TU Electric

Comanche Peak Steam Electric Station
CPSES

Engineering Report

SPENT FUEL POOL BORON DILUTION ANALYSIS

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SPENT FUEL POOL BORON DILUTION ANALYSIS

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1.0 INTRODUCTION

A boron dilution analysis has been performed for crediting boron in the CPSES Spent Fuel Pool (SFP) criticality analysis. The boron dilution analysis includes an evaluation of the following plant specific features:

- Dilution Sources and Flowrates including Piping Failures
- Boration Sources
- Instrumentation
- Administrative Procedures
- Loss of Offsite Power Impact
- Boron Dilution Initiating Events
- Boron Dilution Times and Volumes

The boron dilution analysis was performed to ensure that sufficient time is available to detect and mitigate the dilution before the spent fuel criticality analysis design basis of 0.95 k_{eff} is exceeded.

Revision 2 of this report was prepared to evaluate the effect of revisions to the criticality analysis as documented in Reference 8.

2.0 SPENT FUEL POOL AND RELATED SYSTEM FEATURES

This section provides background information on the SFP and its related systems and features.

2.1 Spent Fuel Pool

The design purpose of the SFP is to provide for safe storage of irradiated fuel assemblies. The pool is filled with borated water. The water functions to remove decay heat, provide shielding for personnel handling the fuel, and reduce the amount of radioactive gases released during a fuel handling accident. Pool water evaporation takes place on a continuous basis, requiring periodic makeup. The makeup source may be unborated water, since the evaporation process does not remove dissolved boron from the pool. Evaporation actually increases the boron concentration in the pool.

There are two spent fuel pools. The SFPs are normally separated by their closed gates. The gates provide leak tight isolation of the pools. A transfer canal connects both pools when their gates are open. In addition, the transfer canal connects the SFPs to the fuel transfer tube of each unit. The wet cask pit is located between the SFPs and communicates with the transfer canal (refer to figure 1).

Since the pools are normally separated by their closed hinged gates, the water volume utilized in the dilution evaluation will be the water volume corresponding to one pool, this volume is approximately 300,000 gallons [1]. This volume has been conservatively determined by using the water level corresponding to the low level alarm set point and reducing the water volume taken up by the fuel storage racks and stored fuel assemblies.

The SFP is a reinforced concrete structure with a welded stainless steel liner. The concrete structure has formed leak chases behind the liner welds that aid in identifying leaks. The pool structure is designed to meet seismic requirements. Each pool is approximately 40 feet deep.

CPSES Spent Fuel Pools

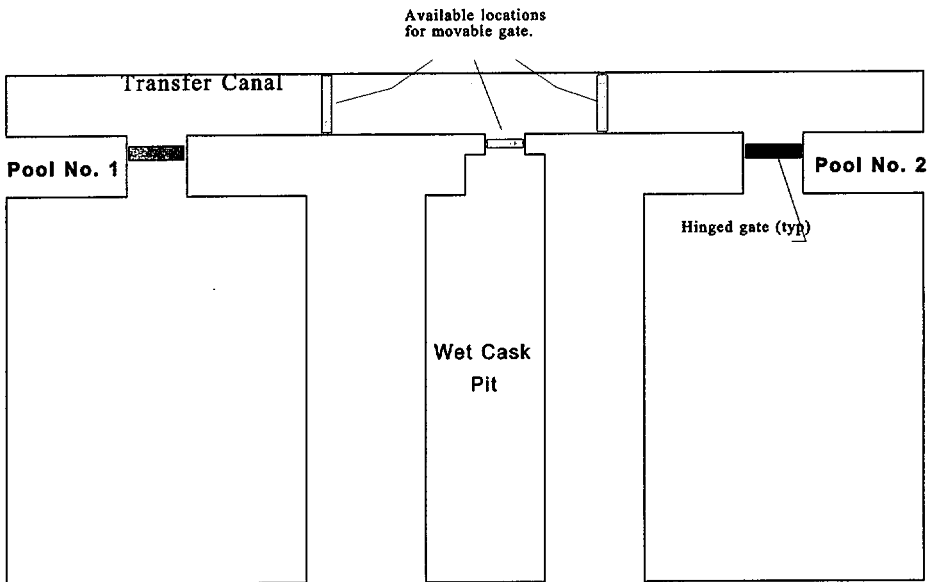

Figure 1 (Drawing not to scale)

2.2 Spent Fuel Storage Racks

The spent fuel racks are designed to support and protect the spent fuel assemblies under normal and credible accident conditions. Their structural strength ensures the ability to withstand combinations of dead loads, live loads (fuel assemblies), and safe shutdown earthquake loads.

