St. Lucie Unit 2

Engineering Evaluation

# SPENT FUEL POOL DILUTION ANALYSIS

PSL-ENG-SENS-97-068

Revision 0

Quality Related

November 26, 1997

PLANT St. Lucie UNIT 2

TITLE SPENT FUEL POOL DILUTION ANALYSIS

LEAD DISCIPLINE DESIGN BASIS

ENGINEERING ORGANIZATION FPL SITE ENGINEERING

# St. Lucie Unit 2

# Spent Fuel Pool Dilution Analysis

## Table of Contents

Section Page

## 1.0 Purpose & Scope

The purpose of this Engineering Evaluation is to examine the potential for an inadvertent dilution of the St. Lucie Unit 2 spent fuel pool. To comply with Technical Specification requirements, the Unit 2 spent fuel pool contains at least 1720 ppm of soluble boron at all times. FPL proposes to credit the negative reactivity associated with a portion of this soluble boron concentration in an updated spent fuel pool criticality analysis. Because 520 ppm of soluble boron will be credited in the criticality analysis for non-accident conditions (see Reference 40), this evaluation will identify the plant systems interfacing with the spent fuel pool that could, through a malfunction or operator error, credibly initiate a dilution event. Time periods required for the loss of reactivity margin to $k_{eff} = 0.95$ are quantified.

## 2.0 INTRODUCTION

A boron dilution analysis has been completed to support crediting soluble boron in the St. Lucie Unit 2 spent fuel pool criticality analysis. The boron dilution analysis includes an evaluation of the following plant-specific features:

- Dilution Sources
- Boration Sources
- Fuel Pool Instrumentation
- Fuel Pool Related Plant Procedures
- Piping
- Impact of a Loss of Offsite Power
- Boron Dilution Initiating Events
- Boron Dilution Times and Volumes

This dilution analysis has been completed to ensure that sufficient time remains available to detect and mitigate a dilution event before the spent fuel pool criticality analysis design basis value of $k_{eff} \leq 0.95$ is violated.

## 3.0 SPENT FUEL POOL and RELATED SYSTEM FEATURES

This section provides background information on the spent fuel pool and its related systems and features. A one line diagram of the spent fuel pool related systems may be found in Figure 1 of this report.

### 3.1 Spent Fuel Pool

The purpose of the spent fuel pool is to provide for the safe storage of irradiated fuel assemblies. The fuel pool is filled with borated water. The water functions as a sink for decay heat generated by the irradiated fuel, as a transparent shield to reduce personnel radiation exposure and to reduce the quantity of radioactive gases released to the environment following a fuel handling accident. Evaporation of fuel pool water occurs on a continuous basis due to the decay heat from irradiated fuel, and periodic fuel pool makeup is required. Because the evaporation process does not remove boron, makeup may be from an unborated water source. Over time, evaporation will actually increase the boron concentration in the pool.

The spent fuel pool is a reinforced concrete structure with a minimum 0.188 inch thickness welded steel liner (References 1 through 4 ). The watertight liner has a network of stainless steel angles attached to the outside of the pool liner walls and the underside of the pool liner floor to collect and detect any liner leakage (Reference 5). The fuel handling building and fuel pool structure are designed as a seismic Class I structure (References 6 & 7). The nominal fuel pool water depth is 38.5 feet. The fuel pool operating deck is located above grade at the 62 foot elevation of the fuel handling building (References 8 & 9).

The St. Lucie Unit 2 spent fuel pool is divided into two regions which are thermally and hydraulically coupled. The larger region is used only for the storage of fuel; the smaller region will be used primarily for loading of fuel storage or transportation casks. The refueling canal lies adjacent to the larger pool and connects to the containment refueling cavity during refueling operations. If draining the refueling canal is desired following the completion of refueling operations, a bulkhead may be installed to isolate the refueling canal from the fuel pool. A bulkhead may also be installed to isolate the cask loading area from the main fuel pool; this bulkhead is normally removed to ensure fuel pool water quality. The elevation of both keyway bottoms is above the top of the fuel seated in the spent fuel storage racks (References 9, 10 & 52). When installed, the elevation of the top of the bulkheads is below the elevation of the spent fuel pool operating deck.

Considering the volume displaced by a full loading of irradiated fuel, the water volume contained in the spent fuel pool and cask loading area is at least 300,070 gallons. When filled, the refueling canal represents an additional volume of 47,500 gallons. (Reference 11)

## 3.2 Spent Fuel Storage Racks

The spent fuel storage racks are designed to seismic Category I requirements and will support and protect spent fuel assemblies during both normal operation and accident conditions (Reference 12). As installed, the storage racks consist of nineteen separate, free standing modules (Reference 13). Section 9.1.2.3 of the updated FSAR indicates that the storage racks are also designed to limit the neutronic interaction between any fuel assembly seated in the storage racks and a hypothetical dropped assembly lying on the top of the storage racks.

## 3.3 Spent Fuel Pool Cooling System

The St. Lucie Unit 2 spent fuel pool cooling system is designed to remove the decay heat generated by the irradiated fuel assemblies stored in the pool. The fuel pool cooling system consists of two pumps and two fuel pool heat exchangers arranged in parallel with each pump capable of directing flow to either heat exchanger. Each fuel pool heat exchanger rejects heat to the component cooling water system which in turn is cooled by the ultimate heat sink. Piping for the fuel pool cooling system is seismic Class I and is arranged so that a piping failure will not drain the fuel pool below the top of the stored fuel assemblies. The fuel pool cooling system has no piping ties into other plant systems (Reference 7).

Each of the two cooling system trains consist of a pump, a heat exchanger, valves, piping and instrumentation. The fuel pool cooling system suction line penetrates the pool liner at an elevation of 56 feet (the operating deck elevation is 62 feet). The return line penetrates the fuel pool liner on the opposite side of the pool at an elevation of 59.25 feet. The fuel pool cooling return line has a 0.5 inch anti-siphon hole placed 1.0 foot below the normal pool water level (Reference 7). The top of the fuel storage racks are located at approximately 36.4 foot elevation (References 9 & 10).

As demonstrated in the (Reference 14) discussion of the revised fuel pool cooling analysis, the system is capable of removing the decay heat load generated by a full core offload of irradiated fuel 168 hours after reactor shutdown together with 1300 assemblies discharged from previous cycles.

## 3.4 Spent Fuel Pool Purification System

The spent fuel pool cleanup or purification system is designed to maintain water clarity and to control water chemistry (Reference 15). The purification system interfaces with the fuel pool separate from the spent fuel pool cooling system and consists of a fuel pool purification pump, a pump suction strainer, a fuel pool purification filter, a fuel pool ion exchanger, an ion exchanger strainer, a surface debris skimmer, and various valves and instrumentation (Reference 7). Purification is conducted on an intermittent basis as required by fuel pool conditions. The fuel pool purification pump has a design flowrate of 150 gpm (Reference 16). The fuel pool purification suction line has a 0.25 inch siphon breaker hole placed 1.21 feet below the normal pool water level (Reference 7).

In addition to purifying the fuel pool water, the refueling water tank may be cleaned through connections to the purification loop.

## 3.5 Dilution Sources

### 3.5.1 Primary Makeup Water (PMW) System

Plant procedures require the periodic determination of spent fuel pool boron concentration to ensure that it remains greater than the Technical Specification 5.6.1 a. limit of 1720 ppm (Reference 17). At fuel pool boron concentrations of ≥1900 ppm, plant procedures permit fuel pool makeup to originate from the primary water tank. In this analysis, the primary water tank is assumed to contain water with 0 ppm soluble boron. The relevant Normal Operating Procedure specifies that primary water makeup to the fuel pool shall be made through a hose connection to a 0.75 inch line (Reference 18). One locked closed, manually operated valve (V-15538) must be opened for delivery to occur. Although not permitted by procedure, primary water can also be added to the fuel pool through a 2 inch valve located nearby. To use this flow path for PMW delivery a hose must be installed, one manually operated, normally closed valve (V-15322) must be opened and a pipe cap removed.

