL 11.1 control this evolution and they require specific sequencing of activities.

The reactor is brought to refueling boron concentration, which is at least the Tech Spec minimum 1720 ppm. Level is reduced to flange elevation and the control rod cooling and leakoff lines and the head vent lines are plugged at the cavity wall. The head is lifted and the refueling pool seal and Steam Generator nozzle dams are installed. At this point the fuel transfer tube flange can be removed.

This is done to guard against Fuel Pool gate failure with an open path for water release. With the seals installed a gate leak can be rectified by rapidly filling the cavity using the LPSI injection pumps.

The fuel pool south tilt pit, the reactor side tilt pit and the refueling cavity are then flooded as a unit with 253,000 gallons (SOP-27 section 7.5.1.a.11) of water from the SIRWT. This water must be between 1720 ppm and 2500 ppm by Tech Spec. It is usually well over 2000 ppm for maximum safety and minimum radwaste processing reasons.

The gate between the fuel pool south tilt pit and the main pool is then removed. This results in a de facto uncontrolled dilution of the pool from its normal level of 3000+ ppm ("No upper limit is specified" per SOP-27 section 4.1.f) to a value intermediate between the two typically about 2600 ppm. This is above the maximum limit for SIRWT, above the minimum limit for the SFP, and above the minimum "refueling concentration" for core unloading. It is also usually above the higher "refueling concentration" required to reload the new core as well, so no further adjustment has to be made until the water is pumped back to SIRWT. This slow mix that begins upon initial flood up, can take several days to equilibrate. During that time the cause and effect relationship between water addition and boron concentration is lost and the ability to detect an unplanned dilution by boron sampling is limited. Detection by unexpected volume change or level change is still available, however, adjustments are to those are also frequently made in this same time frame.

At this time there is little makeup water available should a leak occur. The alarm procedure refers to Off Normal Procedure ONP-23.3 for this condition that instructs all fuel in transit to be returned to the core or to the racks and LPSI be aligned to recirculate the leaked water in the containment sump to the cavity. If the leak is in the fuel pool cooling system the Shift Manager must authorize the use of PMU or fire water to recover level for cooling. There is potentially 32,000 gal left in the SIRWT (if it was brim full to start refueling) and 31,120 gallons of 1720 ppm minimum in the Safety Injection tanks near the containment ceiling, either of which is remotely deliverable by opening one or more locked valves. The procedure (ONP-23.3 step 4.9.8) gives first priority to the SIRWT residual but does not attempt to use SI tank water.

Before the new core is loaded Refueling Boron Concentration is revised to approximately 2350-2500 ppm.

At the end of refueling, the procedure is carefully reversed. The gate is installed, the cavity pumped down, then the transfer tube flange is restored before the refueling seal and the SG nozzle rams are removed. SOP-27 contains cautions about possible low boron concentration in the cavity side tilt pit near the end of drain down due to stratification at the bottom of the cavity if non-borated decontamination water is used on walls and floors during cavity drain down. (SOP-27 section 5.1). This is not a concern once mixing by the pumps occurs. The high reload refueling concentration assures the Tech Spec minimums are generously met in the pool and in the SIRWT at this point in time.

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Pool Volume calculations

The volume of the Spent Fuel Pool is available from several references. To check them the following table was built. It was found necessary to use the conservatively low volumes from this table in the analysis.

Portion	Length	Width	Depth Feet	Volume Cu Ft	Remarks
Main Pool	38'-9"	14'-8"	647-611=36	20,465	
Floor cask blockout	9'	9'	611-607.5=3.5	[283.5]	Use 0 for baseline case, filled with impact limiting pad
N. Tilt Pit	21'	5'	647-610=37	3885	slopes 1/8 per ft to drain
S. Tilt Pit	21'	5'	647-610=37	3885	slopes 1/8 per ft. To drain
Gate Corridor pieces N. Tilt Pit **Sub Total**	6" 2'-4" 1'-2"	4'-0" 2'-6" 3'-6"	647-625=22 647-625=22 647-625=22	44 128.3 89.9 **262.2**	
Gate Corridor S. Tilt Pit	same as above	same as above	same as above	262.2	1961 gallons at 7.4805 gals/ft^3
Transfer Tube	70'-3" -2'-3" =68'-0"	3'-0" Dia.	C.L. @617'-6"	480	3590 gallons
Sub-Total Main Pool, & N. Tilt Pit				20,465 3885 262 = **24,612**	184,110 Gallons
Add volume of cooling system & demin				485	3,628 Gallons see Note 2
subtract volume of racks				715 (detailed rack drawing extraction)	5348 Gallons

Portion	Length	Width	Depth Feet	Volume Cu Ft	Remarks
subtract volume of fuel (892 bundles)				892x2.562= **2285**	17,093 Gallons See Note 3
Total net water volume to **Elv 647'**				**22,097**	**165,297**
S. Tilt Pit and transfer tube				4,627	34,610
50.68 Exemption Case					
Sub-Total Main Pool, floor cask area & N. Tilt Pit				20,465 283.5 3885 262.2 = **24895.7**	Main Pool Floor cask blockout North Tilt Pit NTP Gate Corridor 186,232 Gallons
Add volume of cooling system & demin				485	3,628 Gallons see Note 2
subtract volume of racks, but adjust this volume by not subtracting the NE corner 11x11 rack's volume				715-30.7= 684.3 (detailed rack drawing extraction)	5119 Gallons
subtract volume of fuel (771 bundles)				771x2.593= **1999.2** Note 3	14955 Gallons see Note 3

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Portion	Length	Width	Depth Feet	Volume Cu Ft	Remarks
Transfer Cask and DSC 32PT (oddly shaped shell, basket, and transfer Cask, volume determined from weight of each component divided by density of the various components)				(248.2) for cask compnts. (74.42) for DSC 32PT shell and basket	Weights, Densities and Volumes from reference 25 248.2 + 74.42 = 322.62 322.62 x 7.4805 = 2413 gallons See Note 4
Cask stand (oddly shaped frame, volume determined from weight of frame divided by density of stainless steel)	Approx. 9'-0"	Approx. 9'-0"	Approx. 6" tall	(6.14)	Weights, Densities and Volume from reference 25
Total Net water volume to Elv 647'				**22,368.4**	**167,327 gallons** See Note 4

Note 1
Note 1 deleted

Note 2
Volume of the cooling system is estimated as follows;
100 ft 14" pipe= 107 cu ft
100 ft 12" pipe=79 cu ft
100 ft 8" pipe= 35 cu ft
100 ft 6" pipe= 20 cu ft
500 ft 4" pipe= 44 cu ft (overflow lines and skimmer lines assumed dry)
2 Hx 2' dia x 20' long, tube side volume@ 40 cu ft ea= 80 cu ft
Demin 4'-6" dia x 7'-8" ft high= 120 cu ft (68 cu ft bed)
Total = 485 cu ft x 7.48 = 3628 gal.

Note 3
Volume used in revision 0 was based on observed fuel immersion weight loss of 159.8 pounds in water and

confirmed by fuel rod volume calc of 2.562 cu ft. A full pool is assumed for conservatism even though present loading is about 700 bundles.

For the 10 CFR 50.68 exemption case, volume is based on a fuel assembly volume of 2.593 cu ft, as used in reference 25, from a Siemens letter dated 5/19/1999. Newer fuel assemblies have 216 fuel rods (vs. 208 in most older assemblies) and therefore displace more volume. During cask loading, the northeast 11x11 rack cannot be installed, so a full pool is:

892 assemblies - (assemblies in 11x11 rack) = 892 - 121 = 771 assemblies

In either case, the total volumes displaced by fuel assemblies are conservative as several SFP cell locations are considered blocked and full loading cannot be achieved.

Note 4

For the case where a cask and DSC are being loaded for dry fuel storage, the volume of water is reduced by the water displaced by the cask and DSC.

Volume of the Refueling Cavity

The Refueling cavity is connected to the Spent Fuel Pool via the 36" diameter fuel transfer tube during refueling evolutions. At that time the effective volume of the pool system is the sum of the two pools. Since this configuration is not limiting the cavity volume will be taken as the SOP-27 supplied value of 253,000 gallons for the sum of the cavity, tilt pits and transfer tube.