2.3 Spent Fuel Pool Cooling System

There are two trains of spent fuel pool cooling. Each of the two trains of the cooling system consists of a pump, a heat exchanger, valves, piping and instrumentation. The pump takes suction from the fuel pools at an inlet located below the pool water level, transfers the pool water through a heat exchanger and returns it to the pool. The supply and return lines are designed to prevent siphoning. The SFP heat exchangers are cooled by component cooling water (CCW).

The system is designed to remove an amount of decay heat in excess of that produced by the number of spent fuel assemblies that are stored in the pool during and following refueling, as well as emergency core unloading cases, plus any fuel assemblies that are stored in the pool from previous refuelings. System piping is arranged so that failure of any pipeline cannot drain the SFP below the water level required for radiation shielding.

2.4 Spent Fuel Pool Cleanup System

The SFP cleanup system is designed to maintain water clarity and purity. The cleanup system is connected to the SFP cooling system. During the normal cooling operation, a portion of the spent fuel pool water may be diverted through the purification loop which consists of a filter, demineralizer and resin trap. The design flowrate through the purification loop is a maximum of 250 gpm [2]. The minimum flowrate is governed by the pressure drops in the associated filters, demineralizers and resin traps.

The Refueling Water Storage Tank (RWST) is purified by aligning the tank to the refueling water purification pump which delivers the water to the spent fuel pool filter and demineralizer and then returns it to the tank. The refueling water purification pumps will deliver a reduced flow of 150 gpm whenever taking suction from the RWSTs. For all other operating modes, the design flow rate of these pumps is 250 gpm[2].

To assist further in maintaining spent fuel pool water clarity, the water surface is cleaned by a skimmer loop. The system consists of two surface skimmers per pool, one strainer, pump and filter. The pump discharge flow passes through the filter to remove particulates, then returns to the SFP.

2.5 Dilution Sources

2.5.1 Chemical and Volume Control System (CVCS) [Letdown Divert to SFP Transfer Canal or Wet Cask Pit]

Water can be transferred from the Recycle Holdup Tanks (RHT) to the transfer canal or the wet cask pit. There are two RHTs. Current procedures direct the operators to isolate the RHT receiving the plant effluent during this evolution. A potential dilution path exists if the recycle evaporator feed pumps are misaligned to the RHT receiving the plant effluent and the CVCS letdown divert valve were to divert flow to the RHT. In this mode, diluted water could be transferred directly to the transfer canal or the cask pit area causing it to overflow into the SFP.

A similar path would result if valve 1-8633 (Boron recycle evaporator feed header) was not isolated prior to aligning the system to perform the same water transfer described above and the CVCS letdown divert valve were to divert the flow.

Since the source of water supply to these paths is controlled by the letdown orifices, the maximum letdown flow of 120 gpm[3] is used as the dilution flowrate.

2.5.2 Reactor Makeup Water System

Three reactor makeup water pumps take suction from the reactor makeup water storage tanks. During normal operation, one 150-gpm at 370 ft. TDH, reactor makeup water pump is aligned with a reactor makeup water storage tank to supply deaerated demineralized water to a single unit (one pump per unit). The third pump is used as a redundant standby pump for each unit which is normally isolated from each unit's flow paths by manual isolation valves.

One method of SFP makeup is from the RMWST via a 3 inch connection to the SFP cooling loop. Makeup is provided as needed from the RMWST. Current operating procedures [4] instruct the operators to throttle the RMW supply valve to the SFP. This is done in order to prevent pump run out.

Specific calculations to maximize RMW flow to one SFP indicate that failure to throttle could result in a RMW flow rate of approximately 360 gpm from one RMW pump. This assumes that the pump is not destroyed by the potential run out condition. If the third redundant pump is not isolated from each unit's flow paths due to numerous operator errors, the flow to one SFP from the operation of two RMW pumps is approximately 545 gpm.

An additional flow path from the RMWST which would require numerous operator errors is described as follows.

Following the transfer of borated water from the Boric Acid Tanks to the Recycle Holdup Tank, current procedures [5] direct the operators to flush the line from the Boric Acid Blender to the RHT using RMW at the same boron concentration as the RCS. In the event that the RHT is diluted during a negligent flushing operation and this diluted water is then transferred to the spent fuel transfer canal or the wet cask pit without being sampled, it could overflow into the SFP.

The flow rate through this flowpath is limited by an orifice plate which helps to mitigate a boron dilution accident in the RCS. This flow rate is expected to be approximately 150 gpm. Since this flow path is bounded by the direct SFP makeup from the same RMWST, this flow path is eliminated from this evaluation.

