Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381-2000

OCT 2 9 2001

10 CFR 50.4

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D. C. 20555

Gentlemen:

In the Matter of) Docket No.50-390
Tennessee Valley Authority)

SUBJECT: WATTS BAR NUCLEAR PLANT - RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION (RAI)REGARDING TRITIUM PRODUCTION - INTERFACE ITEM NUMBERS 1, 6, 7, 10, 11, AND 12 (TAC NO. MB1884)

The purpose of this letter is to provide TVA's response to NRC's request for additional information regarding the Tritium Production Program Interface Item Numbers 1, 6, 7, 10, 11, and 12. NRC's request was provided in a letter dated October 2, 2001.

Initial information related to these interface issues was supplied by TVA on May 1, 2001 and with the license amendment request dated August 20, 2001. The enclosure provides both the questions asked and the responses to those questions. These responses provide information both for the interface items related to the Tritium license amendment along with information to assist in NRC's review of TVA's spent fuel cooling methodology submittal dated April 20, 2001 needed for the upcoming refueling outage.

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There are no new regulatory commitments made by this letter. If you have any questions about this letter, please contact me at (423) 365-1824.

Sincerely,

P. L. Pace
Manager, Site Licensing
and Industry Affairs

Enclosures
cc: See page 3

Subscribed and sworn to before me
on this 29th day of October 2001

E. Jeannette Long
Notary Public

My Commission Expires May 21, 2005

OCT 2 9 2001

cc (Enclosure):

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ENCLOSURE 1
TENNESSEE VALLEY AUTHORITY
WATTS NUCLEAR PLANT (WBN)
UNIT 1
DOCKET NO. 390
RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION

Report Section 1.5.1, Interface Issue 1, Handling of TPBARs

1. **Tennessee Valley Authority (TVA) states that a preliminary design of the tritium-producing burnable absorber rod (TPBAR) consolidation fixture is complete.**

   a) **Please elaborate on the "preliminary design" and what changes are anticipated, if any. What is the weight of the consolidation frame?**

RESPONSE

The design of the Consolidation fixture is nearing completion. The design is based upon the design concept demonstrated at the DOE Savannah River Site, which is described in Section 1.5.1 of NDP-00-0344, "Implementation and Utilization of Tritium Producing Burnable Absorber Rods (TPBARs) in Watts Bar Unit 1." The weight of the completed Consolidation Fixture is anticipated to be 8,000 lbs. The actual weight after fabrication will be verified by computations and/or testing.

   b) **TVA states that it will test the consolidation fixture and tools prior to delivery and after installation at the site. Please describe the testing process to be used to ensure proper operation at the site.**

RESPONSE

TVA's plan for testing is as follows: Pre-shipment aqueous testing will follow dry checkout and dry testing, and will consist of the following:

- Assembling the two Consolidation Fixture sections in a water filled tank simulating a spent fuel pool (SFP),
- Loading an empty Consolidation Canister into the Fixture Holster utilizing the Canister Handling Tool,
- Moving the Holster into the 15° position to accept TPBARs,

- Removing a baseplate loaded with 24 simulated TPBARs from a mock fuel assembly located in a mock spent fuel rack into the Consolidation Fixture utilizing the TPBAR Assembly handling tool,
- Releasing the full complement of 24 simulated TPBARs, one at a time, into the Canister utilizing the TPBAR release tool,
- Utilizing the hand-held Baseplate tool to remove the empty baseplate from the fixture,
- Returning the Holster to the vertical position,
- Relocating the Canister from the Holster to the mock fuel rack utilizing the Canister handling tool,
- Disassembling the Consolidation Fixture.

At each stage of testing, attention will be given to smooth operation, repeatability, opportunities to improve methodology, etc. This information will be utilized to modify the fixture if required, and as input to the testing at the site. This site testing will be performed similar to the procedure above, utilizing plant equipment and procedures and will also address the ability to move and assemble the fixture sections from the storage position to the use position.

c) **What contingency plans will TVA use in the event a rod becomes stuck in the fixture before placing it in the canister?**

RESPONSE

If the threaded engagement of the TPBAR to the baseplate becomes galled or is incapable of being removed by conventional methods, a backup method of TPBAR removal is required. To enable TPBAR removal in this case, a small hydraulic cutter would be used to sever the upper end plug of the TPBAR from the baseplate. This method would require that all TPBARs that could be de-torqued be removed by the conventional method. Then, the cutter would be delivered onto the TPBAR just below the baseplate. The cutter would sever the upper end plug of the TPBAR at the smallest diameter. Severing the upper end plug in this region would not affect the integrity of the rod itself. This method has been successfully utilized in other spent fuel pool applications.