Primary water can also be supplied to the fuel pool using portions of the fuel pool purification system piping. A flow path from the primary water pumps to the purification system is used in resin flushing operations (Reference 19). With this flow path, primary water enters the purification system downstream of the fuel pool ion exchanger through a 2 inch line. Each of the primary water lines used for resin flushing contains two normally closed, manually operated valves which must be opened for flow delivery to occur.

Normally, one primary water pump is in service; the second pump remains in standby and is automatically started on low pump discharge header pressure (Reference 20). This low pressure condition is alarmed in the control room (Reference 21). Each pump has a design flowrate of 325 gpm (Reference 22) and provides flow to a variety of plant equipment. Section 9.1.3.3.1 of the Unit 2 UFSAR states that; ". . .the primary water pumps . . . provide makeup to the fuel pool at 100 gpm." For this evaluation, the assumed flow through valve V-15322 will be conservatively increased by 50% to 150 gpm. A recent revision to the Reference 18 procedure has changed the flow path for primary water makeup to the fuel pool from the 2 inch line through V-15322 to the 0.75 inch line which passes through valve V-15538. This evaluation will assume that the makeup flowrate to the fuel pool through V-15538 is 50% of the enhanced V-15322 value, or 75 gpm.

The primary water pumps draw suction from the 150,000 gallon capacity primary water storage tank. This tank has high and low level alarms which annunciate locally and in the control room. The St. Lucie site water treatment plant provides the makeup to the Unit 2 primary water tank (References 20 & 24).

The primary water tank is also the feed source for the sole fire hose station located in the vicinity of the spent fuel pool. Hose station (HS) 15-55 is fed from a 2 inch line which taps off the primary water system piping described above. One normally closed angle valve is used to control this hose station's delivery (Reference 20).

### 3.5.2 Demineralized and Service Water Systems

Demineralized water for both units is supplied by the Unit 1 demineralized water pumps. Each of these pumps has a design flowrate of 190 gpm (Reference 25). The St. Lucie Unit 2 UFSAR states that the function of the demineralized water system is to distribute a supply of water for makeup to various systems and for laboratory use. Demineralized water is supplied to the component cooling water surge tank as required (Reference 26). Demineralized water for both units is stored on-site in a single 10,000 gallon tank (Reference 27).

No demineralized water lines serve the Unit 2 fuel handling building (Reference 28).

The common site service water system supplies water for use in plant washdown stations, decontamination facilities and the potable water system. Service water is stored on-site in two 500,000 gallon city water storage tanks. Service water is not used to supply makeup to the Unit 2 primary water tank.

While two service water lines enter the fuel handling building, there is no service water piping in the vicinity of the Unit 2 fuel pool. Each line is 2 inch diameter or less and contains one normally closed globe valve. Fire protection in the vicinity of the spent fuel pool is not provided by service water flow; as noted above it is provided by flow from the primary water tank (Reference 29).

The lack of service water piping in the vicinity of the fuel pool and the lack of a connection between the city water storage tanks and the primary water tank ensure that the service water system does not represent a viable fuel pool dilution source.

### 3.5.3 Component Cooling Water

Component cooling water (CCW) is the cooling medium for the spent fuel pool cooling system heat exchangers. The portion of CCW that interacts with the fuel pool heat exchangers is seismic Category I (Reference 26). There is no direct connection between the component cooling water system and the spent fuel pool cooling water system. However, if a leak were to develop in either of the fuel pool heat exchangers while in service, a connection between the two systems would be made. To date, there have been no known tube leaks in the spent fuel pool heat exchangers since the heat exchangers entered service in 1983 (Reference 30).

The CCW system contains a surge tank which is designed to accommodate fluid volumetric changes and to maintain a static pressure head at each CCW pump suction. Any leakage path between the fuel pool heat exchanger shell and tube side will result in a reduction in the surge tank level and will cause demineralized water to be added to the CCW surge tank via an automatic water level control system. A continued reduction in surge tank level below the level for automatic makeup would trigger a low level alarm in the control room (References 31 & 32). For the purposes of this evaluation, it is assumed that, following the leak, the makeup of demineralized water to the CCW surge tank is uninterrupted. As a result, unborated component cooling water will continue to enter the spent fuel pool cooling system (Reference 53), resulting in a gradual decrease in the pool boron concentration.

The continued makeup of demineralized water to the surge tank will eventually result in makeup to the demineralized water tank and may result in a low level alarm in the Unit 1 control room (Reference 33).

While no known tube leaks in the St. Lucie Unit 2 spent fuel pool heat exchangers have occurred while the units have been in service, a calculation performed has shown that the upper bound leak rate from a single tube failed due to a double ended guillotine break is approximately 41 gpm. This assumed leak rate was rounded up to 50 gpm (Reference 11) for the purposes of this evaluation.

It was previously noted that demineralized water for both St. Lucie units is stored on-site in a single 10,000 gallon tank. Plant drawings indicate that the CCW surge tank for St. Lucie Unit 2 has a capacity of approximately 2160 gallons (Reference 34). If it is assumed that the entire demineralized water tank capacity is dedicated to Unit 2, the sum of these two volumes is less than 5% of the spent fuel pool water volume. Multiple instances of diverting the entire demineralized water tank contents to the Unit 2 spent fuel pool would be required to achieve any appreciable dilution.

The limited amount of water available from the component cooling water system and the demineralized water system, as well as the mechanisms available to plant operators to help identify such leakage, ensure that a spent fuel pool heat exchanger leak cannot result in any significant dilution of the spent fuel pool. As a result, this dilution path is not considered further in this analysis.

### 3.5.4 Resin Flush Line/Resin Fill Connection

Downstream of the fuel pool ion exchanger, the primary water system has two connections into the fuel pool purification system. These connections are used, approximately once each (18 month) fuel cycle, to flush spent resin from the ion exchanger. Each of these primary water lines is 2 inches in diameter and contains two manually operated, normally closed valves between the primary water system header and the fuel pool purification loop. By procedure, the fuel pool ion exchanger outlet valve is closed and tagged (Reference 19) so as to isolate the downstream portion of the fuel pool purification loop and the spent fuel pool during the resin flushing operation.

Discussions with Chemistry personnel indicate that a typical resin flush requires 195 ft$^3$ (1460 gallons) of demineralized water. Chemistry has estimated that in a worst case scenario, twice this water volume (390 ft$^3$) would be required (Reference 11). For this worst case it is assumed that the resin cask would require dewatering and refilling to complete the resin transfer and that all 2920 gallons of demineralized water would be added to the spent fuel pool. Because of the small volume of water involved, this evolution does not represent a dilution path that could present a viable challenge to fuel pool reactivity margin.

Following removal of spent resin from the fuel pool ion exchanger new resin beads are added and the ion exchanger is re-aligned to the purification system. Initial operation of a fresh resin bed will trap boron in the ion exchanger until a saturation level is reached. Experience has shown that placing a fresh resin bed in service will decrease the fuel pool boron concentration by approximately 2 ppm (Reference 11).

The fuel pool ion exchanger technical manual recommends a 100 GPM flow rate during resin sluicing operations (Reference 35). Although the ion exchanger outlet valve is tagged closed, following the completion of resin flushing, this primary water flow rate to the fuel pool will be assumed to exist.

### 3.5.5 Fire Protection System

One fire protection system hose station is located in the fuel handling building in the vicinity of the spent fuel pool (Reference 20). This hose station is supplied by the primary water system through a 2 inch line that is connected to a flexible hose stored on a wall-mounted reel. In the event of a loss of spent fuel pool inventory this hose station represents a potential makeup source. Based on the flow rating of the hose nozzle, this station is capable of providing 75 gpm of non-borated makeup to the fuel pool (Reference 29).

### 3.5.6 Intake Cooling Water System

The intake cooling water system is the makeup source of last resort for the spent fuel pool. The use of this system would introduce salt water into the fuel pool. An intake cooling water standpipe is attached to the exterior of the fuel handling building (FHB) and enters the FHB above the 62 foot level on the east side of the fuel pool. This standpipe is capped; a pipe wrench is required to remove the endcap. No system piping runs inside the FHB. To utilize the intake cooling water system for fuel pool makeup, a flexible hose must be routed from the CCW pump pit across a road and connected to the lower end of the standpipe attached to the FHB.