To defend the above assertion, consider the following discussion. At this time the SIRW tank has been essentially emptied into the cavity so that the normal make up source is depleted severely. On the plus side all major leak paths on the containment side lead to the containment sump where the ECCS system can recirculate the leakage at high volumetric rates back to the core and thus to the cavity. In any case, with standard conservative safety analysis assumptions which include all control rods removed, the core is always more limiting from a criticality standpoint than the spent fuel racks because of its near optimum reactivity bundle spacing. The core events are a matter of FSAR Chapter 14 analysis and will not be addressed here.

Normal Operation of the Spent Fuel Pool

There are five separate functions involved in operation of the pool. They are:

1. Maintain water level for shielding
2. Maintain boron concentration for subcriticality in the fuel racks.
3. Maintain cooling to insure no boiling and the quality of the pool structural concrete.
4. Maintain water quality to avoid corrosion of the fuel by intermittent use of the demineralizer.
5. Maintain water clarity so that visibility is maintained as needed for fuel handling.

Normally one of the two half capacity pumps is run circulating approximately 1530 gpm of pool water through the Fuel Pool Heat Exchangers. This also insures mixing for relatively uniform boron concentration and water temperature. The Component cooling pumps move approximately 1800 gpm of corrosion inhibited (sodium nitrite) CCW water through the heat exchanger to remove the heat and transport it to Service Water in the CCW heat exchanger. The Service water is removed from and returned to Lake Michigan as the ultimate heat sink.

Boron concentration is controlled by making the only normally available source of makeup the SIRWT which is maintained at between 1720 and 2500 ppm by Tech Spec. All other sources are locked closed and the larger ones are isolated by spool pieces and blind flanges. The resin sluice lines to the Demineralizer, which are normally unpressurized, are an exception to this rule. To ease radwaste handling and to enable concentration differences required by Dry Cask loading, the use of temporary hoses are allowed to add water and concentrated boric acid at a slow rate to the free surface of the pool. There are 3 such sources all of which use a 3/4 inch rubber hose. T-90 is one demineralized source and T-91 is the other. These lines are used to makeup evaporation which leaves the boric acid in solution. Concentrated boric acid comes from T-96 and utilizes backflow from the boric acid batching tank wye strainer as a pump pressurizable source. There is a fire hose in the fuel pool area that can be purposely sprayed in the pool for makeup. There is also a 6" fire line connected to the cooling system with a swing elbow at Elv. 590 of the auxiliary building that can remotely add water to the pool at a high rate if necessary to restore shielding and cooling at the expense of dilution.

P-82 is a small booster pump that can force approximately 160 gpm of the main cooling flow though Demineralizer T-50 to maintain water quality and corrosion resistance.

Visibility is maintained by use of portable Tri-Nuc filters (principally the floating skimmer) and the T-50 demineralizer. The originally supplied Cuno cartridge type filter has been abandoned in place for ALARA reasons.

Instrumentation of the system is rather simple. There is a high/low level alarm EK-1309 from LS-0924 set at a low alarm of Elv. 646 and a high level alarm at Elv. 647'10". There are 2 high and low temperature alarms, in the main pool itself from TIA-0925 and in the north tilt pit from TIA-0926, both of which transmit to the Plant Process Computer (PPC). Low temperature alarms are triggered at 75^0 F, and high temperature at 125^0 F and high-high temperature at 140^0 F. There is also a high temperature alarm from TIA-0917 and EK-1536 at the heat exchanger outlet. This is on the C-40 radwaste panel and warns of temperatures potentially too high for the demineralizer resin but relies on manual action to trip the booster pump and isolate the bed. There is no low temperature alarm. The first indication of water diversion or lack of cooling is usually from PS-0926 which alarms fuel pool cooling pump low discharge pressure low at 30 psig. It is sometimes necessary to throttle butterfly valve SFP-107 to keep this alarm silenced during normal operation especially at lower pool levels and higher temperatures. The demineralizer is supplied with a high differential pressure alarm dPIA-0926 and the out let wye strainer has a high differential pressure alarm dPS-2102 both located on the C-40 panel.

Excess water can be removed from the system by pumping back to SIRWT or by draining to radwaste. All volume additions or removals are done by local operation of manual locked closed valves. Mis-valving and leaking valves have been known to overfill the pool. Consequently the fuel pool level is well watched by all operations personnel.

Dilution Analysis - scenarios

As originally designed the Palisades spent fuel pool was interconnected with the SIRW tank as its sole source of water. Both fuel pool water volume additions and reductions were to be to or from this source. As operating experience was gained with chemical reactivity control and additional plants were built less rigid standards were accepted. In particular the conversion of the plant to a "zero discharge" radwaste system and the advent of very high liquid radwaste costs made it very attractive to "shim" the water level and boron concentration from more direct sources. Consequently a variety of small "ad hoc" systems came into use. This was possible because it became known during reracking licensing activities that fuel pools mix well due to natural thermally driven circulation. Thus mixing was not a concern for small streams of liquid entering at other than bulk pool boron concentration. These small systems are justified based upon the continuous manual attention required to operate them and the very long times a malfunction would have to exist to cause a problem.

The main, permanently piped, source of water to the pool is the SIRW tank containing a minimum of 1720 ppm boron. This is well above the Tech Specs Amendment 207 limits of 850 and 1350 ppm. Since the 1720 low limit on this tank is controlled by Tech Specs and is required for Class 1 ECCS operation, no analysis of low boron concentration in this system will be analyzed here. The reactor itself would be more limiting than the fuel pool for an SIRW Tank dilution event.

The below list of 11 events will be analyzed. They include events deemed most probable and are augmented by those that are limiting or bounding even though they might be very improbable. Although the hardware employed is listed below, the event is a combination of hardware miss-use and human error. The fuel pool has essentially all local manual operated valves (hand wheels and chain locks) so that controller malfunction is not involved.

The events are broken into two groups. The first group involved events which start with the addition of water to the pool which is at or near normal level. The second group of events start with a severe loss of water. Due to the plant being so carefully designed to allow only borated makeup, this can result in uncovering the cooling system suction pipe and even a serious loss of shielding water. This leaves the operators faced with 1000+ Rem/hr dose rates and/or the fuel and pool water being in a serious heat up transient. Plant procedures direct that if non-borated water is all that is available, then that should be used to recover minimum shielding water levels or enough to begin cooling by cold water addition and to carry on to the point (~ Elv. 645) where normal cooling via the Spent Fuel Pool heat exchanger can be restored. The second group assumes that the operator pays insufficient attention to the non-borated addition (being excited by the accident and distracted by many other duties also requiring attention) and fails to shut off the non-borated water in a timely manner or incorrectly calculates the amount that can be safely added. This results in the scenario that is calculated.

In all cases (both type one and two) the transient is terminated by manual action. The calculation is continued to the point where the limiting concentration (used in the Spent Fuel Pool Rack criticality analysis) is reached to demonstrate how much time there is to respond regardless of even unavoidably obvious indications that might be telling the operators to act and terminate the event.

For those cases where this analysis is expanded to support an Exemption Request from the requirements of 10CFR SECTION 50.68(b)(1) for the Palisades Plant to support loading of NUHOHMS®32PT dry fuel storage casks, the calculation is continued to the point where the limiting concentration (1850 ppm used in the Transnuclear criticality analysis) is reached to demonstrate how much time there is to respond regardless of even unavoidably obvious indications that might be telling the operators to act and terminate the event.

Type one - direct dilution

1. Demin water addition via 3/4 inch hose.
2. Fire System water addition via 1 1/2" hose station (with 75 ft hose attached) 40 foot northeast of SFP).
3. Failure to isolate demineralizer before sluice water is valved into the system
4. Cut in of an unborated demin.
5. Fuel Pool Cooling Heat exchanger tube leak

6. Miss application of a portable Tri-Nuc filter system.
7. Normal system dilutions enveloped by SIRWT at 1720 ppm cross connect with SFP at 3000 ppm.

Type two - emergency make up triggered by severe water loss

8. Fire system water addition via 6" swing elbow in the cooling system.
9. South Tilt pit gate leak requiring emergency makeup.
10. Reactor Cavity Pool Seal loss or SG nozzle dam loss while connected via transfer tube.
11. Tornado Event (SIRWT loss, tornado missile in pool, 7' of water loss).