Several features are available in the event that a TPBAR fails to drop into the canister:

- The roller-brake gear-motor can be reversed to raise the TPBAR up into the "funnel" section of the Fixture. The torque, speed, and direction of the roller-brake motor is programmable.
- The compression of the roller-brake rollers on a TPBAR can be released by pulling up on the roller-brake assembly pivot arm with a shepherd's hook, allowing the TPBAR to drop or be pulled out from above.
- A TPBAR can be manipulated manually with an underwater clamping device and placed into a canister, etc.
- The holster can be moved with the holster winch to "settle" TPBARs and allow a partially inserted TPBAR to completely drop.

d) **Figure 3.2-4 shows that a crimp sleeve secures the TPBAR upper end plug to the baseplate. Describe the TPBAR removal tool and process used to break this crimp.**

<u>RESPONSE</u>

Each TPBAR has a top end plug that is threaded into the baseplate. Extending above the baseplate is a hexagonal region on the top end plug to which the crimp sleeve is secured. The hex stud facilitates installation and removal and also serves as the feature to which the sleeve is crimped. The top end plug threads are left-hand such that when the TPBAR is removed, right hand torque is used.

During the consolidating of TPBARs, the TPBARs are unscrewed from the baseplate and removed. A hex socket tool is used to remove the TPBAR using the hex stud. The hex tool is mounted to a pole for manual disassembly. The hex tool is lowered into position from the consolidation platform. Once the tool is engaged on the hex stud, sufficient torque is applied until the resistance of the crimp is exceeded. The TPBAR is turned until it is driven out of the baseplate and drops into the canister.

2. **TVA states that it will handle the TPBARs in the spent fuel pool using the burnable poison rod assembly tool. What is the weight limitation for this tool?**

RESPONSE

The BPRA tool has a hoisting cable breaking strength of 1700 lbs. The tool hoist has been tested to 900 lbs. The BPRA and TPBAR assembly weigh approximately 58 to 65 lbs., respectively, and are nearly identical in configuration. Therefore, the tool is adequate to handle either without further evaluation.

3. **Section 3.7.3 describes two possible shipping cask designs, and states that TVA will provide information later.**

   a) **For the casks being considered, what is the loaded weight of the shipping cask which TVA will use to transfer the canisters from the spent fuel pool (SFP)?**

RESPONSE

The DOE Request For Proposals for the cask services to be used in moving the TPBARs from the TVA reactors to the Tritium Extraction Facility (TEF) at the Savannah River Site in South Carolina was issued on October 12, 2001. Therefore, details regarding the weight of the cask are not known at this time. For purposes of providing an estimate, the cask used to move the LTAs from WBN to the DOE site in Idaho weighed approximately 45,000 pounds. As noted below, the cask will contain no more than 4 canisters with up to 300 TPBARs per canister. Based on a TPBAR weight of approximately 2.4 pounds and a canister weight of approximately 225 pounds, a loaded cask with four canisters containing a total of 1200 TPBARs would weigh approximately 49,000 pounds.

   b) **How many canisters are shipped per cask?**

RESPONSE

As noted in the response to 3.a) above, a cask contract is not in place at this time. However the request for proposals specifies that the cask contain no more than four canisters, with each canister containing no more than 300 TPBARs.

4. **TVA states that the consolidation process will begin 30 days after completion of refueling. How long does it take to complete consolidation, cask loading, and handling operations?**

RESPONSE

TVA estimates it will take 3-4 weeks to consolidate a full unit's load of TPBARs into canisters stored in the Spent Fuel Pool. This is based upon working 8 hours per day 5 days per week to consolidate approximately 2300 TPBARs (approximately 100 base plates at 5 base-plates per day for 20 days). We also estimate that it will take 5 days per shipment to receive, prepare, load, decontaminate, and prepare the cask for shipment.

5. **TVA says that Section 2.15.6.6 addresses the consequences of a breached TPBAR as a result of mishandling in the SFP. This section is not complete. Please provide a summary of the conclusions from this study, including any assumptions not addressed in this report.**

RESPONSE

The calculations have subsequently been completed and the summary of conclusions is included in the license amendment request submitted to the NRC in TVA's letter of August 20, 2001

While reviewing Section 2.15.6.6 to respond to the request for additional information, it was noted that there is a typographical error in the document number for Reference 2 (Section 2.15.6.10). The correct number for this document is TTQP-1-091, Rev. 4, not TTQP-1-109, Rev. 4.