It can be seen that several non-routine manual actions are required to use the intake cooling water system for fuel pool makeup. The use of the intake cooling water system for this purpose requires specific plant management approval (Reference 36). As a result, it is concluded that the intake cooling water system does not represent a credible fuel pool dilution pathway.

### 3.5.7 Dilution from Pipe Break Events

The fuel handling building (FHB) is a seismic category I reinforced concrete structure containing the spent fuel pool, spent fuel cask area, refueling canal, spent fuel cooling and purification pumps, heat exchangers, filters and ventilation equipment. The FHB exterior walls, floors and partitions are designed to protect the equipment inside from the effects of hurricane and tornado winds, external missiles and flooding. The fuel pool portion of the FHB including the walls and roof directly above the pool is designed to withstand, without penetration, the impact of external missiles that might occur during the passage of a tornado (Reference 37). The spent fuel pool is located above grade with a pool floor elevation of 21.5 feet and an operating deck elevation of 62 feet. Spent fuel cask removal is through a key-controlled normally closed L-shaped door in the FHB roof. Any opening of the L-shaped door or deflation of the door seal is annunciated in the control room (Reference 38).

A tornado or hurricane event could be postulated to cause a rupture of piping in the vicinity of the fuel pool. Any weather event severe enough to cause a piping failure here is also likely to cause a loss of offsite power (LOOP). The only piping available for rupture in the vicinity of the Unit 2 spent fuel pool which could cause a pool dilution event is the primary water piping which penetrates the north wall of the fuel handling building at an ~68 foot elevation. If a LOOP were to occur concurrent with the piping failure, no appreciable dilution would result because neither the primary water pumps, the fuel pool cooling pumps, nor the fuel pool purification pump are automatically loaded onto the emergency diesel generator(s) (Reference 39). A number of manual actions would be required to energize one of these pumps. As a result, dilution resulting from a tornado or hurricane is not considered a credible event and is not considered further in this analysis.

In the event a piping rupture occurred while offsite power remained available, dilution of the fuel pool could result. If a primary water pump were in operation, failure of the primary water piping near the fuel pool could result in an unborated water flow rate of up to 300 gpm, based on pump specifications (Reference 54). The effect of a dilution of this magnitude is examined in Section 4.3.5 of this report.

### 3.5.8 Dilution Resulting from a Precipitation Event

As previously noted, the L-shaped door in the roof of the fuel handling building is normally closed. However, if the L-shaped door were to remain open during a prolonged heavy precipitation event, the water level in the fuel pool would increase and some dilution of the pool would occur. Section 2.3.1.2 of the St. Lucie Unit 2 updated FSAR notes the record 24-hour rainfall for the United States of 38.70 inches occurred in Yankeetown, Florida following passage of a 1950 hurricane. The effect of a dilution of this magnitude on the Unit 2 spent fuel pool is examined in this report.

### 3.5.9 Dilution Source and Flow Rate Summary

Based on the evaluation of potential spent fuel pool dilution sources summarized above, the following dilution sources were determined to be capable of providing a significant amount of non-borated water to the spent fuel pool. The potential for these sources to dilute the spent fuel pool boron concentration down to the design basis boron concentration of 520 ppm (from Reference 40) is evaluated in Section 4.0 of this report.

| SOURCE | APPROXIMATE FLOW RATE (gpm) |
|---|---|
| Primary Water System makeup through V15322 | 150 |
| Primary Water System makeup through V15538 | 75 |
| Primary Water addition through resin flush line | 100 |
| Primary Water Addition through Fire Hose Station HS 15-55 | 75 |
| Rupture of primary water piping near fuel pool | 300 |
| Precipitation event through an open FHB L-shaped door | 38.7 inches |

## 3.6 Boration Sources

The normal source of borated water to the spent fuel pool is from the refueling water tank (RWT) (Reference 41). With the exception of a relatively complicated, non-standard valve lineup from the boric acid makeup (BAM) tanks through the RWT, no makeup to the fuel pool flows through chemical volume control system (CVCS) piping. It is also possible to borate the spent fuel pool through the addition of dry boric acid directly to the spent fuel pool water.

### 3.6.1 Refueling Water Tank

The Unit 2 refueling water tank is connected to the spent fuel pool purification loop through separate inlet and outlet lines. These connections are used as a flow path for makeup to the fuel pool from the RWT and are also used to process the contents of the RWT through the purification filters and ion exchanger. Using the makeup flow path, the purification pump can supply a makeup flow rate to the fuel pool of approximately 150 gpm. Technical Specifications 3.1.2.7 and 3.1.2.8 require that the boron concentration in the RWT be maintained at least 1720 ppm.

### 3.6.2 Boric Acid Makeup Tank

The contents of either BAM tank can be directed to the RWT using one of the two boric acid makeup pumps (Reference 42). From the RWT, this fluid may be used to borate the spent fuel pool as described in Section 3.6.1. To pass flow from the BAM tanks to the RWT, a number of valves must be repositioned to utilize this non-standard lineup, including opening two which are normally closed. To be in service, Technical Specification 3.1.2.7 (applicable to Modes 5 and 6) requires the BAM tanks to contain at least 3550 gallons of water with a concentration of greater than 4370 ppm boron. While in Modes 1 through 4, Technical Specification 3.1.2.8, Borated Water Sources - Operating, requires that BAM tanks contain at least 5350 gallons of a boric acid solution of greater than 4371 ppm.

### 3.6.3 Direct Addition of Boric Acid

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

## 3.7 Spent Fuel Pool Instrumentation

Redundant instrumentation is available at St. Lucie Unit 2 to monitor spent fuel pool water level, temperature and radiation levels in the vicinity of the spent fuel pool. Additional instrumentation is available to monitor the status of the each spent fuel pool cooling pump, the pump discharge line pressure and the quantity of CCW return flow from the spent fuel pool heat exchangers (References 7, 26, & 51). Local instrumentation is available to indicate the purification pump suction and discharge pressure.

The instrumentation provided to monitor the spent fuel pool water level and temperature has a local indication and is annunciated in the control room (Reference 43). Each of these control room alarms is located on a annunciator panel that has a safety related power supply (Reference 44). The instrumentation which monitors area radiation levels in the vicinity of the spent fuel pool provides high radiation alarms locally and also annunciates in the control room.

The spent fuel pool water level is maintained at a nominal elevation of 60 feet. Level alarms will actuate in the control room at ± 0.5 foot of this value (Reference 43). A change of one foot in the spent fuel pool level with the refueling canal and cask loading area bulkheads removed would require approximately 11,330 gallons of water (see Appendix A). A dilution event initiated with the fuel pool at the low level alarm point and a boron concentration of 1720 ppm would decrease the boron concentration approximately 56 ppm by the time the upper level alarm setpoint is reached (Appendix A).

## 3.8 Administrative Controls

The following administrative controls are in place to control and monitor the spent fuel pool boron concentration and water inventory:

1. In accordance with Operations Instructions, plant operating personnel perform rounds in the fuel handling building, including the vicinity of the spent fuel pool, at least once per eight hours (Reference 45).

2. Plant procedures require that the spent fuel pool and refueling water tank boron concentrations be determined weekly (Reference 17).

3. The normal operating procedures which control makeup to the fuel pool specify the makeup water source to be used based on the boron concentration present in the fuel pool. Existing procedures require sampling the fuel pool for boron concentration following makeup with a non-borated water source (Reference 18).

4. Administrative controls on the use of the primary water dilution paths are present. Administrative controls are also present for the positioning of valves in lines connecting the RWT and spent fuel pool (Reference 46).

5. A dedicated level watch is required during filling of the refueling canal and during any spent fuel pool level change if the control room annunciation is inoperable (Reference 18). Control room level and temperature annunciation is required to be operable prior to the initiation of any full core fuel offload to the spent fuel pool (Reference 23) .

The current administrative controls on spent fuel pool boron concentration will be evaluated and upgraded if necessary prior to the implementation of any License Amendment permitting credit for soluble boron in the spent fuel pool criticality analysis. Procedures will ensure that appropriate controls are in place to control boron concentration during normal and off-normal conditions.