The spent fuel cooling loop demineralizers are isolated from the SFP cooling loop when resin replacement is required. There is a 2 inch connection from the resin sluice pump to the SFP demineralizer used for flushing and sluicing. The resin sluice pump takes suction from the spent resin storage tank which may be fed from the RMW system via a 1 inch connection. When a demineralizer vessel is sluiced, the Spent Resin Sluice Pump operates at the run out condition of 140 gpm[6]. A potential dilution path would exist if there was a failure to isolate the demineralizer from the SFP cooling loop.

In addition, there is a 1 inch line from the RMW system connected directly downstream of the spent resin sluice filter that may be used for flushing the demineralizer, flow from this source is expected to be less than 100 gpm.

Since these flow paths are bounded by the direct addition of 360 gpm (for one pump) and 545 gpm (for 2 pumps) of RMW, these paths are eliminated from this evaluation. Therefore, an estimated 360 gpm (for one pump) and 545 gpm (for 2 pumps) dilution rate of unborated water from the RMW system is used.

2.5.3 Demineralized Water System

The demineralized water storage tank receives non-deaerated makeup water from the water treatment system through a modulating level control station. The demineralized water storage tank is a 400,000 (~316,000 usable [6]) gallon atmospheric tank located in the yard. Two demineralized water transfer pumps take suction from the demineralized water storage tank.

During normal operation one 200 gpm at 200 ft. TDH demineralized water transfer pump is used to provide non-deaerated demineralized water to both Unit 1 and Unit 2 systems and components. One demineralized water transfer pump remains in a standby mode.

There is a 3 inch demineralized water connection to the SFP cooling loop for makeup. A conservative evaluation assuming that both pumps are operating with all the demineralized water users isolated results in approximately 260 gpm dilution flow rate to the SFP.

In addition, there is also a small line (3/8 inch for pool 2, 1/2 inch for pool 1) in the SFP transfer canal used to supply water as the hydraulic fluid to raise and lower the upender. Because of the size of this line and because it is normally isolated, this line will not be considered as a potential dilution flow path.

Demineralized water is also used to decontaminate fuel handling tools , burned out underwater lights etc. These are small dilution effluents which are normally manned. These evolutions are enveloped by the 260 gpm makeup flow rate. Therefore, they will not be considered as potential dilution flow paths.

2.5.4 Component Cooling Water System

Component Cooling Water (CCW) is the cooling medium for the SFP cooling system heat exchangers. There is no direct connection between the component cooling water system and the SFP cooling system. However, if a leak were to develop in a SFP heat exchanger that is in service, the flow path would be established. In case of a leak, the CCW system would be expected to leak into the SFP cooling system because the CCW system normally operates at a slightly higher pressure than the SFP cooling system.

It would be expected that the flow rate of any leakage of component cooling water into the SFP cooling system would be low due to the small difference in operating pressures between the two systems. Therefore, a conservative 100 gpm flowrate is assumed.

2.5.5 SFP Demineralizer Resin Fill Connection

The SFP demineralizer has a resin fill line in which demineralized water is used to assist in resin addition. This is a flanged connection. Only a small amount of water is used during resin addition. Resin addition and sluicing are procedurally controlled, infrequently performed evolutions. Misalignment of multiple valves would have to occur to start a dilution. Since this path cannot provide a significant dilution rate, it is not considered further in this analysis.

New resin in the SFP demineralizer can reduce the boron concentration from the source until the bed is saturated. Current procedures [5] recommend that the new resin be borated from the Refueling Water Storage Tank prior to returning it to service. Because the reduction in boron concentration is not significant, this dilution mechanism is not considered further in this analysis.

2.5.6 Fire Protection System

The spent fuel pool area has two 2 inch fire protection water supplies to two fire hose stations. The fire protection system consists of two 529,500 gallon tanks with 1 motor driven fire pump and 2 diesel driven fire pumps. The design flowrate for each pump is 2000 gpm at 370 feet of head [7]. A pressure relief valve restricts the pump discharge pressure to approximately 158 psig.

Any planned addition of fire system water to the SFP is under the control of an approved procedure and the effect of the addition of the non-borated water from the fire system on the SFP boron concentration would be addressed. The dilution contribution due to cracks in these lines is addressed under piping.

There are no sprinklers in the open area of the pools, therefore, the sprinkler system cannot create a dilution event.

The fire protection system contains instrumentation which would alarm in the control room should unplanned flow develop in the fire protection system.