6. **TVA states that the 125-ton auxiliary building crane "is considered equivalent single-failure proof" when handling the TPBAR transport cask.**

a) **NUREG-0612 indicates a single-failure proof crane, must meet the requirements of NUREG-0554 and NUREG-0612. Does the auxiliary crane at Watts Bar meet all these requirements?**

RESPONSE

No. The Auxiliary Building Crane, while possessing many of the attributes required for a single-failure-proof crane, has not been evaluated to comply with NUREG-0554.

b) **If not, then Sections 5.1.1 and 5.1.2 of NUREG-0612 provide specific guidelines which must be met. Does Watts Bar comply with each of these? If not, what exceptions does TVA take?**

RESPONSE

As documented in WBN's response to Generic Letter 81-07 dated July 28, 1993, and accepted by the corresponding NRC Safety Evaluation, Supplement 13, Section 9.1.4, the Auxiliary Building 125/10 ton crane complies with the guidelines of Section 5.1.1 of NUREG-0612.

For TPBAR associated heavy load lifts, the Auxiliary Building 125/10 Ton crane meets NUREG-0612, Section 5.1.2, option number one by complying with Section 5.1.6, specifically Appendix C of NUREG-0612 for existing cranes, except for the load hang-up protection and associated testing. Lifts are controlled by site procedures, which require pre-lift briefings, trained operators, etc., and therefore this lift will be adequately monitored to help preclude load hang-ups. Certain items of compliance are contingent upon the fact that the loads for TPBAR associated lifts are less than half of the hook capacity, thereby yielding increased safety factors for the structurally/wear related requirements.

Lifting devices and interfacing lift points for TPBAR related heavy loads are required to meet the requirements of NUREG-0612 Section 5.1.6, either by redundant paths or increased safety factors, as delineated in ANSI/ASME N14.6.

c) **TVA says that the consolidation fixture will normally be stored in the cask lay-down area when not in use. NUREG-0612, Section 5.1.1 discusses general guidelines to minimize the potential impact of heavy loads on spent fuel stored in the pool. Enclosure 2 states that TVA takes precautions when handling the fixture and cask due to the close proximity to the fuel. What special precautions does TVA take to minimize this potential (e.g., shuffling fuel such that none are stored adjacent to the cask handling area)?**

RESPONSE

Special precautions in addition to the requirements of Section 5.1.1 are that the lifting devices, slings, and crane will meet equivalent single failure proof criteria, mainly by doubling the normal safety factors. The cask laydown section of the spent fuel pool area is separated from the irradiated fuel storage section by a wall, providing several feet separation. It is not deemed necessary nor warranted to relocate resident discharged fuel while storing and/or handling of the consolidation fixture in the cask laydown area.

7. **What is the licensed storage capacity of the SFP, and the current inventory of spent fuel assemblies?**

RESPONSE

Currently, the licensed storage capacity is 1610. However, the license amendment request submitted by WBN on August 20, 2001, reduces that capacity to 1386 by the removal of the Region II racks. There are currently 244 assemblies stored in the pool.

8. **TVA states that it will handle the cask in accordance with NUREG-0612. Please verify that TVA will comply with the guidelines of NUREG-0612 Section 5.1.1 (e.g., operator training, crane inspection and maintenance, and safe load paths).**

RESPONSE

TVA complies with all seven points of NUREG-0612 Section 5.1.1, as is delineated in WBN's response to Generic Letter 81-07 dated July 28, 1993, and accepted by the corresponding NRC Safety Evaluation, Supplement 13, Section 9.1.4.

Report Section 1.5.6, Interface Issue 6, Specific Assessment of Hydrogen Source and Timing or Recombiner Action

1. **This section states a time to start a hydrogen recombiner train at 3% containment volume concentration:**

   a) **Is this recombiner start time TS or EOP controlled by technical specifications (TS) or an emergency operating procedure?**

RESPONSE

The recombiner operation is controlled by plant emergency operating procedures. Each procedure contains guidance similar to the following generic process:

- CHECK hydrogen analyzers in service, if not, place in service
- CHECK containment hydrogen less than 5%, if not, consult Technical Support Center to determine further action
- CHECK containment hydrogen greater than 0.6%, if not, skip placing in service
- PLACE hydrogen recombiners in service

The step arrangement in the emergency procedures assures that the action is accomplished in a timeframe consistent with the need for the recombiners. These steps also assure the recombiners are used within their design capability by confirming the hydrogen concentration is in an appropriate range for their design. The safety analysis demonstrates

that with one recombiner started at 3 percent concentration, the hydrogen concentration will remain below 4 percent inside containment.