## 3.9 Piping

Less than 30 linear feet of primary water system piping is routed through the fuel handling building in the vicinity of the spent fuel pool. This piping is 2 inch diameter line attached to the north wall of the fuel handling building. An additional 30 feet of small diameter auxiliary steam system piping is also present in the vicinity of the fuel pool.

As noted previously, one fire hose station fed by the primary water system is present in the vicinity of the spent fuel pool. This hose station is also attached to the north wall of the fuel handling building.

## 3.10 Loss of Offsite Power

Of the dilution sources listed in Section 3.5.9, only the precipitation event with an open L-shaped door is capable of providing non-borated water to the spent fuel pool during a loss of offsite power (LOOP). Power supplies for the fuel pool level and temperature annunciation are backed by the emergency diesel generator.

A LOOP would also affect the ability to respond to a dilution event. The fuel pool purification pump is not a load automatically placed on the emergency diesel generator, although sufficient uncommitted capacity exists to permit its manual loading (References 16 & 47). Manual boron addition could be used if it became necessary to increase spent fuel boron concentration during a LOOP.

The Unit 2 spent fuel pool cooling pumps are not automatically loaded onto the emergency diesel generators (EDG's) in the event of a LOOP. The St. Lucie Unit 2 UFSAR and the existing emergency operating procedures specify that a fuel pool cooling pump is to be manually loaded onto the EDG's approximately 1 hour following the loss of offsite power (Reference 47).

## 4.0 SPENT FUEL POOL DILUTION EVALUATION

### 4.1 Description of Methodology Used

In its initial configuration (prior to any postulated dilution) the Unit 2 spent fuel pool is essentially a filled container with an open top. Because the container is considered to be initially full, any additional volume added (beyond that required to reach the bulkhead spillway slot) is removed in one of two ways: 1) by overflow of the fuel pool; or 2) through an independent, concurrent action to open the return line flowpath from the spent fuel pool to the RWT. Either mechanism is assumed to also remove soluble boron. As is discussed elsewhere in this evaluation, valves on the return line to the RWT are administratively controlled and maintained locked closed. Thus, the more likely mechanism for the removal of excess volume (and boron) from the fuel pool following an inadvertent dilution is through fuel pool overflow.

This calculational methodology provides conservative results for those cases where there is no spillage (e. g. filling the fuel pool from the low level alarm point) since it assumes a loss of boron with the spillage. Without spillage, there is no loss of boron.

Irrespective of the removal pathway, the rate of change of boron concentration in the fuel pool is described by the following equation:

$$V\, dC/dt = -QC$$

where:

V = Spent fuel pool volume (300,070 gallons)
C = Fuel pool boron concentration
Q = Volumetric flowrate of unborated water
t = dilution time

The solution of the above equation can be written as:

$$C(t) = C(0)\, e^{-t/\tau}$$

where:

C(0) = Initial boron concentration
$\tau$ = V/Q = boron dilution time constant

For example, if Q is assumed to be 100 gallons/minute, then $\tau = 3000.7$. The boron concentration after 1500 minutes (25 hours) of dilution from 1720 ppm is:

$$C(1500) = 1720\, e^{-1500/3000.7}$$

$$\text{and } C(1500) \approx 1043 \text{ ppm}$$

The volume of water added during this 1500 minute dilution period is 150,000 gallons (1500 minutes * 100 gallons/minute).

This evaluation is primarily concerned with the time required to reach a specific boron value. For ease of calculation, the above equation may be rewritten as:

$$t = \ln(C_o/C) * V/Q$$

or

$$t = \ln(C_o/C) * \tau$$

where:

C is the boron concentration endpoint
all other terms are as defined above

## 4.2 Calculation of Boron Dilution Times and Volumes

(See Reference 11) As previously noted, this evaluation uses a total pool volume available for dilution of 300,070 gallons. This is the total combined volume of the fuel pool and the cask loading area filled to the nominal elevation. This value of pool volume is conservatively derived by treating the fuel storage racks and the contained fuel assemblies as a solid, three-dimensional array containing no water. The water volume that could be present in the refueling canal (approximately 47,500 gallons) is also neglected in this calculation.

The cask loading area contains approximately 49,700 gallons and can be isolated from the spent fuel pool by means of a bulkhead. Normally this bulkhead is removed and the spent fuel pool and the cask loading area are thermally and hydraulically coupled. With the bulkhead installed, the cask loading area becomes a stagnant volume. As a stagnant volume, the cask loading area has, in the past, been susceptible to water quality problems.

By procedure, the operating band for boron concentration in the Unit 2 spent fuel pool is between 1800 ppm and 1950 ppm (Reference 48). Based on the criticality analysis for St. Lucie Unit 2 (Reference 40), the soluble boron required to maintain the spent fuel $k_{eff} \leq 0.95$, including uncertainties and burnup, with a 95% probability at a 95% confidence level (95/95) is 520 ppm.

For the purposes of identifying the required dilution times and volumes, the initial spent fuel pool boron concentration is assumed to be at the Technical Specification limit of 1720 ppm. Evaluations are based on the spent fuel pool being diluted from 1720 ppm to 520 ppm. To dilute the combined pool/cask area volume of 300,070 gallons from 1720 ppm to 520 ppm would require 358,959 gallons of non-borated water (see Appendix A). With an initial boron concentration of 1800 ppm, dilution to 520 ppm would require 372,601 gallons of non-borated water.

This analysis assumes thorough mixing of all non-borated water added to the fuel pool. If fluid mixing was insufficient, it is conceivable that a localized volume of non-borated water could form somewhere in the spent fuel pool. Reference 40 results demonstrate that the $k_{eff}$ of the St. Lucie Unit 2 spent fuel pool will remain $<1.0$ on a 95/95 basis with the spent fuel pool filled with non-borated water.

As Section 4.1 shows, the time to dilute depends on the initial volume of the fuel pool and the postulated rate of dilution. The dilution times and required volumes for the scenarios discussed in Sections 4.3 and 4.4 have been calculated based on the equations given in Section 4.1.

## 4.3 Evaluation of Boron Dilution Events

The spent fuel pool boron dilution events that could potentially occur at St. Lucie Unit 2 are evaluated below:

### 4.3.1 Primary Water Makeup to the Spent Fuel Pool (through V-15322 or V-15538)

The contents of the primary water tank can be transferred to the Unit 2 spent fuel pool through a single 3 inch branch line using the primary water pumps as motive force. This primary water line diameter reduces to 2 inches at the fuel handling building. The line enters the fuel handling building at approximately the 68 foot elevation attached to the north wall adjacent to and above the spent fuel pool. Makeup to the fuel pool through this 2 inch line may be accomplished by removing a pipe cap and connecting a flexible hose to manually operated normally closed valve V-15322 or by opening the smaller (0.75"), manually operated valve V-

15538 which is not capped but is locked closed. Valve V-15538 is the procedurally specified makeup path.

The capacity of the primary water tank (PWT) is 150,000 gallons. Normally, the tank contains unborated water. Assuming that the PWT is filled to capacity and the entire contents are transferred to the spent fuel pool, the spent fuel pool would be diluted by a maximum of 677 ppm to 1043 ppm (Appendix A). At the assumed maximum flowrate available through V-15322, this dilution would require more than 16.6 hours. More than 33 hours would be required to transfer the PWT contents to the fuel pool using V-15538.

To avoid overflow of the spent fuel pool or the receipt of a high level alarm during the addition of primary water, a coincident draining of the existing fuel pool inventory would be required. The spent fuel pool may be drained to the refueling water tank or, for smaller volumes, to the equipment drain tank. To accomplish draining by the normal method, by procedure a locked closed return line from the spent fuel pool to the refueling water tank must be opened and the fuel pool purification pump aligned to remove fuel pool inventory.

The postulated dilution event described above requires the addition of the entire volume of water contained in the primary water tank and still leaves the soluble boron concentration in the spent fuel pool more than 500 ppm greater than the concentration required to ensure $k_{eff} \leq 0.95$. Using the non-standard makeup path through V-15322, plant operations personnel would have made at least two tours of the fuel handling building during the period of dilution. Using the procedurally specified makeup flow path, almost one and one half days of continuous dilution would be required to deplete the primary water tank. In the real-life situation, the rising fuel pool level would cause water to overflow the transfer canal bulkhead, enter the fuel pool ventilation duct banks and subsequently overflow onto the operating deck (where operator rounds are made) as the additional primary makeup water is added.