<u>Calculation of required dilution volumes</u>

The proposed Tech Spec (now adopted as amendment 207) uses a minimum boron concentration of 850 ppm for normal conditions and 1350 for accident (double contingency) events. There are two ways dilution can happen. If the container is big enough so that the dilution water is contained without spill over, dilution by simple volumetric averaging is appropriate. This leads to the lowest boron concentration for any given volume of dilution water. If the container overflows due to the addition of the diluting volume of water, then some of the dilution water overboards with the borated water resulting in less total dilution water being retained. Thus the final boron concentration will be higher.

Since the pool is never run brim full due to a leaky skimmer system, nearly all events are really a combination of the two conditions. It involves addition only to fill the pool to elevation 649, followed thereafter by over flowing until the limiting concentration is reached.

In the normal dilution cases, the pool will be assumed to start at the 1720 ppm minimum Tech Spec required boron concentration even though it almost always is in the 2700 to 3100 ppm range.

For those cases where this analysis is expanded to support an Exemption Request from the requirements of 10CFR SECTION 50.68(b)(1) for the Palisades Plant to support loading of NUHOHMS®32PT dry fuel storage casks, the pool will be assumed to start at the 2500 ppm minimum boron concentration required for cask loading, and at a slightly reduced pool volume due to the presence of the cask and fuel basket system.

Batch Dilution from SFP low level alarm point at Elv 646 to SFP High Alarm and Overflow points.

From previous analysis above and from Procedure SOP-27 it is known that 426 gallons will fill the pool and North Tilt pit combination by 1 inch. Check calculations indicate the value is closer to 427 gal per inch and that will be used here as a dilution conservative value. This is valid at all elevations above 625' where the bottom of the gateway to the North Tilt Pit begins to come into play. This calculation starts from the standard plant configuration and is the starting point for all analysis in this evaluation except events related to the refueling condition with cavity cross connected to the pool by the transfer tube.

Overboard Elv = 649'-0" [the top of curb is at 649'-6" but that is cut away at some points]
High Lvl Alarm = 647'10" [Procedure ARP-8 Annunciator 9]
Low Lvl Alrm = 646'-0" [Procedure ARP-8 Annunciator 9]

Difference = 3'-0" = 36" [low level alarm to overboard]
36" x 427 gal per inch = 15,372 gallons to go from low level alarm to overboard.

Difference = 1'-10" = 22" [low level alarm to high level alarm]
22" x 427 gal per inch = 9,394 gallons to go from low level to high level alarm.

Difference = 1'-2" = 14" [high level alarm to overboard]
14" x 427 gal per inch = 5,978 gallons to go from high level alarm to overboard.

Calculate pool boron concentration at overflow point. (Normal case)
Pool volume full to Elv 647 = 165,297 gallons
Subtract 12" to Elv 646 = 5,124 [12" x 427 gal per in. = 5,124 gal]
Assumed start volume = 160,173 gal @ 1720 ppm

Do the volumetric mixing calculation [assumes the density of water and 1% boric acid are the same]
(160,173 x 1720 + 15,372 x 0) / (160,173 + 15,372) = 1569.3 ppm

The first 15,372 gallons dilutes the pool to 1569.3 ppm and fills it to the top. The pool volume at that point is 175,545 gallons and further water addition will cause overflow.

Calculate pool boron concentration at high level alarm point. (10 CFR 50.68 exemption cases)
Pool volume full to Elv 647 = 167,327 gallons
Subtract 12" to Elv 646 = 5,124 [12" x 427 gal per in. = 5,124 gal]
Assumed start volume = 162,203 gal @ 2500 ppm

Do the volumetric mixing calculation [assumes the density of water and 1% boric acid are the same]
(162,203 x 2500 + 9,394 x 0) / (162,203 + 9,394) = **2363.1 ppm at high level alarm**

Calculate pool boron concentration at overflow point. (10 CFR 50.68 exemption cases)
Pool volume full to Elv 647 = 167,327 gallons
Subtract 12" to Elv 646 = 5,124 [12" x 427 gal per in. = 5,124 gal]
Assumed start volume = 162,203 gal @ 2500 ppm

Do the volumetric mixing calculation [assumes the density of water and 1% boric acid are the same]
(162,203 x 2500 + 15,372 x 0) / (162,203 + 15,372) = **2283.6 ppm at point of pool overflow**

The first 15,372 gallons dilutes the pool to 2283.6 ppm and fills it to the top. The pool volume at that point is 177,575 gallons and further water addition will cause overflow.

Dilution with perfect mixing and replacement (1 gallon letdown for each gallon added)

The appropriate equation taken from Brienzo 77 [attached to WL Roberts to PRC 5/23/1979 Cart 9055 frame 2089 or initial CVCS design Calc P-SEC-42 by Combustion Engineering 6/14/67 page 45 of 54 Cart C683 Frame 1532]

$V_{added}/V_{Pool} = \ln (C_{Initial} / C_{final})$

Where: $C_{Initial}$ = Initial boron concentration of V_{pool}

C_{final} = Final concentration after over flowing V_{added} gal by adding 0 ppm water

Water to Dilute Pool to 850 ppm Boron

$V_{added} = V_{pool} \times \ln (C_{Initial} / C_{final})$ = 175,545 x ln (1569.3/850) = 107,635 gal of 0 ppm water

The next 107,635 gal of dilution reduces the pool to 850 ppm and puts 107,635 gal of boric acid, ranging from 1569.3 ppm for the first gal to 850 ppm for the last, on the Auxiliary building floors

Total Water to Dilute Pool to 850 ppm Boron

The total water would be the amount to fill the pool plus the amount to overboard it and get to 850 ppm boron.

$V_{tot} = V_{fill} + V_{overboard}$ = 15,372 + 107,635 = 123,007 gal of water to get pool to 850 ppm

Water to Dilute Pool to 1850 ppm Boron (10 CFR 50.68 exemption case)

$V_{added} = V_{pool} \times \ln (C_{Initial} / C_{final})$ = 177,575 x ln (2283.6/1850) = 37,392 gal of 0 ppm water

The next 37,392 gal of dilution reduces the pool to 1850 ppm and puts 37,392 gal of boric acid, ranging from 2283.6 ppm for the first gallon to 1850 ppm for the last, on the Auxiliary building floors

Total Water to Dilute Pool to 1850 ppm Boron (10 CFR 50.68 exemption case)

The total water would be the amount to fill the pool plus the amount to overboard it and get to 1850 ppm.

$V_{tot} = V_{fill} + V_{overboard}$ = 15,372 + 37,392 = 52,764 gal of water to get pool to 1850 ppm

Analysis of the 11 Dilution Scenarios

Type One Events - Direct Over Dilution

Demin water via 3/4 inch hose

The addition of unborated demineralized water from either Demin Water Tank T-90 utilizing Demin water pump P-90A or B is allowed by System Operating Procedure SOP-27 section 7.2.4, which refers to SOP-27 attachment 2. The Attachment requires Shift Manager signature to begin, places restrictions on fuel movement during the addition, and for additions greater than 50 gallons a verified calculation of the target level change and boron concentration change in the pool. The operator must be present at the SFP at all times during the addition unless it can be monitored by the Control Room TV. A pool sample and boron analysis is required at completion of the addition.

There is a hose bib attached to the demin water line serving the Boric Acid Batching Tank (HC-11-1 1/2 which is to the east of the pool and a level (Elv. 622) below. A 60' length of 3/4 inch "red rubber hose" is stored in the AO's locker for this purpose. The hose has standard quick disconnect fittings that match the bib and is supplied with a valve on the pool end. It is passed up through the grating below the new fuel racks to Elv. 649 on the SFP deck. Pump P-90A or B is then started if it is not already operating, the Bib valve is opened and the hose is opened at the pool on Elv 649 being careful not to spray the area. After the desired elevation is reached the hose is rinsed and removed.

The event being analyzed is that the operator leaves the area and forgets to watch such as might happen if another "emergency" occurred in his assigned area.

Demin water pump P-90 is capable of generating 375 feet of head at shutoff and has a very flat flow characteristic out to 350 feet at its 164 gpm design point. The supply line from the pump to the bib is a combination of 3" and 1 1/2" line. The loses in those lines will be small compared to the 3/4" hose and are neglected here. The tank suction source will be assumed to be at least 10' full to Elv 600. The delivery point is Elv 647 which is 47' above. The available pressure is then:

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375' - 47' = 328'

328 x 0.43 psi/ft = 141 psig available for drop in the hose.