b) **At what time after initiation of a design basis accident is it necessary to start a recombiner train for a non-TPBAR core to keep the containment hydrogen concentration below 4%? This may be shown on Figure 6.2.5-7a.**

RESPONSE

Figures 6.2.5-7 or 7a (no recombiner curve) of the WBN UFSAR (prior to tritium incorporation) may be referenced to determine this time. However, since the curves have low definition at early timeframes, the following supplemental information is provided. The previous analysis for the non-tritium core indicates that a hydrogen concentration of approximately 3.75 percent is reached 4 days after the event if no recombiners are used. For the analysis incorporating the tritium core, and additional margins for zinc and aluminum in containment, the hydrogen concentration reaches 3.78 percent approximately 2 days after the event with no recombiner placed in service. In both the non-tritium and the tritium cases, starting one recombiner within 24 hours maintains the hydrogen concentration below 4 percent inside containment. For the tritium case, starting one recombiner within 24 hours (hydrogen concentration of 3.19 percent) limits the peak hydrogen concentration to 3.56 percent at 6 days. Therefore, adequate time is available for a recombiner to be placed into service.

2. **The submittal shows that amount of Zr available for a metal-water reaction appears to be 300 grams per TPBAR. Does this amount include any Zr present in the burst node volume from the Zircaloy liner? Additionally, if the lithium aluminate pellets are also part of the burst node volume, has TVA considered the potential chemical reactions of the lithium with reactor coolant to produce hydrogen?**

RESPONSE

The Zircaloy liner was included in the calculation of Zr available for metal-water reaction.

In response to the second half of this question, yes, potential hydrogen-forming chemical reactions between the

lithium aluminate pellets and reactor coolant were considered, but none were found. Lithium aluminate ($LiAlO_2$) can be considered to consist of lithium oxide (Li_2O) and alumina (Al_2O_3), and these are the highest oxidation states that exist for lithium and for aluminum. There is no unoxidized lithium metal in these pellets since they are fired at a very high temperature in air. Thus, in reactions of the lithium aluminate ceramic with the reactor coolant, hydroxides will form, but not with accompanying formation of H_2 gas.

Section 1.5.7, Interface Issue 7, Light-Load Handling

1. **Similar to the description used for the auxiliary crane, the spent fuel bridge crane is described as "single-failure proof equivalent." Elaborate on this description. What is the load limit for the bridge crane?**

   RESPONSE

   As stated, the aspects of the single failure proof criteria referred to for the SFP Bridge Crane in the response to Section 1.5.7 pertain to the structural integrity aspects of the crane, and are satisfied, to an acceptable extent, because the loaded canister weight (<700 lbs in water, < 1000 lbs dry) is less than half of the rated capacity (4000 lbs) for the crane, yielding greater than 10:1 safety factors. Together with the other design features as described in this section, provide sufficient aspects of the single failure proof criteria, for this lift, to preclude a handling event from damaging more than 24 TPBARs.

Section 1.5.10, Interface Issue 10, New and Spent Fuel Storage

1. **Enclosure 2, Section II.1 states that the SFP racks are seismically qualified to store loaded canisters. Is there any restriction regarding how many loaded canisters can be stored in a rack?**

   RESPONSE

   No. Based on a review of existing Spent Fuel Pool rack structural analysis calculations, there are no restrictions regarding how many Tritium Rod Consolidation canisters can be stored in a rack.

2. **Enclosure 2, Section II.2 discusses the heat produced by the consolidated TPBARs in a canister, and the slots located on the bottom and sides of the canister for natural circulation. Does the canister design account for blockage of these slots, and if so, what percentage of the slots can be blocked and still provide adequate heat dissipation?**

RESPONSE

The heat produced by a TPBAR 30 days after reactor shutdown is approximately 3 watts and the total maximum heat load for each canister is approximately 900 watts. This heat load is considered negligible for an open topped thin-walled canister with drain holes at the base; and natural circulation, with or without the drain holes, is deemed adequate to dissipate this small heat load. Additionally, drainage holes are on all four sides near the bottom and peripherally in the canister bottom plate. This configuration precludes significant natural circulation/drainage blockage from occurring.

3. **Provide the analysis supporting the assumption that all the neutronics characteristics of the fresh fuel containing TPBARs which affect vault criticality are conservatively bounded by the fuel assemblies included in the current new fuel storage vault criticality analysis.**

RESPONSE

TPBARs are a different type of poison than has been previously used. However, the existing New Fuel Storage Vault criticality analysis evaluated fresh (unirradiated) fuel with nominal enrichments up to 5.0 w/o U^{235}, without taking credit for discrete or integral poisons in the fuel (such as IFBA, BPs or TPBARs). With respect to the characteristics modeled in the existing new fuel criticality analysis, the fuel assembly design does not change with the use of TPBARs. Therefore, the existing New Fuel Storage Vault criticality analysis, approved by SER related to Amendment 15 to NPF-90 (letter dated December 1, 1998), is still bounding for TPBAR fuel.