If we assume that the St. Lucie site water treatment plant continues to provide automatic makeup to the Unit 2 PWT at a rate equal to the assumed rate of fuel pool dilution through the non-standard flow path (150 gpm) and that the reduced PWT level does not lead to cavitation of the primary water pumps, an additional 23.2 hours (for a total of over 39 hours) of dilution would be required to reduce the fuel pool boron concentration from 1043 ppm to a value such that $k_{eff} = 0.95$. Using the procedurally specified flow path through valve V-15538, more than 46.4 additional hours (for a total of 79.7 hours) would be required to dilute to a $k_{eff}$ of 0.95.

This evaluation shows that the direct addition of primary water to the fuel pool through V-15322 is not a dilution path that presents a credible challenge to the reactivity margin required by Reference 40. This conclusion is based on several factors which are listed below:

> the large quantity of unborated makeup water required to achieve a significant dilution,
>
> the presence of a pipe cap and the procedural requirement to use another flow path,
>
> the difficulty in adding large quantities of makeup water to the fuel pool without causing overflow,
>
> the frequency of rounds in the FHB by operations personnel,
>
> the available fuel pool and primary water tank instrumentation, and
>
> the presence of a locked closed valve on the return line leading to the RWT.

As noted above, dilution of the fuel pool to 520 ppm using the procedurally-specified makeup path (V-15538) would require more than 79 hours of continuous dilution at 75 gpm. With the exception of the installed pipe cap and procedural direction to use another flow path, all of the factors identified above as applicable to valve V-15322 are also applicable to flow through valve V-15538. It has been previously noted that valve V-15538 is maintained locked closed. This degree of control (locally locked closed) is comparable to that maintained over the potential dilution path through V-15322. This control, combined with the lower flowrate of unborated water and the other factors noted above, ensure that flow through V-15538 does not represent a dilution pathway that presents a credible challenge to the reactivity margin required by Reference 40.

### 4.3.2 Primary Water Addition through Resin Flush Line

During a resin sluicing operation, primary water flowing at approximately 100 gpm is used to move depleted resin from the fuel pool ion exchanger to the spent resin tank or to an external shipping cask. This dilution scenario assumes that following the resin sluicing evolution, the primary water flow stream is not secured, but is inadvertently redirected to the spent fuel pool as makeup. Dilution of the fuel pool is postulated to occur through a 2 inch primary water line downstream of the fuel

pool ion exchanger. Dilution flow would enter the spent fuel pool through the purification loop with the primary water pumps providing motive force.

As the dilution flow enters the spent fuel pool, the pool level will rise unless a coincident pool draining evolution is undertaken. Without a coincident draining, the high level alarm will annunciate in the control room; if makeup continues, the pool will overflow the bulkhead separating it from the transfer canal, overflow into the fuel handling building ventilation ducts, and eventually overflow onto the operating deck. Any of these effects would be visible to operators during their rounds.

Draining the spent fuel pool is controlled by plant procedures (Reference 18) and is undertaken as described in Section 4.3.1 above. Pool letdown flow is normally directed to the refueling water tank to conserve water and because of its greater capacity. As noted earlier, the refueling water tank is isolated from the spent fuel pool by locked closed valves in both the supply and return lines.

Twenty-five hours is required to transfer the entire contents of the primary water tank to the spent fuel pool at the assumed 100 gpm dilution rate. As discussed in Section 4.3.1, the contents of the primary water tank are sufficient to dilute the pool to approximately 1043 ppm. With a 100 gpm flowrate to the fuel pool and assuming adequate makeup to the primary water tank from the site water treatment plant, an additional 34.8 hours would be required to reduce the soluble boron concentration to a level where $k_{eff}=0.95$.

Thus, assuming sufficient makeup water is available, 59.8 hours would be required to dilute the Unit 2 spent fuel pool to 520 ppm using the purification system flowpath.

### 4.3.3 Primary Water Addition through Hose Station HS-15-55

Primary water is also the supply source for Fire Hose Station HS-15-55. A reel containing flexible hose is mounted on the north wall of the fuel handling building. The hose on this reel is attached to a short pipe stub which branches from the primary water line described in Section 3.5.5. Any discharge from this hose to the fuel pool would require its manual removal from the reel. If unattended, the deployed hose would be easily visible to an observer in the area. Based on the nozzle flow rating, a dilution rate of 75 gpm is assumed to result from initiation of fire hose flow.

Assuming an initial fuel pool boron concentration of 1720 ppm, a dilution rate of 75 gpm would require 33.3 hours to empty the primary water tank. An additional 46.4 hours of dilution would be required to reduce the boron concentration so that

$k_{eff}=0.95$, assuming additional makeup from the site water treatment plant was available.

A fuel pool dilution through a deployed fire hose is an evolution that is easily observable by operations personnel during their rounds in the Fuel Handling Building. This easy visibility, combined with the frequency of operator rounds, the quantity of water required to achieve a substantial reduction in boron concentration and the administrative controls on letdown from the fuel pool mean that primary water supplied to the fuel pool through hose station HS-15-55 is not a credible dilution path for the purposes of this analysis. As a result, this scenario is not considered further in this evaluation.

### 4.3.4 Precipitation Event Through an Open FHB L-Shaped Door

Normally, the fuel handling building L-shaped door is maintained closed. Operator key control and an energized power interlock that is controlled by the Security Department are required to open this door. A control room annunciator alarms when this door is open or the door seal is not fully inflated. However, if this L-shaped door were to be left open during a prolonged precipitation event, dilution of the spent fuel pool could occur. When open, the cross section of the L-shaped door exposes only a small portion of the fuel pool to any precipitation flux. For the purpose of this evaluation, the horizontal and vertical cross sectional area exposed by the open L-shaped door has been conservatively determined (from References 8 and 9) to be 808.4 $ft^2$. Further, the fuel pool is assumed to not overflow as a result of the additional water volume. Initial pool boron concentration is maintained at the 1720 ppm Technical Specification limit.

The volume associated with 38.7 inches of precipitation falling on a 808.4 $ft^2$ area is 19,504 gallons. This volume of unborated water would be sufficient to decrease the pool boron concentration by approximately 108 ppm (see Appendix A).

This simplified, conservative analysis demonstrates that the rainfall associated with an extreme precipitation event over the St. Lucie Unit 2 spent fuel pool is not sufficient to cause a dilution event that would present a credible challenge to fuel pool reactivity margins. This dilution initiator is not considered further in this evaluation.

### 4.3.5 Dilutions Resulting from Seismic Events or Random Pipe Breaks

A seismic event could cause a rupture of the primary water system piping near the spent fuel pool. As discussed in Section 3.9, the length of this piping run is less than 30 feet. For a seismic (or other) event at St. Lucie Unit 2 where offsite power remains available, it is assumed that a rupture of the primary water line inside the fuel handling building could result in flow of up to 300 gpm, as discussed in Section 3.5.7.

Seismic instrumentation is installed at St. Lucie with annunciation in the Unit 2 control room (Reference 49). If a seismic event were to occur at St. Lucie, the site emergency plan will be activated. Emergency plan implementing procedures require that a walkdown of each unit's spent fuel pool be completed within two hours following any seismic event at St. Lucie (Reference 50). Fuel pool level and temperature will be determined during this walkdown. During any fuel pool walkdown, the condition of the primary water piping will be immediately visible to plant personnel.

With a postulated 300 gpm dilution rate to the fuel pool through the ruptured primary water line and offsite power available, the primary water tank will be emptied in 8.3 hours. A reduction in boron concentration of approximately 677 ppm would result as presented in Section 4.3.1. As discussed previously, the spent fuel pool $k_{eff}$ will remain $<<0.95$ with this quantity of unborated makeup.

If offsite power is not available, the primary water pumps would not be available and thus there would be no dilution source.

The specific location of the primary water system piping in the vicinity of the spent fuel pool ensures that any randomly initiated breaks in this system would be detected during periodic operator rounds.