Apply modified Darcy's equation to the hose. Assume hose wall friction is equal to smooth steel pipe of the same diameter.

$\Delta P = [K + f(L/D)]\rho V^2/2g$ f = 0.024 [Crane Technical Paper 410 p. A-23]

L= 60'

D= 3/4"

L/D= 60' x 12"/0.75" = 960

K= 1 = Hose discharge coefficient

$\Delta P = [1 + 0.024(960)]\ 62.4\ V^2/2 \times 32.2$

$\Delta P = [1+23](.969)V^2$

or $V^2 = \Delta P / 23.25 = 873.3$ ΔP = 141 psi x 144 sq. In. Per sq. Ft. =20,304 psf

then V = 29.55 feet per second

By the continuity equation the volumetric flow is the velocity times the cross sectional area.

Q = AV =29.55(0.003068) $A = \pi D^2/4$ = 0.4418 sq. in. = 0.003068 sq. ft.

Q = 0.09066 cu. ft. per second

GPM = Q x 60 x 7.48 = 40.7 gpm of Demin water at 0 ppm boron.

The calculations above showed that it would take 123,007 gal of water to get the pool to 850 ppm. At 40.7 gpm this would take 3,022 minutes or 50 hours to cause a criticality problem. In the meantime there would have been 6 shift operations changes and 107,600 gallons of borated water would have had to be ignored on the auxiliary building floors and, after the 3,800 gallon Dirty Waste Tank that accepts the floor drains overflows, in the East Safeguards room sump. The spent fuel pool high level alarm would have had to be ignored.

10 CFR 50.68 exemption case: The calculations above showed that it would take 52,764 gallons of water to get the pool to 1850 ppm. At 40.7 gpm this would take 1296 minutes or 21.6 hours to cause a criticality problem. In the meantime there would have been 3 shift operations changes and 37,392 gallons of borated water would have had to be ignored on the auxiliary building floors and, after the 3,800 gallon Dirty Waste Tank that accepts the floor drains overflows, in the East Safeguards room sump. The spent fuel pool high level alarm would have had to be ignored.

There is also a hose bib on Elv. 949 between the cask washdown pit and new fuel storage. This supplies non-borated Utility Water from tank T-91. The Utility Water Pumps P-91A and B only put out 88 gpm at 166 feet of head. Essentially the same hose is used so that the analysis of the Primary Water Make Up system from T-90 envelopes the T-91 transfer from a dilution standpoint.

Dilution from the Fire System via 1 1/2" hose station on Elv 649.

There is a fire hose station available for manual use in fighting fires that is located 40 foot northeast of SFP and has 75 ft hose attached that could easily reach the pool. Fire hoses in the pool area were avoided in the original plant design. However this one was added when the building was expanded to house "Zero Discharge Radwaste" system. That system and the Radioactive Tool Crib that was later placed in the area greatly expanded the fire loading and made the hose station a prudent necessity.

It is conservatively assumed that the fog nozzle attached is removed and the open hose is thrown in the pool. Further, the flow resistance of the 10" fire header and the 2 1/2 inch riser to the hose bib will be ignored. The 1 1/2 inch hose will be assumed to have the same friction factor as an equivalent diameter steel pipe.

The P-9A fire pump has a shutoff head of 378 ft and a design rating of 1500 gpm at 313 ft of head. It is estimated that the fire hose will deliver 250 gpm. At that flow head is 366 ft.

The pump suction is Lake Michigan whose surface Elevation is assumed here to be at Elv 579'. It delivers water to Elv 649' for a difference of 70'.

The available head to drive flow through the hose is 366' - 70' = 296'.
Converting to psi 296' x 0.43 psi per foot = 127 psi

Using Darcy's equation:

$\Delta P = [K + f(L/D)]\rho V^2/2g$ f = 0.020 [Crane Technical Paper 410 p. A-23]
L=75'
D= 1.5"
L/D= 75' x 12"/1.5" = 600
K= 1 = Hose discharge coefficient

$\Delta P = [1 + 0.020(600)]\ 62.4\ V^2/2 \times 32.2$

$\Delta P = [1+ 12](.969)V^2$

or $V^2 = \Delta P / 12.6 = 1451$ ΔP = 127 psi x 144 sq. In. Per sq. Ft. =18,288 psf

then V = 38.1 feet per second

By the continuity equation the volumetric flow is the velocity times the cross sectional area.

$Q = AV = 38.1(0.01227)$ $A = \pi D^2/4 = 1.767$ sq. in. = 0.01227 sq. ft.

Q = 0.4676 cu. ft. per second

GPM = Q x 60 x 7.48 = 209.8 gpm of Demin water at 0 ppm boron.

Previous calculations above show that it would take 123,007 gal of water to get the pool to 850 ppm. At 209.8 gpm this would take 586minutes or 9.8 hours to cause a criticality problem. Again the 107,600 gal of boric acid solution on the Auxiliary building floors and sump would have to be ignored for more than one shift to cause a criticality problem. The spent fuel pool high level alarm would have had to be ignored.

10 CFR 50.68 exemption case: Previous calculations above show that it would take 52,764 gal of water to get the pool to 1850 ppm. At 209.8 gpm this would take 251 minutes or 4.2 hours to cause a criticality problem. Again the 37,392 gallons of boric acid solution on the Auxiliary building floors and sump would have to be ignored to cause a criticality problem. The spent fuel pool high level alarm would have had to be ignored.

As previously shown, the volume difference to go from the low level alarm to the high level alarm is 9,394 gallons. At 209.8 gpm this would take 44.8 minutes, or 0.75 hours. The volume change to go from the high level alarm to pool overflow was previously shown to be 5,978 gallons. At 209.8 gpm, this would take 28.5 minutes, or 0.5 hours.

Failure to isolate demineralizer before sluice water is valved into the system.

The Spent Fuel Pool Demineralizer is interconnected with the clean and spent resin handling systems by 3" ball valves MV-SFP135 and 136. It is standard procedure to move the resins by sluicing them using demineralized water from tank T-90. The water lines are 3" diameter also.

Procedure SOP-27 section 7.4 requires the demineralizer to be isolated from the pool cooling system prior to engaging in resin moving operations. If that is not done it will cause problems with resin movement. It would be natural to use as much water as is available to attempt to start resin movement since getting it started is a common problem. In this case with the demin NOT isolated, essentially a 3" line from T-90 to the fuel pool would be open. The flow would be dependent on the water level in T-90, whether the fuel pool booster pump P-82 is running, and how many Demin water transfer pumps P-90A and/or B are running.

The primary mode of force would be P-90A or B. Although these pumps have a rather flat head curve they are rated at 165 gpm at 148 psi of differential head. With a full tank as suction and delivering to a wide open 3" line well over twice that could be delivered and a second pump could be started for even more.

Because this is not the limiting event, a 165 gpm flow equal to the design flow of one pump will be analyzed. Projected times to dilution limits can easily be linearly scaled from there to cover any given set of assumptions.

The previous calculations have shown that 123,007 gallons would be required to be added with system overflow of 107,600 gallons to reduce the pool to the analyzed concentration of 850 ppm given that the event started at minimum Tech Spec concentration of 1720 ppm.

123,007 gal / 165 gpm = 745minutes or 12.4 hours for the operator to respond.

Resin sluice is a local manual operation that is closely watched and controlled (operator in continuous attendance) because retrieval of stray resin is both difficult and potentially harmful to plant systems. Maintaining full water pressure to attempt to move resin for 12 hours would be highly unusual. Furthermore the location of the operator maneuvering the valves would put him in the direct path of the water overflowing the pool. With 12 hours being available the Shift Manager and another shift of operators would also be involved before the limit would be reached.

10 CFR 50.68 exemption case: The previous calculations have shown that 52,764 gallons would be required to be added with system overflow of 37,392 gallons to reduce the pool to the analyzed concentration of 1850 ppm given that the event started at minimum DFS load concentration of 2500 ppm.

52,764 gal / 165 gpm = 320 minutes or 5.3 hours for the operator to respond.