2.5.7 Recycle Holdup Tank Discharge to SFP Transfer Canal

A line runs from the outlet of the Recycle Holdup Tanks (RHT) to the SFP transfer canal (SFPTC) to allow for filling of the transfer canal from the RHTs. There are 2 RHTs (shared between units) each with a volume of approximately 112,000 gallons. Each tank is sampled for appropriate boron concentration prior to transferring its contents to the SFPTC. If both RHTs were full of dilute water and transferred to the SFPTC, the total amount of water transferred would be approximately 224,000 gallons. If this evolution was to occur with the transfer canal full, a maximum of 224,000 gallons of water could enter the SFP. A dilution of approximately 950 ppm would occur resulting in a final boron concentration of 850 ppm from an initial concentration of 1800 ppm (see section 3.1 for calculation of boron dilution times and volumes). An addition of both RHTs cannot result in an unacceptable dilution of the SFP and is not considered further in this analysis.

There is currently a modification being evaluated to allow the transfer of water from the RHT directly to the Refueling Water Storage Tank using the Recycle Evaporator Feed pumps. This modification would use a portion of the Refueling Water Purification piping that is connected (but isolated) to the SFP cooling system. This would allow the transfer of the RHT to the RWST without using the SFP transfer canal. The potential dilution created by this flow path is enveloped by the evaluation stated above.

2.5.8 Chilled Water

The Non-Safety related Chilled Water surge tank is mounted on the roof of the fuel building. A 4 inch and a 2 inch line are routed inside the building open to the Spent Fuel Pool area where cracks could spray the pools. The dilution flows of these cracks are addressed under piping.

In addition, Safety Related Chilled water is routed to the Spent Fuel Pump rooms fan coil units. These rooms are located at elevation 810', while the pools open area is at elevation 860'. Dilution from this source is not considered credible.

2.5.9 Piping

The boron dilution effluent contribution due to piping is assumed to occur when lines in the vicinity of the pools develop cracks in accordance with MEB 3-1. The piping located in the open area of the Spent Fuel Pools, the Wet Cask Pit and the Fuel Transfer Canal consists of one 4 inch and one 2 inch chilled water line, two 2 inch fire protection lines, and one 3 inch demineralized water line which feeds some service valves and the upender hydraulics.

None of the lines were originally seismically designed; however, they are seismically qualified and supported.

The estimated leakage rate from the 2 inch fire protection line is approximately 21 gpm per line. The estimated leakage rate from the 2 inch Non-safety chilled water line is approximately 6 gpm. The estimated leakage rate from the 4 inch Non-safety chilled water line is approximately 19 gpm. The estimated leakage rate from the 3 inch demineralized water line is approximately 36 gpm.

2.5.10 Dilution Source and Flow Rate Summary

Based on the evaluation of potential SFP dilution sources summarized above, the following dilution sources were determined to be capable of providing a significant amount of non-borated water to the SFP. The potential for these sources to dilute the SFP boron concentration down to the design basis boron concentration (800 ppm) will be evaluated in Section 3.0.

Source	Approximate Flow Rate	Section
CVCS, Letdown divert to SFP transfer canal	120 gpm	2.5.1
Reactor Makeup Water System (2 pumps)	545 gpm	2.5.2
Reactor Makeup Water System (1 pump)	360 gpm	2.5.2
Demineralized Water System	260 gpm	2.5.3
Component Cooling Water System	100 gpm	2.5.4
Piping Cracks		
2 inch fire protection line	21 gpm	2.5.9
2 inch Non-Safety Chilled water line	6 gpm	2.5.9
4 inch Non-Safety Chilled water line	19 gpm	2.5.9
3 inch demineralized water line	36 gpm	2.5.9

2.6 Boration Sources

The normal source of borated water to the SFP is from the RWST through the Refueling Water Purification pump. In addition, borated water from the Boric Acid Tanks can be transferred to the Recycle Holdup Tanks which in turn can be transferred to the fuel transfer canal. It is also possible to borate the SFP by the addition of dry boric acid directly to the SFP water.

2.6.1 Refueling Water Storage Tank

The refueling water storage tank connects to the SFP purification loop. These connections are normally used to purify the RWST water when the purification loop is isolated from the SFP cooling system. If necessary, this connection can supply approximately 150 gpm of borated water to the SFP via the refueling water purification pump to the inlet to the SFP cooling system purification loop. The RWST is required by Technical Specifications to be kept at a minimum boron concentration of 2400 ppm and at a minimum indicated water level of 95% (In excess of 400,000 gallons) during modes 1 through 4. In addition, a minimum boron concentration of 2400 ppm at a minimum indicated water level of 24% in modes 5 and 6.

2.6.2 Boric Acid Tanks

Current plant procedures [5] describe the process required to transfer borated water from the Boric Acid Tank(s) to the Recycle Holdup Tank(s). This water can alternately be transferred to the fuel transfer canal. The fuel transfer canal can communicate with either of the 2 spent fuel pools. (See figure 1).