As a result, no dilution of the spent fuel pool due to a random pipe break or a seismic event can credibly be considered to challenge the fuel pool reactivity margins required by Reference 40. These initiating events are not considered further in this evaluation.

## 4.4 Evaluation of Infrequent Spent Fuel Pool Configurations

### 4.4.1 Dilution of Spent Fuel Pool with Cask Storage Area Isolated

Although unlikely, it is possible that the main spent fuel pool could be unintentionally isolated from the cask storage area. The Unit 2 cask storage area has no installed mechanism to circulate flow or to permit makeup and letdown. If the cask loading area were isolated, the effective volume of the fuel pool would be reduced. If the cask loading area were isolated coincident with a dilution event, the amount of unborated water required to achieve a dilution would also be reduced.

The intentional use of the spent fuel pool configuration represented by this scenario is infrequent at St. Lucie Unit 2. The cask loading area may be isolated from the remainder of the spent fuel pool during certain cask loading evolutions. No irradiated fuel has been removed from the Unit 2 spent fuel pool; current cask loadings involve packaging of reactor vessel surveillance capsules, incore detectors, or other non-fuel hardware. During any cask loading activity, significant numbers of plant personnel are in the vicinity of the fuel pool. Activities are underway at St. Lucie to increase the storage capacity of the Unit 2 spent fuel pool. If these activities are successful, and assuming no prior removal of spent fuel by the Department of Energy, the routine handling of casks containing irradiated fuel will not begin until approximately year 2005.

With this cask loading area isolated, the volume of the spent fuel pool is 250,404 gallons (Reference 11). This volume conservatively represents the effect of a full loading of spent fuel and assumes that the fuel pool is filled to its nominal water depth. This 16.6% reduction in fuel pool water volume decreases the volume of unborated water required to reach 520 ppm by 59,413 gallons. If the contents of the primary water tank (150,000 gallons) were added to this reduced pool water volume, the resulting pool boron concentration would be 945 ppm, 425 ppm more than the value required to ensure that $k_{eff}$ remains $\leq 0.95$. As noted previously, more than 33 hours at a dilution rate of 75 gpm is required to empty the primary water tank. An additional fuel pool dilution of 149,546 gallons (33.2 hours) would be required to reach a $k_{eff}$ of 0.95.

As noted earlier, plant operators make rounds through the fuel handling building in the vicinity of the fuel pool at least once every eight hours. Thus, operators would have made multiple sets of rounds during the period any hypothetical dilution was in progress prior to the fuel pool reaching a $k_{eff}$ of 0.95. Operators would also have numerous opportunities to observe any inadvertently installed bulkhead isolating the cask loading area.

Because this spent fuel pool configuration will be used infrequently for the foreseeable future, the large personnel contingent present in the fuel pool area during any cask handling activity, and because of the large volume of water and length of time required to dilute the pool to a $k_{eff}$ of 0.95, this event is not considered a credible challenge to required reactivity margins and is not considered further in this analysis.

### 4.4.2 Filling the Refueling Canal

To prepare for refueling activities, the fuel transfer (refueling) canal must be filled. As noted previously, a bulkhead is normally installed between the fuel pool and the refueling canal. The top of this bulkhead contains a spillway or slot at an elevation below the elevation of the fuel pool ductwork but above the level associated with the fuel pool high level alarm. Plant procedures used for filling the transfer canal specify that, using makeup from the refueling water tank, the fuel pool level should be increased until flow through this slot is observed. Because the control room annunciator for fuel pool high level will continuously alarm during this evolution, plant procedures call for operations personnel to be stationed in the fuel pool area while the refueling canal is being filled (Reference 18).

If the makeup for this evolution were to inadvertently come from the primary water tank instead of from the RWT, a fuel pool dilution could result. Filling the 47,500 gallon refueling canal using primary water as the makeup source would reduce the boron concentration in the fuel pool by no more than 252 ppm (Appendix A). This reduction in pool boron concentration is not sufficient to present a credible challenge to the 520 ppm boron limit required by Reference 40. As a result, this event is not considered further in this analysis.

## 4.5 Summary of Dilution Events

Sections 3.5, 4.3 and 4.4 considered a variety of fuel pool dilution events that could provide up to 300 gpm of unborated water to the Unit 2 spent fuel pool. An examination of these postulated dilution scenarios, the plant design features and administrative controls shows that most postulated dilution events do not represent a credible challenge the fuel pool reactivity margin requirements from Reference 40. Together, the St. Lucie site water treatment plant and the Unit 2 primary water tank are assumed to be capable of supplying the 358,959 gallons of water necessary to dilute the spent fuel pool from 1720 ppm to 520 ppm. Based on the analysis in Section 4.3, the limiting credible scenario would require at least 59.8 hours of continuous dilution.

For this scenario to result in the successful dilution of the spent fuel pool to 520 ppm, the addition of more than 358,000 gallons of water over a period of nearly 60 hours would have to go unnoticed or multiple indications of an off-normal event would have to be ignored. One of the first indications of an off-normal event would be the receipt of high level alarms in the control room from the spent fuel pool instrumentation. If pool level continues to rise above the high level alarm setpoint, borated water will spill over the top of the bulkhead into the transfer canal. When the transfer canal is filled, a continuing increase in the fuel pool level will cause borated water to enter the fuel pool ventilation ducting. If the high level alarms fail and water in the fuel pool ventilation ducting is not detected, plant operators would observe and/or walk through water on the fuel pool operating deck as they make their rounds following the overflow that would eventually result from a dilution event. This overflow will be readily detected by plant operators in time to take corrective actions. Operations personnel make rounds through the fuel handling building in the vicinity of the spent fuel pool at least once every eight hours; during the ~60 hours required for the limiting dilution at least seven sets of rounds would be made.

For any of these dilution scenarios to successfully add over 358,000 gallons of unborated water to the spent fuel pool, plant operators would also have to fail to question or investigate the continuous makeup of water to the primary water tank and fail to recognize that the need for 358,959 gallons of primary water makeup was unusual.

If the assumed flow rate of unborated water to the St. Lucie Unit 2 spent fuel pool were increased to 500 gpm, almost twelve hours would be required to reduce the pool boron concentration to 520 ppm. Thus, even a spent fuel pool dilution at a flow rate significantly higher than that assumed in Sections 4.3 and 4.4 would still be detected by alarms, flooding, or operator rounds before the boron concentration reached 520 ppm.

## 5.0 Conclusions

A boron dilution analysis applicable to the St. Lucie Unit 2 spent fuel pool has been completed. As a result of this dilution analysis, it is concluded that an unplanned or inadvertent event which would result in the dilution of the spent fuel pool boron concentration from 1720 ppm to 520 ppm is not a credible event. This conclusion is based on the following:

1. More than 358,000 gallons of unborated water is required to dilute the Unit 2 spent fuel pool to the design $k_{eff}$ value of 0.95. To actually achieve this dilution, plant personnel would be required to take continued, manual actions to assure that this quantity of water would be delivered to the spent fuel pool.

2. The normal makeup path to the spent fuel pool from the primary water system is maintained locked closed. The alternate primary water makeup path is capped.

3. In-place administrative controls on the primary letdown path from the spent fuel pool (return line to the RWT) ensure that any prolonged, inadvertent fuel pool makeup would result in pool overflow.

4. The large volume of water required to achieve this dilution would be readily detected by plant personnel through installed alarms, overflow of the spent fuel pool and flooding in the fuel handling building, or by operations personnel on their normal rounds on the spent fuel pool operating deck and elsewhere in the plant.

5. Available flow rates to deliver unborated water to the spent fuel pool ensure that sufficient time is available for operations personnel to detect and respond to any dilution event.

All dilution scenarios examined in this analysis utilized 1720 ppm as an initial soluble boron concentration in the spent fuel pool, and utilized 520 ppm as the boron endpoint. It is important to reiterate that the spent fuel pool boron concentration is procedurally maintained greater than 1720 ppm (typically >1800 ppm) and that the assumed 520 ppm endpoint ensures that $k_{eff}$ of the storage racks will always be ≤0.95. The criticality analysis discussed in Reference 40 demonstrates that the spent fuel pool will remain subcritical with non-borated water in the pool including the effect of any relevant biases or uncertainties. Thus, even if the spent fuel pool were diluted to 0 ppm, which would require significantly more water than the 358,959 gallons presented above, the fuel storage racks would remain subcritical and the health and safety of the public would be assured.