10 CFR 50.68 exemption case: Resin sluice is a local manual operation that is closely watched and controlled (operator in continuous attendance) because retrieval of stray resin is both difficult and potentially harmful to plant systems. Resin sluicing while in the midst of a DFS operation would be highly unusual. Furthermore the location of the operator maneuvering the valves would put him in the direct path of the water overflowing the pool. With 5.3 hours being available, the Shift Manager would also likely be involved before the limit would be reached.

<u>**Cut in of an unborated demin**</u>

The Fuel Pool Demineralizer is designed for 68 cu. ft. of resin. The volume of the pool is 21,992 cu. ft. An unborated demineralizer cut into the PCS per Procedure SOP- 2B will remove 20 ppm boron.

Ratioing the demineralizer volumes and the system volumes results in predicting 22.5 ppm for the fuel pool.

PCS Volume =10,900 per FSAR Table 4-1
CVCS Demin contains 30 cu.ft. Resin

10,900 cu ft x 62.4 # per cu ft x 20 ppm / 1,000,000 ppm per wt fraction = 13.6 # boron

13.6 # boron / 30 cu ft = 0.453 # per cu ft resin

68 cu ft resin x 0.453 # per cu ft resin = 30.83 # boron

30.83 # boron / 21,992 (62.4) # of water = 22.5 E-6 wt fraction boron = 22.5 ppm

The 22.5 ppm is within administrative margin of 50 ppm maintained in the fuel pool and is not a problem. The demineralizer is routinely borated this way.

__Fuel Pool Cooling Heat exchanger tube leak__

The Spent Fuel Pool Heat Exchanger (SFPHx) is cooled by the Component Cooling Water (CCW) System. The CCW system contains corrosion inhibited water. Water is circulated by pumps that are located just across the hall in the Auxiliary Building from the SFP Hx. The pump suction is pressurized by a 1030 gal head tank (T-3) located on the Spent Fuel Pool deck elevation just southeast of the pool. The tank is kept full by an automatic makeup valve operated by LS-0918 with water from Primary Makeup Pumps P-90A or B which is unborated. A light comes on in the control room to notify the operators that the valve is open.

The level in T-3 will be conservatively assumed to be 8 ft above the 649 Elv deck. Because the pressures on both sides of the heat exchanger are so close to equal, the SFP pumps P-51A and B will both be assumed to be off. The head to drive the break flow will be assumed to be the elevation between the head tank level and the pool normal water level (657 - 647 = 10 ft) and the design maximum Hx shell side pressure drop (15 psi).

The break will be assumed to be right at the tube sheet. Flow will be from outside the tube to inside, therefore an entrance loss coefficient of 0.5 into the tube and 1.0 as the tube leaves the tube sheet will be employed. All other friction will be ignored and the break will be assumed to be double ended (no friction in the 20 ft trip down the tube for the second side of the break).

ΔP = 15 psi + 10 ft (0.43 psi per foot) = 19.3 psi

$\Delta P = K \rho V^2 / 2g$

19.3(144 psf per psi) = (0.05 + 1.0) 64.2 V^2 / 2 (32.2)

Solving for V

V^2 = 1912 and V = 43.7 FPS

The tubes are 5/8 inch OD. Ignoring the wall the area is 0.3068 sq in

Q = AV = 0.3068 x 2 x 43.7 / 144 sq in per sq ft = 0.186 CFS

0.186 x 7.48 x 60 = 83.6 gpm = double ended flow rate of non borated water

From previous analysis the volume of water to dilute the pool from minimum Tech Spec concentration of 1720 ppm to the criticality analysis value of 850 ppm is 123,007 gal.

123,007 gal / 83.6 gpm = 1471 minutes or 24.5 hours

From previous calculations addition of 24" of water at normal pool level of 647' will overflow the pool at 649'. The pool rises at the rate of 1 inch per 427 gallons.

427 x 24 / 83.6 gpm = 122 minutes = 2 hours to overflow the pool.

If the operator is first alerted at 2 hours by pool overflow there will be 22 hours left to react to the leak before criticality is any concern.

10 CFR 50.68 exemption case: The previous calculations have shown that 52,764 gallons would be required to be added with system overflow of 37,392 gallons to reduce the pool to the analyzed concentration of 1850 ppm given that the event started at minimum concentration of 2500 ppm.

52,764 gal / 83.6 gpm = 631 minutes or 10.5 hours for the operator to respond.

From previous calculations an addition of 22" of water is required from low level to high level alarm at 647'10". The pool rises at the rate of 1 inch per 427 gallons.

427 x 22 / 83.6 gpm = 112 minutes = 1.9 hours to actuate the pool high level alarm.

If the operator is first alerted at 1.9 hours by the pool high level alarm, there will be 10.5 - 1.9 = 8.6 hours left to react to the leak before criticality is any concern.

<u>Miss-application of a portable Tri-Nuc filter system</u>

For ALARA reasons the permanently installed Fuel Pool Filter and skimmer system are abandoned in place. Portable Tri-Nuc units are used instead to maintain visibility in the pool and refueling cavity. There are 3 different size units 100, 250, and 600 gpm units. The units sit on the bottom of the pool or cavity and have a suction hose port that can be attached to a hose, or a vacuuming wand, or the hose can be used as a means of remote suction to force circulation. The 600 gpm unit has no suction hose capability. All three types of units have ports for discharge hoses which can be used to increase the distance from suction to discharge and cause various "engineered" circulation paths to speed cleanup or increase visibility in a specific area. The main ALARA attraction is that the filters are shielded by remaining under water at all times and can also be changed under water if necessary. The decision can be made after the filter is full so that correct estimation of the activity that might be collected is not critical to dose.

The concern in this dilution analysis is that the suction hose can be placed or dropped into a non-borated water source of unknown and unpredictable volume. Furthermore such sources are commonly in the area when decontamination is done.

The worst case would be the 250 gpm unit attached to a continuously replenished source. This could continue for:

123,007 gal / 250 gpm = 492 minutes = 8.2 hours

in the spent fuel pool before a criticality problem would be created.

It should be noted that 200,000 gallon tank T-90 is probably the only reasonably available source that has 123,007 gallons of water and that this required volume far exceeds any portable source (Tanker Truck) or reinforced tank that could be moved to the area by crane while full of water. The weight of water required to accomplish this much dilution is over 510 tons. That weight exceeds the lifting capacity of all site cranes, most temporary construction cranes, and the road weight limits of the State. It, therefore, cannot come from any single temporary or portable source. It would have to come from the locally supplied hose bibs and site piping from T-90. Although the short term delivery rate might be higher due to use of a small local tank or drum for decontamination, in the long term this event is the same as the dilution event utilizing the 3/4 inch hose to deliver Primary Makeup Water from T-90 and is enveloped by that event.

Assuming it is not operators involved, their first notification might be from the 107,600 gal of water that would have to be over boarded. At 250 gpm there would be 7 hours after first overboard to get operator action to stop the dilution. If the event happened with the pool and cavity connected, the time would be extended considerably as would the response time requirement and the total volume that would have to be over boarded without operations noticing.

Procedure SOP-27 also allows the use of other portable pumps of unspecified size such as HydroLazers with unspecified volumes of water. This is only allowed in the refueling cavity when the South Tilt Pit gate is installed in the fuel pool. The procedure requires the amount of dilution available to reach the limiting boron concentration to be calculated. The calculated volume is then divided by the pump capacity to create a maximum time that the pump can be run. In any case this is not a Spent Fuel Rack criticality issue since the gate must be in place as a prerequisite to use of this section of SOP-27. Furthermore the size of the equipment and volume of water needed to create a problem, as calculated above, virtually preclude it from ever being a Spent Fuel Pool Rack criticality problem.

10 CFR 50.68 exemption case: This case is not a credible accident and is not analyzed.

<u>Normal system dilutions developed by SIRWT cross connect with SFP</u>

The fuel pool and the SIRWT are not at the same boron concentration during normal plant operation even though the SIRWT is the first priority emergency makeup source for the pool. The worst case actually happens every refueling when the cavity is filled from the SIRWT and then the cavity and pool are cross connected via the 36" diameter transfer tube when the tilt Pit gate is removed. The pool usually runs above 3050 ppm. The SIRWT cannot exceed 2500 ppm by Tech Spec Limit. It is kept close to that as a matter of conserving waste water handling. These very high boron levels are very good from a criticality safety viewpoint.