2.6.3 Direct Addition of Boric Acid

If necessary, the boron Concentration of the SFP can be increased by depositing dry boric acid directly into the SFP. The dry boric acid will dissolve into the SFP water and will be mixed throughout the pool by the SFP cooling system flow and by the thermal convection created by the spent fuel decay heat.

2.7 Spent Fuel Pool Instrumentation

Instrumentation is available to monitor SFP water level and temperature. Additional instrumentation is provided to monitor the pressure, flow, temperature of the SFP cooling and cleanup system.

Some of the instrumentation include:

- Lo level alarm at the local Spent Fuel Panel.
- Lo-Lo level SFP pump trip.
- Hi level alarm at the local Spent Fuel Panel.
- Hi temperature alarm at the local Spent Fuel Panel.
- Continuous Temperature analog indicator at the local Spent Fuel Panel
- Continuous Temperature monitoring is available at standard computer terminals in the control room on demand by the operator.
- General spent fuel pool local panel Trouble Alarm is initiated in the control room when an alarm is actuated at the local SFP panel.

A change of 1 inch in a single SFP level requires approximately 775 gallons of water. If a dilution event caused the pool level to rise from the low level alarm point to the high level alarm (1 foot span), a dilution of approximately 9295 gallons could occur before an alarm would be received in the control room. If the SFP boron concentration were at 1900 ppm initially, such a dilution would only result in a reduction of the pool boron concentration of approximately 58 ppm.

2.8 Administrative Controls

The following administrative controls either are in place or will be in place to control the SFP boron concentration and water inventory:

1. Procedures to aid in the identification and termination of dilution events.

2. Procedures for loss of inventory (other than evaporation) to specify that borated makeup sources be used and to specify that nonborated sources be used only as a last resort.

3. Plant personnel perform rounds in the SFP building once every twelve hours. The personnel making rounds to the SFP are trained to be aware of the change in the status of the SFP. They are instructed to check the temperature and level in the pool and conditions around the pool during plant rounds.

4. The proposed Technical Specifications associated with the use of soluble boron credit will require the SFP boron concentration to be verified at least every seven days.

Prior to implementation of the License Amendment allowing credit for soluble boron in the SFP criticality analysis, current administrative controls on the SFP boron concentration and water inventory will be upgraded as necessary to ensure that the boron concentration is formally controlled during both normal and accident situations. The procedures will ensure that the proper provisions, precautions and instructions will be in place to control the SFP boron concentration and water inventory.

2.9 Loss of Offsite Power Impact

The SFP trouble control room annunciator is powered from plant batteries.

The loss of offsite power would affect the ability to respond to a dilution event. The normal source of borated water to the SFP would not be available upon a loss of offsite power. Manual addition of dry boric acid to the SFP is available if it became necessary to increase the SFP boron concentration during a loss of offsite power.

The SFP cooling pumps are not automatically restarted following a loss of offsite power but are supplied from power supplies supported by the emergency diesel generators. These pumps can be manually loaded on the emergency diesel generators following a loss of offsite power.

3.0 SPENT FUEL POOL DILUTION EVALUATION

3.1 Calculation of Boron Dilution Times and Volumes

For the purposes of evaluating SFP dilution times and volumes, the total pool volume available for dilution is conservatively estimated to be 300,000 gallons. This is the total volume of the SFP when it is filled to the elevation associated with the pool low level alarm and taking into account the volume displaced by the SFP racks and fuel.

The transfer canal is normally isolated from the SFP. Therefore, the dilution analysis only considers the SFP. For CPSES, the boron concentration currently maintained in the SFP is greater than or equal to 2400 ppm [9]. Based on the CPSES criticality analysis [8], the soluble boron concentration required to maintain the spent fuel at $K_{eff} < 0.95$, including uncertainties and burnup, with a 95% probability at a 95% confidence level (95/95) is 800 ppm.

For the purposes of evaluating dilution times and volumes, the initial SFP boron concentration is assumed to be at 1900 ppm. The proposed Technical Specification limit is 2000 ppm. The evaluations are based on the SFP boron concentration being diluted from 1900 ppm to 800 ppm. To dilute the pool volume of 300,000 gallons from 1900 ppm to 800 ppm would conservatively require 259,500 gallons of non-borated water.

This analysis assumes thorough mixing of all the non-borated water added to the SFP. It is likely, with cooling flow and convection from the spent fuel decay heat, that thorough mixing would occur. However, if mixing was not adequate, a localized pocket of non-borated water could form somewhere in the SFP. This possibility is addressed by [8] which shows that the spent fuel K_{eff} will be less than 1.0 on a 95/95 basis with the SFP filled with non-borated water. Thus, even if a pocket of non-borated water formed in the SFP, K_{eff} would not be expected to equal or exceed 1.0 anywhere in the pool.