4. **Provide the re-analysis of the spent fuel storage racks for fuel containing TPBARs including the basis for taking credit for integral fuel burnable absorber and fuel burnup.**

<u>**RESPONSE**</u>

TVA has reanalyzed the spent fuel racks which accounts for the use of TPBARs. This analysis includes taking credit for integral fuel burnable absorber and fuel burnup. This analysis was performed for TVA by Holtec International which contains proprietary information. Therefore, TVA plans to provide this information by separate correspondence.

5. **Provide the basis for concluding that the storing fuel containing TPBARs does not require changes to the TSs.**

<u>**RESPONSE**</u>

The subsequent license amendment submitted on August 20, 2001 provided the basis for any required changes to the Technical Specifications for fuel containing TPBARs.

<u>**Section 1.5.11, Interface Issue 11, Spent Fuel Pool Cooling and Cleanup System**</u>

1. **TVA states that it will perform outage-specific decay heat analysis for each outage (non-scenario based) rather than use the NRC-approved scenario-based approach.**

   a) **The NRC Standard Review Plan (SRP) 9.1.3 recommends the SFP bulk water temperature be kept below 140°F with a single failure for the maximum normal heat load. However, Table 1.5.11-1 refers to 159.24°F as the maximum SFP temperature: Please explain how this temperature is selected.**

<u>**RESPONSE**</u>

The maximum SFP temperature of 159.24°F was selected for consistency with maximum SFP temperatures provided in previously submitted responses to RAIs which supported previous licensing submittals. The WBN spent fuel pool underwent a re-rack project in 1996 (See TAC No. M96930). In support of the re-rack project, the SFP cooling performance was reanalyzed. The result of this reanalysis

indicated 159.24°F was the highest SFP temperature reached, assuming the loss of a single train of cooling. This value was discussed in TVA's responses to RAIs provided in support of the re-rack licensing amendment request, and establishes the basis for all subsequent related SFP piping and support design, CCS heat loads, etc.

The SRP guidance contained in section III.1.d considers a full core offload as an abnormal maximum heat load, and a normal maximum spent fuel heat load is set at a refueling load (inferred as a nominal 1/3 core offload, with in-core shuffle of remaining fuel). However, general industry and WBN practice consistently offloads the entire core to facilitate outage work requiring core empty periods. The SRP guidance therefore is inconsistent with general industry practices and terminology. In addition, the use of the value of 159.24°F is consistent with previous submittals, in that if the old maximum heat load of 32.6 MBtu/hr were placed in the SFP, maximum SFP temperature would exceed 140°F based on single failure criteria (loss of single train of cooling).

A single active failure within the SFPCCS system, however, will not exceed the 140°F criteria, as WBN has two trained SFPCCS pumps plus a single SFPCCS pump which can be powered off either train of power, therefore a failure of the only active SFPCCS component which provides flow will not result in a loss of normal cooling of the SFP. A single active failure within the CCS system, however, may result in a loss of a SFPCCS cooling train. The proposed change in methodology will not result in a maximum SFP temperature exceeding the 159.24°F previously approved during the rerack licensing submittal.

b) **The NRC SRP 9.1.3 recommends that the SFP cooling system should have the capacity to remove the decay heat from one full core and one refueling load after 36 days of decay, (i.e., emergency full core offload) without SFP bulk water boiling (single failure need not be considered). How does the non-scenario-based approach address this recommendation?**

RESPONSE

The decay heat load associated with one Tritium refueling load of 96 assemblies, combined with the maximum residual

SFP heat load from older fuel at full pool capacity, results in a total decay heat load in the SFP of approximately 14.23 MBtu/hr. This heat load exists in the SFP before any fuel is moved from the core. There is no requirement on how soon the emergency off-load must commence after shutdown. The only limit being fuel movement cannot begin prior to the Tech Spec limit of 100 hours. In this scenario, if core off-loading were to be allowed to commence at 100 hours, and assuming 36 hours to off load the core, the maximum allowable SFP heat load limit of 47.4 MBtu/hr would be exceeded. However, even with maximum fouling of the SFP heat exchangers and with maximum design CCS temperatures (95°F), the maximum SFP temperature for this case would not exceed 150°F, (assuming no single failure, consistent with SRP requirements). However, procedures would not allow TVA to initiate off-loading the core until the maximum total SFP heat load is less than the maximum allowable, consistent with actual fouling of the SFP heat exchangers and actual CCS temperatures. The procedure would force a delay in commencement of off-loading the core. Following these procedural requirements, the maximum normal SFP temperature will never exceed 140°F (assuming no single failure), provided the SFP heat load is limited to design limitations consistent with SFP heat exchanger fouling and CCS temperatures.