This analysis will assume the SIRWT is at 1720 ppm since it is a worst case enveloping event. Upon gate removal the 1720 ppm in the cavity will mix in an irregular manner via the large transfer tube. The equalization can take as long as 3 days and can also be accelerated very much by varying alignments of the Shutdown Cooling System that is cooling the core in the reactor vessel and the SFP Cooling System that is cooling the fuel in the pool racks. The pumps involved can be aligned to move 1,500 to 3,000 gpm though the tube as opposed to only a few gpm due to thermal circulation and normal imbalances. The pool starts at 3050 ppm. Cavity volume is available from previous analysis above as 253,000 gallons as approximated in SOP-27.

[253,000 gal (1720 ppm) + 165,297 gal (3050 ppm)} / (253,000 + 165,297) = 2244 ppm

This is a significant 806 ppm dilution of the Spent Fuel Pool. Since the dilution source is 1720 ppm or higher there will never be any direct criticality hazard for the fuel pool racks from this evolution. The primary concern is that the boron concentration is changing a major amount over a long, up to 3 day, period of time and thus making it difficult for operations to track the evolution. The event is placed here as the enveloping event representing all uses of the primary Spent Fuel Pool makeup source since every such use also involves some dilution, given the way the plant is presently configured and operated.

10 CFR 50.68 exemption case: This analysis will assume the SIRWT is at 1720 ppm since it is a worst case enveloping event, and the spent fuel pool at 2500 ppm. Will assume direct flow from the SIRW into the spent fuel pool.

Calculate pool boron concentration at high level alarm point. (10 CFR 50.68 exemption case)

Pool volume full to Elv 647 = 167,327 gallons

Subtract 12" to Elv 646 = 5,124 [12" x 427 gal per in. = 5,124 gal]
Assumed start volume = 162,203 gal @ 2500 ppm

Do the volumetric mixing calculation [assumes the density of water and 1% boric acid are the same]
(162,203 x 2500 + 9,394 x 1720) / (162,203 + 9,394) = **2457.3 ppm at high level alarm**

Calculate pool boron concentration at overflow point. (10 CFR 50.68 exemption cases)

Pool volume full to Elv 647 = 167,327 gallons
Subtract 12" to Elv 646 = 5,124 [12" x 427 gal per in. = 5,124 gal]
Assumed start volume = 162,203 gal @ 2500 ppm

Do the volumetric mixing calculation [assumes the density of water and 1% boric acid are the same]
(162,203 x 2500 + 15,372 x 1720) / (162,203 + 15,372) = **2432.5 ppm at point of pool overflow**

The first 15,372 gallons dilutes the pool to 2432.5 ppm and fills it to the top. The pool volume at that point is 177,575 gallons and further water addition will cause overflow. From the Palisades Tech Data Book(ref 32):

$$\boxed{Vol_A = \frac{(\text{Final Concentration} - Conc_B) \times Vol_B}{Conc_A \times \left(1 - \dfrac{\text{Final Concentration}}{Conc_A}\right)}}$$

Where: Vol_A = final volume of SIRW needed to dilute spent fuel pool to 1850 ppm
Vol_B = initial volume of Spent Fuel Pool = 177,575 gals at conc of 2432.5 ppm
$Conc_A$ = Conc of 1720 ppm
Final concentration = 1850 ppm after over flowing with SIRW at 1720 ppm water

Final Vol_A is 795,643 gallons. Total dilution is (795,643 + 15,372) = 811,015 gallons. This is not possible as the SIRW does not contain this amount of water. Critical boron concentration will never be obtained.

Type Two Events - Dilution by Emergency Pool Refill

Dilution by the Fire system via 6" swing elbow in the Fuel Pool Cooling System.

A 6 inch swing elbow was supplied in the fuel pool cooling system room at elevation 590. This line was provided to meet a regulatory requirement to have a tornado protected makeup source. This was done in light of the SIRWT being the only normal supply and its exposed position on the Control Room roof making it vulnerable to tornado damage. It was supplied with a swing elbow to insure it was not used accidentally by operator error. The elbow allows rapid makeup without exposing the operator to potentially very high radiation levels that are generated due to loss of shielding water at very low pool levels. The tornado case is explicitly analyzed as the last case in this dilution evaluation and does not require the remote feature since plenty of shielding water is left in that particular case. All other potential uses are covered here. It is anticipated that only the tornado use will be proceduralized after boron credit is allowed in the rack criticality analysis.

The 6 inch line tees into the 12 inch cooling system return line to the pool. SOP-27 section 7.2.3 allows the elbow to be swung into place on the Shift Manager's approval without an emergency being declared. The caution in the procedure simply says "Caution, performance of this section will result in lake water entering the SFP". ONP-23.3 step 4.9.8 requires the use of the swing elbow as the fourth and last priority makeup source.

Use of the swing elbow is one of 2 limiting and enveloping transients. It results in flow in excess of 2000 gpm and will start not only Electric Fire Pump P-9A but also Diesel Fire Pump P-9B which comes on at 83 psig in the fire header. For this reason a more detailed analysis is done.

The water source for the fire system includes 4 pumps. The system is normally pressurized by the Fire Jockey pump P-13 which is rated for 50 gpm at 270 ft of head (116 psig). It runs continuously against RO-1600 (0.3593" orifice) which recirculates water back to the plant intake bay in the screen house. This supplies normal system leakage, minor usage, and keeps system pressure above the Electric Fire Pump P-9A start pressure of 98 psig. Should pressure continue to drop Diesel Fire Pump P-9B starts at 83 psig and Diesel Fire Pump P-41 starts at 68 psig.

All three Fire Pumps are identical Worthington pumps type 15M185WF-3 rated for 1500 gpm at 313 feet of differential head. They all take suction from the same plant intake bay which for this analysis is assumed to be at Elv 579'. Normal operation of the Service Water pumps and Dilution Water pumps draw the bay down a couple of feet but that is ignored here since more flow is conservative in this analysis.

Fire Water is supplied around the plant by a 10" external loop with outdoor hydrants. A combination of 8" and 10" pipe forms an internal header that cuts across this loop to make a double loop arrangement. The external loop piping is class KC cast iron mechanical joint pipe and the internal is class KB or KBF welded steel pipe with cast iron valves.

The pipe that feeds the 6" swing elbow leaves the 10" section of the internal header in the 1-2 Diesel Generator (K-6B) room. An 8" line leaves the header on the west wall and runs across the top of both Diesel Generator rooms for a distance of 40'. This brings it to the wall just outside the NW corner of the SFP Hx Room. There it reduces to 6" and goes straight through the wall at Elv. 604'-6". Just inside the wall an elbow drops it to Elv. 591 (near the floor) and it turns south 3 and 1/2 feet where the swing elbow is located. Class HG-4-6" pipe then rises to Elv. 600'-0 5/8" to the 12" heat exchanger discharge header and tees in there to get to the pool. The total distance of 6" pipe is 26 ft, 3 elbows, and a 12 x 12 x 6" tee with side branch flow inward.

A simple model was constructed assuming flow was controlled by the local piping arrangement at the swing elbow. The calculated flow was higher than a single pump could deliver and high enough to suggest that the network of fire mains would be important in the analysis. There is a computer network analysis of the system done in 1996 during the Appendix R reanalysis. These 26 different cases confirmed the fact that the network would be important in the total flow determination.

The Appendix R model (EA-FPP-96-001 to EA-FPP-96-026) was not directly useable because it considered low flow to be conservative and reverted to "Code" values where the system exceeded code requirements. It also restricted the pumps to one at a time, used conservative aged pipe friction factors, and employed the highly conservative "short loop out" criteria wherein the least resistance path is assumed to be blocked and unavailable. This is a proxy for the almost impossible code requirement that the "worst" flow path deliver adequate flow.