## 6.0 Verification Summary

The applicable portions of each referenced document were provided to the independent reviewer (verifier). Each referenced item was examined by the verifier to ensure that it was appropriate for the application, properly applied and supported the relevant statements and conclusions of this Engineering Evaluation. The verifier agrees with the conclusions and safety classification of this evaluation.

## 7.0 References

7.1 Drawing 2998-G-830, sheet 1 of 4, <u>Fuel Handling Building Pool Liners</u>, Revision 7
7.2 Drawing 2998-6951, <u>FHB</u> - <u>Spent Fuel Pool South Wall</u>, Revision 3
7.3 Drawing 2998-6952, <u>FHB</u> - <u>Spent Fuel Pool East Walls</u>, Revision 4
7.4 Drawing 2998-6953, <u>FHB</u> - <u>Spent Fuel Pool West Wall</u>, Revision 3
7.5 Drawing 2998-G-894, <u>Fuel Handling Building Floor Plans</u> <u>&</u> <u>Riser Diagrams Plumbing</u> <u>&</u> <u>Drainage</u>, Revision 9
7.6 St. Lucie Unit 2 UFSAR , Section 3.8.4.1.3
7.7 Drawing 2998-G-078, sheet 140, <u>Flow Diagram Fuel Pool System</u>, Revision 5
7.8 Drawing 2998-G-073, <u>General Arrangement Fuel Handling Building</u> - <u>Plans</u>, Rev. 16

7.9 Drawing 2998-G-074, General Arrangement Fuel Handling Building - Sections, Revision 12

7.10 Drawing 2998-18511, Max Cap Spent Fuel Storage Module Assembly, Revision 0

7.11 FPL calculation PSL-2FJF-95-041, Revision 0, pages 5, 6, 8, 11, 14, 15, 18 & 19

7.12 St. Lucie Unit 2 UFSAR, Section 9.1.2.1

7.13 Drawing 2998-18514, Max-Cap Spent Fuel Storage Module Installation, Revision 0

7.14 ABB-CE calculation 016-AS95-C-009, Rev. 0, St. Lucie 2 Spent Fuel Pool Thermal Hydraulic Analysis, 6/9/95

7.15 St. Lucie Unit 2 UFSAR, section 9.1.3.1

7.16 2998-6089, Revision 5, Instruction Manual - Fuel Pool Purification Pump

7.17 Chemistry Procedure COP-05.04, Revision 0, Chemistry Department Surveillances and Parameters, Appendix B, page 3 of 7

7.18 Operating Procedure OP 2-0350020, Fuel Pool Cooling and Purification System - Normal Operation, Revision 26

7.19 Operating Procedure OP 2-0520020, Radioactive Resin Replacement , Revision 24

7.20 Drawing 2998-G-084, sheet 1, Flow Diagram Domestic & Make-Up Water Systems, Revision 28

7.21 Off-Normal Operating Procedure ONOP 2-0030131F, Plant Annunciator Summary (Panel F), Revision 2

7.22 2998-870, Revision 8, Instruction Manual - Miscellaneous Pumps

7.23 Operating Procedure OP 2-1600023, Refueling Sequencing Guidelines, Revision 52

7.24 Drawing 8770-G-084, sheet 1A, Flow Diagram Fire Water, Domestic and Make-Up Systems, Revision 37

7.25 8770-7431, Revision 6, Instruction Manual - Demineralized Water Pumps

7.26 Drawing 2998-G-083, sheet 1, Flow Diagram Component Cooling System, Rev. 34

7.27 Drawing 8770-G-084, sheet 1B, Flow Diagram Domestic and Make-Up Systems, Revision 37

7.28 Drawing 2998-G-084, sheet 2, Flow Diagram Domestic & Make-Up Water Systems, Revision 28

7.29 EBASCO letter SL-2-83-411, Containment Fire Protection - Hose Station Discharge Pressures and Flow Rates, dated May 24, 1983

7.30 Letter from Joy Johnson (CSI) to Andy Flowers (MM), PSL-2 Spent Fuel Pool Heat Exchangers, File \psl1bop\psl2sfhx.ltr, November 17, 1997.

7.31 Off-Normal Operating Procedure ONOP 2-0030131LA, Plant Annunciator Summary (Panel LA), Revision 3

7.32 Off-Normal Operating Procedure ONOP 2-0030131LB, Plant Annunciator Summary (Panel LB), Revision 4

7.33 Off-Normal Operating Procedure ONOP 1-0030131M, Plant Annunciator Summary (Panel M), Revision 0

7.34 Drawing 2998-4965, Component Cooling Water Surge Tank, Revision 6

7.35 2998-5070, Revision 0, Technical Instruction Manual - Ion Exchangers

7.36 Off-Normal Operating Procedure ONOP 2-0350030, Fuel Pool Cooling System, Revision 10

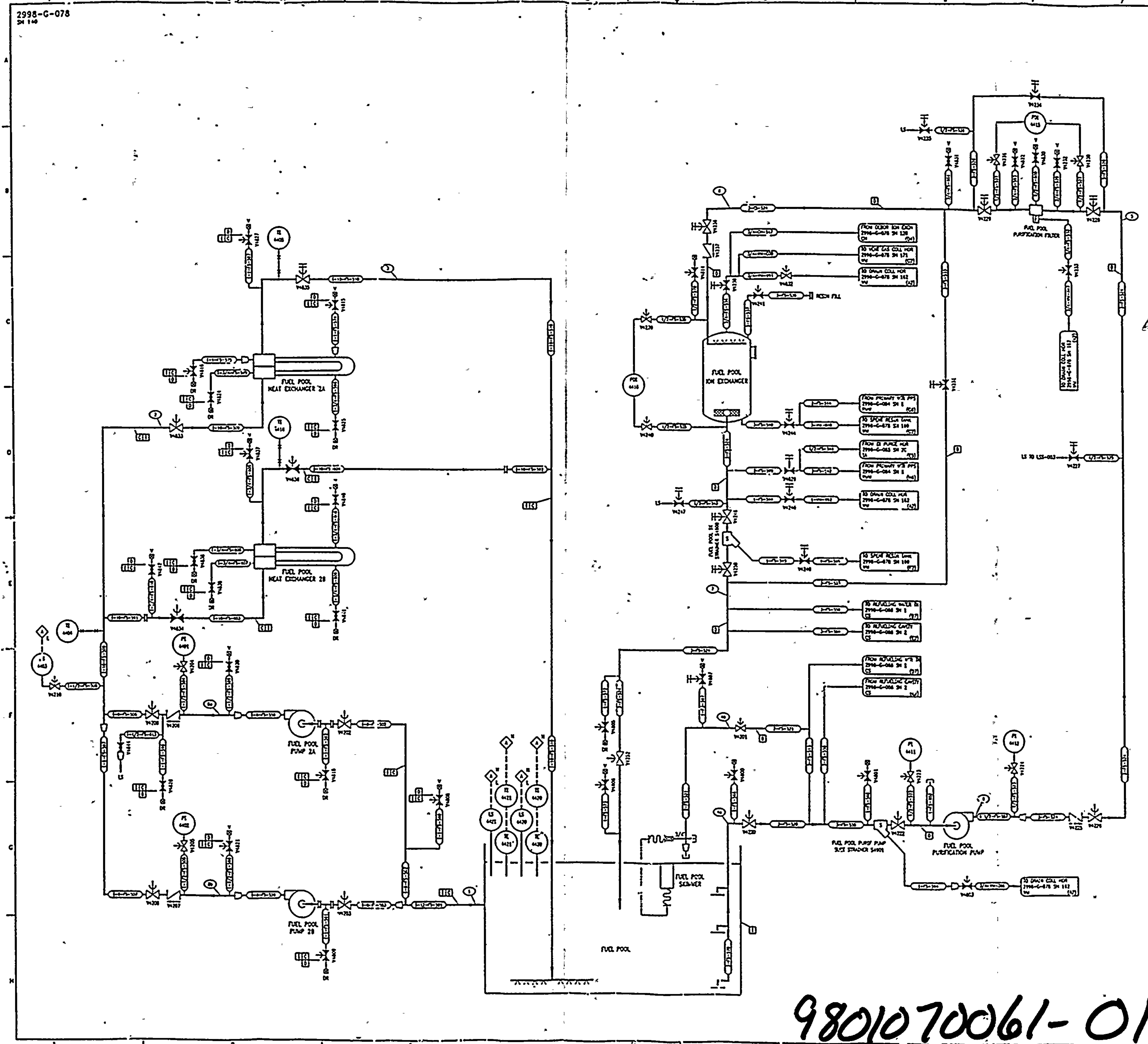
7.37 St. Lucie Unit 2 UFSAR, Section 9.1.2.2