c) **Please provide an analysis showing (describe) how the maximum SFP temperature is calculated given the decay heat, heat exchanger fouling factors and component cooling system (CCS) temperature. Please list major assumptions if any (such as a single failure assumption.)**

RESPONSE

The following provides a summary of TVA Calculation MDQ-0078-000058, Rev 0.

The SFP Alternate Analysis is based on methodology contained in the Thermal Hydraulic analysis developed by Holtec International, Inc. However, computations were performed using an Excel spreadsheet in lieu of a specific computer code. The spreadsheet was developed to perform a Spent Fuel Pool Cooling and Cleanup System (SFPCCS) heat balance by calculating fuel decay heat as a function of time, and removing that heat via the SFPCCS Hx as a function of time and losses to the environment as a function of SFP

temperature. The analysis ignores heat losses through the liner to the concrete structure, and through the SFPCCS piping as described later. The time interval chosen for the iterations in the analysis was 1 minute. Observed changes in SFP temperature for this interval were typically less than 0.01°F. This thermal model and analysis ignores heat losses through the SFP walls and piping systems.

The Alternate Analysis performed by TVA, while similar to the analysis of record, made certain changes to allow variability on key inputs. The analysis allows varying the CCS temperatures and fouling factors for the SFP Heat exchanger to allow determination of more realistic SFP temperatures based on various input parameters.

The spreadsheet based model makes extensive use of heat exchanger temperature effectiveness values and Performance Factors, (further explanation below) which were developed in other analysis to predict off-design heat exchanger performance. The excel spreadsheet was bench marked against the Holtec analysis of record resulting in excellent agreement between the models. The close agreement is expected due to each model utilizing the same equations and methodology, only the software platform is different.

Net Heat Balance

The basic methodology used performs a heat balance around the SFP. The heat balance requires that the heat removal capability of the SFPCCS heat exchanger(s) plus the heat lost to the environment exactly match the decay heat load within the SFP. If more heat is in the SFP than is being removed, SFP temperatures will increase until a new equilibrium is reached whereby the higher heat load rejected to the heat exchanger(s) plus higher heat loss to the environment via evaporative heat losses again match the SFP decay heat load. In equation form, the heat balance is as follows:

$$Q_{sfp} = Q_{hx} + Q_{evap}$$

Where:

Qsfp = Decay heat rate in the SFP, both core and residual (Btu / hr).
Qhx = Heat removal rate by the SFPCCS Heat Exchanger(s) (Btu / hr).

Qevap= Rate of Heat lost to the surroundings via evaporation (Btu / hr).

Since the equation above is a heat rate equation, a classical solution would require integration of the equation with respect to time. However, since the Excel spreadsheet will be used to effectively calculate these quantities each minute, the "C dT/dt" term has been effectively incorporated into the spreadsheet analysis. Each row of the spreadsheet effectively solves for "dT/dt", with the results of one row providing input into the next row.

Heat Generation

The heat generation term Qsfp consists of heat from both the core and residual (old) fuel that is in the SFP. The analysis allows specification of the start time of off-load activities and time to offload, therefore modeling actual heat buildup within the SFP during core offload. The core decay heat generation values were taken from which predicts post shutdown core decay heat and decay heat from older stored fuel. DEHEAT is based on methodology contained in ANSI/ANS-5.1-1994, REG GUIDE 3.54, and NUREG/CR-2397. The residual decay heat from older fuel is sufficiently decayed that its decay heat does not decrease appreciably over the outage period, therefore this parameter has been held constant at a value determined for the start of the outage which is conservative.