For this dilution analysis high flow is considered conservative so adjustments had to be made. The Appendix R model of fire system loop geometry was used. Standard new pipe friction factors from Crane Technical Paper 410 were substituted for the aged factors given in the Fire Codes. The actual new pump head curves were used instead of the flat curves forced on the system by the fire sprinkler analysis computer program (HASS see Ref 2.5 of the above series of EA's). To enable a hand estimate to be done the system geometry from the HASS network analysis cases was used to identify the three primary flow paths from the pumps to the swing elbow. Hand adjustments to the Fire "Code grade" calculations assumed these paths were independent parallel flow paths. The fact that some of the pipe was common to more than one path for short distances was temporally ignored. The three parallel flow path system was used to estimate the total flow and branch flow ratios. The resulting flows were then used in the exact network model to check pressure balancing. Adjustments were then made to the flows to compensate for excessive flow rates in the piping common to more than one path. The short interconnection point at MV-FP-281 which is 4.5 feet of 6" pipe with the valve and one elbow was the primary problem with this technique. This cross tie which was added in 1989 by FC-834 is involved in two and a half of the paths. This small pipe connects an 8" header to a 10" header and flow at this point in the model required considerable adjustment to "converge" the pressure distribution.

Depending on the exact friction factors and form loss coefficients used the fire system will deliver between 4,000 gpm and 4,500 gpm to the fuel pool via the swing elbow path. If the elbow is swung to the fuel pool position and both of the locked closed valves are opened wide, both Electric Fire Pump P-9A and Diesel Fire Pump P-9B will start. Acting together they will deliver 2,250 gpm each at a discharge pressure of about 90 psi. This is sufficient to keep the second Diesel Fire Pump P-41 from starting at 65 psi if the last valve is opened slowly. Since it is a hand operated valve this is the most reasonable assumption.

The fuel pool and north tilt pits rise at the rate of one inch per 427 gallons. The 4,500 gpm from the pumps will raise level at 10.5 inches a minute. It is clear that the line was intended to allow rapid makeup under the more severe accident conditions. No unique starting level could be identified for this kind of usage so the problem is presented parametrically in starting level. If started from the low level alarm point at Elv. 646 the pool will over flow in 3.4 minutes. If the pool started at the Tech Spec Minimum boron concentration of 1720 ppm, the pumps could run for 27 minutes before the pool would reach the 850 ppm assumed in the boron credit criticality analysis. The time to reach 850 ppm turns out to be very insensitive to starting level but is essentially directly proportional to the pool boron concentration at the beginning of the analysis and inversely proportional to the flow rate of the non-borated water.

Both of the later variables are handled very conservatively. The initial boron concentration is assumed to be the Tech Spec limit of 1720 ppm even though the pool as now operated is almost always in the 2700 to 3300 ppm range. This is the direct result of Dry Cask Loading requirements as they interact with waste water minimization goals. Use of actual concentrations would roughly double the water volumes required which would double the available reaction times.

The Lake water flow rate is very conservatively assumed to be delivered through new pipes. Most of the pipes are 37 years old and, based on industry experience with similar pipes in identical service, would be expected to obstructed by 10 to 30% of the flow area and have roughness coefficients consistent with half inch scale/tubricles at the pipe to water interface. A 30% decrease in flow area would result in a 70% increase in flow resistance which would cause a reduction in flow rate of a similar amount.

To use the line operators would have to manually swing the 6" bolt flange elbow, unlock and manually open 2 large valves. Then to create the analyzed event they would have to ignore Fire System low pressure, 2 Fire Pump Running alarms and High Safeguards room sump level alarms in the control room. They must also, in general terms, ignore a virtual deluge of water coming down the main Auxiliary Building stair way for on the order of 27 minutes as approximately 100,000 gal. of overflow rushes from the top floor and perculates through the building to seek the lowest levels which is usually the 570' Elv in the Engineered Safeguards Rooms. The event that triggers this dilution must involve local, manual, hands on, time consuming activities. The pool would overflow quickly (2 to 10 minutes). The over flow path would be wetting the normal egress path from the area. It is therefore very highly likely that the operator who initiated the event would notice the overflow.

Dilution of the Spent Fuel Pool starting from 1720 ppm with 4,500 gpm of Fire Water

Case	Pool level at start	Feet from Top (Elv. 649'-0")	Gal Borated water in Pool at start	Gal to fill Pool - start overflow	ppm in pool @ start of Overflow	Total Volume added to 850 ppm	Time to 850 ppm Minutes
1	649'-0" full	0'-0"	175,545	0	1720.0	123,732	27.50
2	647'-0" normal	2'-0"	165,297	10,248	1619.6	123,422	27.42
3	646'-0" Lo Lvl Alm	3'-0"	160,173	15,372	1569.3	123,007	27.33
4	644'-5" Cooling out	4'-7"	152,060	23,485	1489.9	122,006	27.11
5	639'-0" 10 ft low	10'-0"	124,305	51,240	1217.9	114,374	25.42
6	631'-9" first no overflow	17'-4"	86,752	88,793	850.0	88,793	19.73
7	625'-0" Gate Threshold	24'-0"	52,569	Stop at Elv 635'-6"	850.0 Stop pump	53,806	11.97
8	625'-0" Gate Threshold	24'-0"	52,569	122,976	515.1	122,976 Refill to brim	27.33
9	625'-0" Gate Threshold & refill to normal	24'-0"	52,569	112,728 Stop at normal Lvl	850.0 Case Start 2673 ppm	112,728	25.05

The cases were chosen to represent specific identifiable boundaries or concepts of recovery. Case 1 starts with a full pool and over flows throughout the event. Case 2 starts from normal level and would be the erroneous activation case. Case 3 starts at the nominal low level alarm point and would represent an operator over reaction to an alarm. Case 4 starts at the cooling system suction "dry pipe" point which is the loss of heat exchanger case with operator over reacting to use the large pipe and then failing to shut it off. Case 5 is an arbitrary very low level point chosen to help illustrate the level vs time to act insensitivity that results from the logarithmic dilution equations. Case 6 is the highest "no overflow" case chosen to be at 850 ppm when the pool is brim full. Cases 7, 8, and 9 are all pool gate threshold cases which is the level that results from erroneous actuation of the tilt pit drains or refueling cavity seal (or SG dam) blowout events. Case 7 is stopped at 850 ppm which is 12 feet short of normal level but shielding is restored and 50,000 gallons of cold water has cooled the pool significantly although level is still 10 feet short of re-establishing cooling via the normal heat exchanger. Further refill could await lineup of borated water sources. Case 8 is allowed to violate the 850 ppm assumed in the criticality analysis and continue to a full pool. Normal cooling is re-established but boron is at 515 ppm which is less than 5% shutdown margin although well subcritical. Case 9 is included to demonstrate that, if the analysis starts from "actual" boron concentration rather than Tech Spec low limit, full pool refill with non-borated water can be accommodated with full 5% shutdown margin available.

Taken as a whole these cases demonstrate the physical limitations of the system while enveloping available margins in time to recover and volumes of water required for all other events. No judgment of their credibility or probability to actually happen is intended to be implied and multiple human errors are most definitely required.

10 CFR 50.68 exemption case: Some of the Type 2 events are not credible accidents and are not analyzed for DFS loading situations. The refill via 6" swing elbow is not separately analyzed. The dilution from the Fire System via a 1 1/2" hose station emergency makeup is previously analyzed in the Type 1 events and is the more credible event.

<u>South Tilt pit gate leak requiring emergency makeup</u>

The plant normally operates with the south tilt pit gate in place and the fuel transfer tube isolated from containment by the double O-ringed blind flange. In this condition a gate leak will draw down the pool to fill the tilt pit until the pool and pit equilibrate. The resulting water level will be below the elevation of the cooling system suction line so that cooling will be interrupted. It can be postulated that non-borated water would be used to make up the difference so that cooling could be restored.

The south tilt pit and transfer tube volume from the previous volume table is 34,610 gallons. The level versus volume characteristic of the south pit is non-linear due to the transfer tube and the gate corridor. By ratioing pool drop against pit rise (area ratio = 5.862 pit rise to 1 pool fall above Elv 625) it is determined that level will drop to 641'-2.5". This does uncover the pool cooling suction line as postulated.

Refilling the tilt pit pool combination will require adding (without overboarding) one pit volume or 34,610 gallons.

$$[34{,}610\ (0\ \text{ppm}) + 165{,}297\ (1720\ \text{ppm})]\ /\ (34{,}610 + 165{,}297) = 1422\ \text{ppm}$$

This is well above 850 ppm so this event is not a criticality problem. Operator attention to loss of pool cooling will be triggered by the Fuel Pool Cooling Pump Low Discharge Pressure alarm and Fuel Pool Low Level alarm in the control room and by observation of pool vapor rising which happens well before boiling. The pool high temperature alarms might not work due to the level dropping below the instrument sensor leaving it out of the water.