7.38 Off-Normal Operating Procedure ONOP 2-0030131N, Plant Annunciator Summary (Panel N), Revision 2

7.39 Emergency Operating Procedure 2-EOP-99, Appendixes/Figures/Tables, Table 8, Emergency Diesel Generator Loading (LOOP), Revision 15

7.40 ABB-CENO Report CENPD-387, Revision 00, St. Lucie Unit 2 Criticality Safety Analysis for the Spent Fuel Storage Rack Using Soluble Boron Credit, October 1997, through Revision 02
7.41 Drawing 2998-G-088, sheet 1, Flow Diagram Containment Spray and Refueling Water Systems, Revision 28
7.42 Drawing 2998-G-078, sheet 121A, Flow Diagram Chemical & Volume Control System, Revision 20
7.43 St. Lucie Unit 2 Fuel Pool Level Switch LS-4420 & LS-4421 Parameters, TEDB, System 04, 10/16/97
7.44 Drawing 2998-G-275, sheet 1, Revision 6 and sheet 2, Revision 4, 125 V DC Panels One Line Diagrams Bus 2A & 2AA (sheet 1), Bus 2B & 2BB (sheet 2)
7.45 Operations Instruction 0-OI-99-02, Appendix D, Unit 2 Senior Nuclear Plant Operator Generic Rounds, Revision 1
7.46 Administrative Procedure AP 2-0010123, Administrative Control of Valves, Locks and Switches, Revision 82 (+ PCR for V-15538)
7.47 St. Lucie Unit 2 UFSAR, Table 8.3-2, Emergency Diesel Generator Loading Sequence
7.48 Chemistry Operating Procedure C-61, Maintaining Fuel Pool Chemistry, Revision 9
7.49 Off-Normal Operating Procedure ONOP 2-0030131S, Plant Annunciator Summary (Panel S), Revision 4
7.50 E-Plan Implementing Procedure 3100024E, Natural Emergencies, Revision 28
7.51 St. Lucie Unit 2 UFSAR Section 12.3.4.1.4 and Table 12.3-2, Area Radiation Monitors
7.52 St. Lucie Unit 2 UFSAR, Figure 4.2-6, Fuel Assembly
7.53 2998-4514, Revision 1, Instruction Manual - Fuel Pool Heat Exchanger
7.54 EBASCO Specification 39-70, Centrifugal Pumps and Accessories, Part One - Specific Requirements, Project Identification No. FLO-2998.120C

PSL-ENG-SENS-97-068
Revision 0
Page 31 of 31



ANSTEC APERTURE CARD

Also Available on Aperture Card

NOTES

1. THE FUEL POOL PURIFICATION SUCTION LINE (3-FS-320) HAS A 1/4" DIAMETER SYPHON BREAKER HOLE LOCATED 1'-2 1/2" BELOW THE NORMAL POOL WATER LEVEL.
2. THE FUEL POOL COOLING RETURN LINE (1-10-FS-310) HAS A 1/4" DIAMETER SYPHON BREAKER HOLE LOCATED 1'-4" BELOW NORMAL POOL WATER LEVEL.
3. THE FUEL POOL PURIFICATION RETURN LINE (3-FS-324) DOES NOT REQUIRE A SYPHON BREAKER SINCE THE PIPE TERMINATES AT A SUBMERGENCE ELEVATION THAT WOULD PRECLUDE EXCESSIVE DRAINAGE BY SYPHON ACTION.

REFERENCE DRAWINGS

| | |
|---|---|
| PIPE, VALVE & INSTRUMENT SYMBOLS | 2998-G-078 SH F20 |
| VALVE LIST | 2998-A-051 |
| LINE LIST | 2998-B-052 |
| VALVE OPERATIONAL NUMBER SHEET | 2998-B-057a |
| INSTRUMENT INSTALLATION DETAILS | 2998-B-231 |
| INSTRUMENT LIST | 2998-B-275 |

NOTE
THIS DRAWING IS MADE FROM REV 4
OF DRAWING 2998-G-078 SH 140

REVISION OF THIS DRAWING MAY REQUIRE UPDATE OF THE FOLLOWING DOCUMENTS FSAR FIGURE 9.1-6

NUCLEAR SAFETY RELATED
IN PART ONLY

FLORIDA POWER & LIGHT COMPANY
ST LUCIE PLANT
1983 - 890 MWe EXTENSION - UNIT 2
FLOW DIAGRAM
FUEL POOL
SYSTEM

EBASCO SERVICES INCORPORATED

2998-G-078

DRAWING

DRAWING NUMBER

NUMBER

2998-G-078
SH 140

9801070061-01

# Appendix A to Evaluation PSL-ENG-SENS-97-068

This appendix has the following purpose:

I. To demonstrate the derivation of boron dilution times and volumes for the Unit 2 spent fuel pool that are discussed in this evaluation.

---

## I. Derivation of boron dilution times and volumes for the Unit 2 spent fuel pool (Derivations assume perfect mixing and overflow where appropriate)

Determine surface areas (in ft$^2$) and volumes (in gallons) from pages 6, 7 and 15 of Reference 11:

spent fuel pool = 1194;
cask loading area = 156.25;
fuel transfer canal = 165; Total = 1515.25 ft$^2$

Pool volume (incl. cask area) = 300,070;
transfer canal = 47,500; Total = 347,570 gallons

Volume of surface area to a depth of 1 foot = 1515.25 ft$^3$ * 7.481 gallons/ft$^3$ = 11,335.6 gallons

Adding 11,335.6 gallons of unborated water to the Unit 2 spent fuel pool when filled to the low level setpoint, with an initial boron concentration of 1720 ppm, and solving for the new boron endpoint (x) yields the expression:

$$11335.6 = (\ln(1720/x)) * ((300070 - (11335.6/2)) + 47500)$$

with x = **1663.9 ppm**

as the boron concentration endpoint. (Δ boron = 56.1 ppm)

Assuming the fuel transfer canal is isolated from the fuel pool, determine the quantity of unborated water (y) that is required to dilute the spent fuel pool from an initial concentration of 1720 ppm to an endpoint of 520 ppm:

$$y = (\ln(1720/520)) * 300{,}070 \quad \text{yields } y = 358{,}959.0 \text{ gallons}$$

Item I (continued)

At an initial boron concentration of 1800 ppm:

y = (ln(1800/520)) * 300,070 yields y = 372,600.9 gallons

With an initial boron concentration of 1720 ppm, the contents of the primary water tank (150,000 gallons) would dilute the fuel pool to z ppm:

Solving for z yields: 150,000 = (ln(1720/z)) * 300,070

z = 1043.3 ppm

With an initial boron concentration of 1720 ppm, an extreme precipitation event into the spent fuel pool, such as described in Section 3.5.8 (19,504 gallons of unborated rain) would dilute the pool to x ppm:

19,504 = (ln(1720/x)) * 300,070 x = 1611.8 ppm

With an initial fuel pool boron concentration of 1720 ppm and a drained fuel transfer canal, filling the transfer canal by overflowing the fuel pool through the use of unborated makeup water would result in a fuel pool dilution to:

47,500 = (ln(1720/x)) * 300,070

x = 1468.2 ppm

With the cask storage area and fuel transfer canal isolated from the fuel pool, the volume of unborated water required to dilute the spent fuel pool to 520 ppm is:

y = (ln(1720/520)) * 250,404 y = 299,546.0 gallons