Core Decay Heat

The core decay heat data used in the alternate analysis is based on conservative decay heat projections of a typical tritium production 80-feed assembly core, and included power up-rate assumptions as well as a full run, no coast down power generation core. The decay heat values follow an exponential decay in heat value as a function of time. Core decay heat is determined each outage for confirmation of total heat load imposed on SFPCCS. Data prepared for the Tritium Production Project was used to allow relative comparisons between a tritium production core assuming 80 Feed assemblies of tritium and 96 Feed assemblies of tritium. 96 Feed assemblies is the largest allowable quantity that can be placed in the core. The data provided was based on conservative assumptions, such as full power production and no coastdown. The data was developed using DEHEAT which determines post shutdown decay heat as an

exponential function of time. Only the data between outage days of interest were used to develop a simplified polynomial expression of the core decay heat, allowing ease of inputting into spreadsheet formulae. Since fuel movement cannot proceed during an outage until 100 hours (Tech Spec limit) and start of off-load is unlikely to begin as late as 15 days, the data for days 4 through 15 were used to develop the polynomial equation. An equation was developed utilizing a sixth order polynomial regression using techniques and tools found in Excel. The resulting equation yielded a R^2 value very close to 1.0, indicating very close agreement between the polynomial predicted and actual values. Extrapolation beyond the input data was not permitted. The polynomial was further tested to ensure accurate prediction of core decay heat values as a function of time for the period of interest. A separate spreadsheet was used to determine the 6^{th} order polynomial equation coefficients for a number of data sets. The Tritium Production Core 80-Feed case data by inspection was the limiting case of higher decay heat values, and establishes the basis for all analysis performed in support of the proposed change.

Residual SFP Decay Heat

Residual SFP Decay heat is defined as decay heat from fuel assemblies placed in the SFP from previous outages. By the time the unit reaches the next outage, the "youngest" fuel is approximately 18 months old, since all cycles at WBN are based on 18 month runs. The 18 month old fuel is added to the decay heat generated by the fuel deposited by earlier outages, however, the most recent outage contributes a large percentage of the overall residual decay heat value. Full-Pool residual decay heat was determined in another analysis to be approximately 1.8 MWt. This value was used as a non time-dependent input in the spreadsheet, however, the value can be varied as necessary based on current SFP heat load data, or full-pool heat load of 1.8 MWt.

Heat Losses to Surrounding Structures and Environment

The alternate analysis, consistent with the existing analysis of record (Holtec), considered heat losses to some of the surroundings. This component of the overall heat balance equation becomes significant at the higher temperatures associated with the SFPCCS design basis single failure analysis for loss of one train of cooling.

Losses to Air

As the SFP temperature increases, the difference between the SFP temperature and the ambient temperature results in a significant heat loss from the pool. The Holtec analysis for WBN reported several resulting values for heat loss, as a function of SFP temperature. The Holtec analysis also contains numerous raw data printouts of evaporative heat losses as a function of SFP temperature. A review of the data clearly indicated that the evaporative heat loss is dependent only on the difference between SFP temperature and ambient temperature on the refueling floor. Excel spreadsheet standard regression techniques were used to obtain a 3rd order polynomial equation to allow the spreadsheet based alternate analysis to utilize the existing data. Testing of the equation yielded close correlation (R^2 =1)with the existing data. The explicit analysis performed by Holtec is based on physical features of the SFP. The review of the resulting data indicated that the third order polynomial equation accurately predicts the SFP evaporative heat losses (Qevap) at varying temperatures, within the range of temperatures utilized within the model.

Losses to Walls and System Piping

The Holtec analysis ignored heat losses through the SFP liner and concrete walls and floor, and also ignored the losses from un-insulated system piping. Ignoring such losses is conservative, therefore the Alternate SFP Decay Heat Analysis similarly ignored these SFPCCS heat losses.

Heat Removal by SFPCCS Hx

The amount of heat removed by the SFPCCS Heat Exchangers is greatly influenced by off-design considerations. The Holtec Analysis utilized design values for tube and shell side fouling (0.0005 $hr*ft^2*°F/Btu$), tube plugging (5%), CCS

temperature (95°F), and shell side and tube side flow rates (3000 and 2300 gpm, respectively). The objective of the Alternate SFP Decay Heat Analysis is to provide the capability to predict SFP system performance based on off-design parameters. Several areas were investigated for varying parameters for greatest impact on desired results. Of those investigated, heat exchanger fouling factor and CCS temperature were the two variables that yielded the greatest improvement in heat exchanger performance.

Heat Exchanger Temperature Effectiveness

The existing SFP Thermal-Hydraulic analysis of record developed by Holtec utilized the concept of Heat Exchanger Temperature Effectiveness. The benefit of utilizing this methodology is that for a fixed value for effectiveness, which is a function of coolant inlet and outlet temperature values and the hot stream inlet temperature, the system thermal balances can be written as a function of hot fluid stream inlet temperature and coolant inlet temperature.