10 CFR 50.68 exemption case: Refill the pool assuming the pool started at 2500 ppm

Restoring the pool to normal level with lake water results in:

[34,610 (0 ppm) + 167,327 gal (2500 ppm)] / (34,610 + 167,327) gal = 2071.5 ppm

The resulting 2071.5 ppm is greater than the criteria of 1850 ppm so there is no criticality concern even if the pool is fully refilled to normal level with lake water. Refilling to minimum level to cover the pump suction line would result in even more margin as would adding boron from the Recycled Boric Acid Tank with a hose and SOP-27 procedures simultaneous with lake water refill.

<u>Reactor Cavity Pool Seal loss or SG nozzle dam loss while connected via transfer tube.</u>

When the refueling cavity is flooded it relies on two different kinds of seals to retain the water. There is a temporary seal that is installed between the reactor vessel flange and the refueling cavity floor and steam generator nozzle dams that seal the nozzles so that the water box man ways can be open for tube inspection while refueling is being done. There are six of these. The new style dams are supplied with double seals and leakage alarms.

After the cavity is flooded and the Tilt Pit Gate is removed it is possible that one of these temporary seals could fail. Work in the area could cause tension bolts and retention clips to be knocked loose for example.

With 253,000 of the total possible 285,000 gallon volume of the SIRW Tank having been used to flood the cavity, little if any is left for makeup. These are large seals and upon failure the crew has only 5 or less minutes to get the fuel set down in the vessel, tilt machines or fuel racks before the cavity empties and the pool empties to the gate thresholds at Elv. 625'. The radiation doses in the pool area will be very high due to only a single foot of shielding water being left. Cooling would have been lost by the suction being 20 feet above the water surface.

In this condition the operator is directed by ONP -23.3 to align the ECCS System to pump the containment sump back into the reactor cavity. This attempts to refill the cavity with borated water. If successful the pool will also refill. Some of the seal blowouts could be large enough so that the cavity will only partially refill and stop when the leakage out equals the pump back rate. ONP-23.3 at step 4.9.2 allows for aligning the SFP cooling to the Reactor cavity Tilt Pit drain line and at step 4.9.3 to the SFP South Tilt Pit drain line. These 8" and 6" lines will be wet until the level reaches Elv 625, however they are only 20% of the normal 14" line flow area and might not cool the pool very well. If this happens the fuel pool gate must be reinstalled to resume Spent Fuel Pool cooling.

If the gate cannot be reinstalled the fuel pool can be cooled by boil off. To continue this process a remote makeup source of water must be established in the Spent Fuel Pool Heat Exchanger room because radiation levels on the 649 Elv. would be very high. Since boil off concentrates the boric acid, use of non-borated water is acceptable. When the gate can be reinstalled the boil off mode must continue until a borated water source is available to refill the pool because refilling from this very low elevation with non-borated water could be a potential fuel storage rack criticality problem. ONP-23.3 at step 4.9.8 allows the use of non-borated water as 2nd through 4th priority water sources and presently has no specific caution against its use to refill the pool from Elv. 625. There are other sources of borated water such as the four Safety Injection Tanks, two concentrated Boric Acid Storage Tanks, the Recycled Boric Acid Tank, and up to four 50,000 gallon Clean Waste Receiver Tanks which the ONP procedure does mention that operators could utilize to begin the pool refill process. At about 4 feet of water coverage over the fuel the dose levels drop to the point where manual installation of the Tilt Pit gate could be safely accomplished.

10 CFR 50.68 exemption case: *The Reactor cavity seal loss is not a credible accident since the plant is not* in refueling mode during a cask loading situation, and thus is not analyzed for DFS loading situations. The dilution from the loss of the south tilt pit gate seal failure and subsequent pool refill is the more credible event and was previously analyzed.

<u>Tornado Event (SIRWT loss, tornado missile in pool, 7' of water loss)</u>

As explained in the first sections of this analysis, the plant fuel pool is not tornado protected at the fuel pool deck level even though the lower levels of the pool cooling system are tornado protected. The tornado event is a 300 mph circular wind translating at 60 mph for a total maximum wind velocity of 360 mph. It is also specified that this is caused by (accompanied by) a 3 psi barometric pressure drop at its center.

Three simultaneous consequences are generated due to this single initiating event.

The SIRWT which is on the plant roof is assumed to rupture spilling its contents. The normal borated pool makeup source is then gone.

A Standard Review Plan specified tornado missile impacts downward into the pool damaging the fuel and the racks. The safety analysis of the damage is covered as being enveloped by the bundle miss-loading event. The miss-loading event needs 1350 ppm to meet this specified criteria.

The tornado winds which produce the 3 psi pressure drop can suck water out of the pool up to a 3 psi negative suction head. There are documented reports (EPRI and Bechtel Topical Reports) of up to 6' of water being removed from ground level pools in Florida by tornados of lesser velocity than the design basis tornado which authenticates this effect as real.

Removal of the water will cause the cooling system suction to be uncovered and cooling will be lost. It is postulated that lake water will be used to makeup the pool to normal level so that the cooling system can be restarted. Although there are other sources that are tornado protected that do contain some boron, their existence is not guaranteed by plant specifications and their flow paths to the pool are not documented in plant procedures.

The pool and north tilt pit volume is 165,297 gallons when the level is at the normal value of 647'-0". The vortex of the tornadic wind which causes the pressure drop of 3 psi is much larger than the 14'-8" width of the pool therefore it will have to suck a column of water upward. The water column height is limited by its suction pressure to:

3 psi x 0.43 ft per psi = 7.0 ft

The top of the pool curb is at Elv. 649'-6" and it will stop or seriously reduce the velocity of the winds. The pool will then be emptied to:

Elv 649'-6" - 7'-0" = Elv 642'-6"

Elv 647'-0" - Elv 642'-6" = 4'-6" = the amount of water actually removed by the tornado

4'-6" = 54" of drawdown x 427 gal per inch = 23,058 gal lost from the pool

165,297 gal - 23,058 gal = 142,239 gal left in the pool at 1720 ppm boron

Restoring the pool to normal level with lake water results in:

[23,058 (0 ppm) + 142.239 gal (1720 ppm)] / 165,297 gal = 1480 ppm

The resulting 1480 ppm is greater than the criteria of 1350 ppm so there is no criticality concern even if the pool is fully refilled to normal level with lake water. Refilling to minimum level to cover the pump suction line would result in even more margin as would adding boron from the tornado protected Recycled Boric Acid Tank with a hose and SOP-27 procedures simultaneous with lake water refill.

10 CFR 50.68 exemption case: Refill the pool assuming the pool started at 2500 ppm

167,327 gal - 23,058 gal = 144,269 gal left in the pool at 2500 ppm boron

Restoring the pool to normal level with lake water results in:

[23,058 (0 ppm) + 144,269 gal (2500 ppm)] / 167,327 gal = 2155.5 ppm

The resulting 2155.5 ppm is greater than the criteria of 1850 ppm so there is no criticality concern even if the pool is fully refilled to normal level with lake water. Refilling to minimum level to cover the pump suction line would result in even more margin as would adding boron from the tornado protected Recycled Boric Acid Tank with a hose and SOP-27 procedures simultaneous with lake water refill.

Conclusions

The above dilution analysis supports fully the assumptions made in generating the Spent Fuel Pool Rack criticality analysis taking credit for boron in the pool water to 850 ppm for normal events and 1350 ppm for infrequent accident events as specified in the Tech Spec Change request. Many of the events are terminated by operator action. There is more than ample time to act with no more than normal levels of operator vigilance required. This is due to available alarms or huge quantities of un-contained water that would be generated.

10 CFR 50.68 exemption case: The above dilution analysis supports fully the assumptions made in generating the Transnuclear criticality analysis, taking credit for boron in the pool water at 2500 ppm to dilute to 1850 ppm for normal events as specified in the Exemption request. Many of the events are terminated by operator action. There is more than ample time to act with normal levels of operator vigilance required. This is due to available alarms or huge quantities of un-contained water that would be generated.

Attachments

Attachment 1, Transnuclear Boron Dilution Criticality Analysis for the NUHOMS®-32PT with CE 15x15 Fuel. Transnuclear calc number 11030-01, Rev 0