The time to dilute depends on the initial volume of the pool and the postulated rate of dilution. The dilution volumes and times for the CPSES dilution scenarios discussed in Sections 3.2 and 3.3 are calculated based on the following equation:

$$t_{end} = \ln\left(\frac{C_O}{C_{end}}\right)\frac{V}{Q}$$

t_{end} = *time to dilute (minutes)*
C_O = *Initial boron concentration (ppm)*
C_{end} = *final boron concentration (ppm)*
V = *volume being diluted (gallons)*
Q = *dilution rate (gpm)*

(Equation 1)

3.2 Evaluation of Boron Dilution Events

The potential SFP dilution events that could occur at CPSES are evaluated below:

3.2.1 Dilution From Reactor Makeup Water Tank

Water level in the Reactor Makeup Water Storage Tank is manually controlled from the Potable and Demineralized Water Panel located in the Turbine Building. A three-position, Close-Auto-Open with spring return to Auto, control switch is provided on the Potable and Demineralized Water Panel. RMWST water level is monitored by a level indicator on the Potable and Demineralized Water Panel and by a level indicator on the main control board.

The RMWST makeup valve will close automatically on a HI level signal. Flow can only be restored manually from the Potable and Demineralized Water Panel. Low level in the tank will only activate an alarm.

The total capacity of the RMWST is 112,000 gallons. Since the normal configuration of the reactor makeup water system does not allow for the contents of the reactor makeup water tank to be automatically replenished, only one tank volume will be evaluated first.

As mentioned above, 259,500 gallons of unborated water is required to dilute one pool to 800 ppm, since the content of the RMWST (112,000 gallons) is less than the volume required to dilute the pool to 800 ppm, dilution from the RMWST is not considered a credible scenario.

The following errors/failures are evaluated:

1.
   - o Hardware failure results in water continuously being made up to the RMWST (failure of RMWST makeup to isolate while simultaneously making up to a SFP).
   - o Operator error in not throttling the SFP makeup valve while performing manual makeup to the pool.
   - o Operator error in ignoring the trouble alarm signaling high pool level or failure of the alarm.
   - o Operator error in ignoring the various sump pump operations.

   Although the capacity of the RMW pump is 150 gpm, in order to account for operator error, a dilution flow rate of 360 gpm of unborated water is used (see section 2.5.2).

To reach the dilution endpoint of 800 ppm, the RMWST tank would have to be replenished to allow for over 2 tank volumes (259,500 gallons) of dilute reactor makeup water to enter the pool area. At an estimated flowrate of 360 gpm, the dilution would take approximately 12 hours to reach its endpoint *(259,500 ÷ 360 ÷ 60)*.

2. o Operator error in misalignment of 2 RMW pumps to one pool.

   o Operator error in not throttling flow while performing manual makeup to the pool.

   o Operator error in ignoring the trouble alarm signaling high pool level or failure of the alarm.

   o Operator error in ignoring the various sump pump operations.

Although the flow of both pumps combined is 545 gpm, the event would terminate when the RMWST is drained. As stated above, the capacity of the RMWST is less than the volume required to dilute the pool.

3.2.2 Dilution From CVCS Letdown

Assuming the CVCS blender controls were set to provide unlimited non-borated water and the Reactor Makeup Water Storage Tank was repeatedly replenished manually, (see RMWST makeup above) the 120 gpm flow from the CVCS letdown line to the SFP (as described in section 2.5.1) would take approximately 36 hours *(259,500 ÷ 120 ÷ 60)* to reduce the pool boron concentration from 1900 ppm to 800 ppm.

This scenario assumes that the water supplied by the CVCS blender to the RCS is non-borated. If the blender controls are set to provide borated water or the RCS contained greater than zero ppm boron, the SFP dilution rate would be reduced. The controls which supply the non-borated water to the blender utilize an integrator to limit the amount of water that can be supplied to the blender. If the blender controls were set to provide only a limited amount of water, the amount of dilution of the SFP would be reduced.

3.2.3 Dilution From Demineralized Water System

Non-borated water can be provided from the demineralized water system directly to the SFP cooling system through a 3 inch line that is isolated by a closed manual valve. If the valve was left open following a SFP makeup evolution, it is possible that a dilution event could take place. Using a conservative makeup flowrate of 260 gpm (section 2.5.3), the dilution event would take over 16 hours *(259,500 ÷ 260 ÷ 60)*.

3.2.4 Dilution Resulting From SFP Heat Exchanger CCW Leak

If a tube leak in the SFP heat exchanger were to occur, the low level alarm on the CCW surge tank would alert the operators of a potential malfunction in the component cooling water system. At this point, the operators have the option to makeup from the demineralized water system or the reactor makeup water system.

Current operating procedures [10] recommend make up from the RMW system for chemistry reasons. If the level alarm failed, or is ignored, then the level in the tank would decrease until a valve automatically opens to allow refilling the tank with Reactor Makeup water. This valve could continue to cycle open.

If the surge tank alarm in the CCW system fails, the level alarms in the spent fuel pool would alert the operators that the level in the spent fuel pool is increasing. If the alarms failed to alert the operators to a malfunction and the leak rate is within the makeup capabilities to the surge tank so that the suction to the CCW pumps is not lost, then the plant personnel on rounds in the fuel handling building would identify that the level in the pool was increasing. In addition, sumps in the fuel and auxiliary building would be operating continuously.

Since the makeup is from the RMWST or the demineralized water system, this dilution path is enveloped by that from the 545 gpm direct supply to one pool from the RMW system and by the 260 gpm direct water supply from the demineralized water system.(see 3.2.1 and 3.2.3 above).

If the assumed 100 gpm leakage rate is used as discussed in 2.5.4, then it would take in excess of 43 hours to complete the dilution event. Note that if makeup is supplied from the RMWST, then it would also take over 2 tank volumes which require manual makeup to supply this event.

3.2.5 Dilution From Spent Fuel Pool Demineralizer

As discussed previously, new resin in the SFP demineralizer can reduce the boron concentration from the source until the bed is saturated. Current procedures [5] recommend that the new resin be borated from the Refueling Water Storage Tank prior to returning it to service. Because the reduction in boron concentration is not significant, this dilution mechanism is not considered a credible dilution source for the purposes of this evaluation.

3.2.6 Dilution Resulting From Piping Failures

The boron dilution effluent contribution due to piping is assumed to occur when lines in the vicinity of the pools develop cracks in accordance with MEB 3-1. The sources have been identified in section 2.5.9. Assuming an unlimited water source, the times to achieve pool dilution are as follows:

Source	Flow Rate (gpm)	Time to reach 800 ppm
2 inch fire protection line	21 gpm	8 days - 14 hours
2 inch Non- safety chilled water	6 gpm	30 days -1 hour
4 inch Non- safety chilled water	19 gpm	9 days - 12 hours
3 inch demineralized water	36 gpm	5 days
All cracks combined	103 gpm	1 day - 18 hours

This assumes that all the water sprayed from the line cracks is being directed to one pool only and that the operators have ignored the pool hi level alarm as well as the continuous sump pump operations.

3.3 Evaluation of Infrequent Spent Fuel Pool Configurations

The most limiting SFP configuration at CPSES for the boron dilution analysis is when the spent fuel pools are separated. Since this is the normal mode of operation, other spent fuel pool configurations, such as when the two pools are in communication, can only result in longer dilution times and therefore these configurations are not evaluated here.

Other pool configurations, such as when performing refueling operations, can only extend the dilution times since additional volumes (refueling cavity, transfer canal) would be available.

There is a configuration where pool dilution could be well under way without spilling water on the floor for the sumps to alert the operators. If the transfer canal and the wet cask pit volumes were drained and the dilution event were to begin in one pool, it is possible to overflow the pool into the transfer canal and wet cask pit. There would not be any water spilled on the floor for the sumps to alert the operators, because the top of the pool gate is at a lower elevation than the top of the pool. This event would require failure of the HI pool level alarm. However, since the shortest dilution event is in excess of 12 hours, operator rounds would easily see the water flowing over the pool gate.

It is also worth noting that the cooling of the spent fuel pools is normally performed by one train supplying common water to both pools. This cooling configuration would substantially increase the dilution time estimates presented above. However, because the flexibility exists for the cooling system to be totally dedicated to one pool, only one pool volume is considered in this evaluation.

3.4 Summary of Dilution Events

Scenario	Flow Rate (gpm)	Time to dilution	Comments
Reactor Makeup	545	NA	RMWST is drained prior to dilution to 750 ppm with operator errors and hardware failures (3.2.1)
Reactor Makeup	360	12.0 hours	Requires numerous operator errors and multiple hardware failures (3.2.1)
CVCS Letdown	120	36 hours	Requires RMWST replenishment which would require operator errors and/or hardware failure. (3.2.1, 3.2.2)
Demineralized Water	260	16.6 hours	Requires operator errors. (3.2.3)
Component Cooling Water	100	43.2 hours	Requires operator errors and equipment failures. (3.2.4)
Piping Failures			
2 inch fire protection line	21	8 days - 14 hours	Assumes an unlimited water supply. (3.2.6)
2 inch Non- safety chilled water	6	30 days - 1 hour	Assumes an unlimited water supply. (3.2.6)
4 inch Non- safety chilled water	19	9 days - 12 hours	Assumes an unlimited water supply. (3.2.6)
3 inch demineralized water	36	5 days	Assumes an unlimited water supply. (3.2.6)

For any one of these scenarios to successfully result in the dilution of the SFP from 1900 ppm to 800 ppm, the addition of 259,500 gallons of water to the SFP would have to go unnoticed. The first indication of such an event would be trouble alarms in the control room from the spent fuel pool level instrumentation. If the high level alarms fail, it is reasonable to expect that the significant increase in pool level and eventual pool overflow that would result from a pool dilution event will be readily detected by plant operators in time to take mitigative actions. This is because the sump pumps in the fuel building and the auxiliary building would start to operate signaling operators of a potential flooding event.

In the pipe crack event of the fire protection line case, alarms for a fire pump running would alert operators of this condition. In the case of the Non-Safety chilled water crack event, the continuous makeup to the Non-safety chilled water surge tank would alert the operators. In cases where tanks require makeup from the water treatment system or the demineralized water system, the operators would be expected to investigate the continuous supply of large quantities of water to plant systems. In addition, because the time required to reach a boron concentration of 800 ppm from an initial concentration of 1900 ppm is greater than twelve hours, it can be assumed that the operator rounds through the SFP area that occur once per shift will detect the increase in the pool level even if alarms other than the high level alarm fail and the flooding isn't detected.

For any one of these dilution scenarios to successfully add 259,500 gallons of water to the SFP, plant operators would have to fail to question or investigate the continuous makeup of water to the reactor makeup water tank or demineralized water tank, and fail to recognize that the consumption of 259,500 gallons of makeup water was unusual.

4.0 CONCLUSIONS

A boron dilution analysis has been completed for the CPSES Spent Fuel pools. As a result of this SFP boron dilution analysis, it is concluded that an event which would result in the dilution of the SFP boron concentration from 1900 ppm to 800 ppm is not a credible event. This conclusion is based on the following:

1. In order to dilute the SFP from a boron concentration of 1900 ppm to 800 ppm resulting in a K_{eff} of 0.95, a substantial amount of water (greater than 259,500 gallons) is needed.

2. Since such a large water volume turnover is required, a SFP dilution event would be readily detected by plant personnel via alarms, flooding in the fuel and auxiliary buildings or by normal operator rounds through the SFP area.

3. Evaluations indicate that, based on the flow rates of non-borated water sources normally available to the SFP, taken in conjunction with significant operator errors and equipment failures, sufficient time is available to detect and respond to a dilution event.

In addition, there is significant conservatism built into this evaluation for example, the cooling of the spent fuel pools is normally performed by one SFP pump train supplying common water to both pools. This cooling configuration would allow credit to be taken for the volume of both pools and therefore substantially increase the estimated dilution times presented. However, because the flexibility exists for the cooling system to be totally dedicated to one pool, only one pool volume is considered in this evaluation.

It should be noted that this boron dilution evaluation was conducted by evaluating the time and water volumes required to dilute the SFP from 1900 ppm to 800 ppm. The 800 ppm end point was utilized to ensure that K_{eff} for the spent fuel assemblies would remain less than or equal to 0.95. As part of the CPSES criticality analysis, a calculation has been performed on a 95/95 basis to show that the spent fuel K_{eff} remains less than 1.0 with nonborated water in the pool. Thus, even if the SFP were diluted to concentrations approaching zero ppm, the spent fuel in the racks would be expected to remain subcritical. Therefore, the health and safety of the public would be protected.

5.0 REFERENCES

1 CPSES Calculation ME-CA-0235-5067 Rev. 1

2. CPSES DBD-ME-235 Rev. 8 "Spent Fuel Pool Cooling and Cleanup System"

3. CPSES DBD-ME-255 Rev. 7 "Chemical and Volume Control System"

4. CPSES System Operating Procedure SOP-506 Rev. 12.

5. CPSES System Operating Procedure SOP-105 Rev. 9.

6. CPSES DBD-ME-241 Rev. 6. "Demineralized and Reactor Makeup Water System"

7. CPSES DBD-ME-0225 Rev. 6. "Fire Suppression System"

8. Westinghouse Report CAB-00-163, Comanche Peak High Density Spent Fuel Rack Criticality Analysis Using Soluble Boron Credit with No Outer Wrapper Plates.

9. CPSES Chemistry Procedure CHM-519, Rev. 5.

10. CPSES System Operating Procedure SOP-502A Rev. 12, SOP-502B Rev. 3