The equation for heat exchanger capacity was provided in the Holtec Analysis, as:

$$Q_{HX} = W_t * C_p * p * (T_{h,i} - T_{c,i})$$

where:

W_t = Coolant flow rate, lbm/hr
C_p = Coolant Specific Heat, Btu/lbm* °F
p = Temperature effectiveness
$T_{h,i}$ = Hot (SFP) inlet fluid temperature, °F
$T_{c,i}$ = Coolant inlet temperature, °F

C_p varies minimally with small changes in temperature; therefore, the cold stream shell side inlet conditions are used to calculate C_p. The error introduced by this simplification is within the overall accuracy of this analysis.

The temperature effectiveness was defined in the Holtec analysis as:

$$p = [T_{c,o} - T_{c,i}] / [T_{h,i} - T_{c,i}]$$

where:

$T_{c,o}$ = Coolant outlet temperature, °F

From data generated utilizing QA software STER (Shell and Tube Heat Exchanger Rating program), values for effectiveness "p" can be determined for design and off-design conditions.

Holtec developed effectiveness values for the original SFP Thermal Hydraulic Analysis . TVA utilized the same methodologies to develop similar effectiveness values, except parametric values were developed by varying certain input variables, specifically, CCS Temperature, SFP Temperature and allowable fouling factors. The Holtec analysis is based on design limiting conditions of 95°F CCS Temperature and 0.0005 $hr*ft^2*°F/Btu$ design fouling factor. The Alternate SFP Decay Heat Analysis has been developed to utilize the new effectiveness values based on these variables, which allows off-design SFP evaluations.

Equations were developed by TVA for SFPCCS Hx effectiveness "p" values relative to SFP temperature (T_{SFP}) for the listed CCS Inlet temperatures between 95°F and 80°F, at design fouling of 0.0005 $hr*ft^2*°F/Btu$ and 5% tube plugging: The equations were utilized in the spreadsheet based model to determine appropriate Hx effectiveness values for off-design conditions. The Holtec Analysis utilized a single value for effectiveness. However, heat exchanger effectiveness decreases with cooler CCS temperatures and increases with warmer SFP temperatures. These equations were used in the Excel spreadsheet in order to accurately predict SFPCCS heat exchanger thermal performance during varying conditions of SFP temperature, at off-design CCS temperatures.

Fouling Factor

The fouling factor design value of 0.0005 $hr*ft^2*°F/Btu$ as recommended by TEMA Heat Exchanger Design Standard is for systems which utilize essentially demineralized water. Since both the CCS and the SFPCCS are very clean water systems, the appropriate design value was used. For predicting off-design performance, however, experience at Sequoyah Nuclear Plant has shown that fouling over many years is significantly less than the design value. Further investigation indicated that significant benefit in increased SFP decay heat load without an increase in SFP

temperature could be realized by taking credit for lower as-found fouling factors for the SFPCCS Hxs.

Since the analysis of record utilizes effectiveness values based on STER model outputs, which are fouling factor dependent, direct utilization of fouling factor data as a controllable variable was not possible with the existing methodology. To allow direct input of fouling factors within the spreadsheet based model, the SFPCCS thermal model was modified from the Holtec methodology by the introduction of Performance Factors (PF). Performance Factors allowed developing explicit equations for PF as a function of fouling. TVA developed an equation which expresses $PF_{fouling}$ as a function of fouling.

The resulting equation as developed by TVA is:

$$PF_{fouling} = 1.2564e^{-458.37*FF}$$

Where:

$PF_{fouling}$	=	Performance Factor at desired fouling
FF	=	Desired Fouling Factor per side (shell and tube), $hr*ft^2*°F/Btu$

With the above equation, the overall SFP Hx effectiveness could be multiplied by the Performance Factor to "adjust" the effectiveness of the heat exchanger, allowing the spreadsheet based model to predict off-design performance at less than design fouling factors.

Tube Plugging

Design tube plugging for the low maintenance SFPCCS Hx is 5%. Evaluations with reduced tube plugging allowance did not yield significant SFP thermal capacity benefit, as would be expected, since as tubes are plugged, the overall velocity through the open tubes will increase, somewhat off setting the degraded performance one would expect from a limited number of blocked tubes. For this reason, the Alternate SFP Decay Heat Analysis utilizes the same tube plugging allowance as utilized in the Holtec analysis.

CCS Temperature

CCS temperature ($T_{c,i}$) is a direct input into the thermal performance equation given above. By varying this parameter within the spreadsheet, heat exchanger duty is directly influenced.

The SFPCCS Hx design is based on a CCS temperature of 95°F. However, by the time refueling is in progress, the design basis heat load on CCS (from RHR) is substantially reduced, RHR heat rejection is essentially zero once all fuel has been moved to the SFP. For this reason, CCS temperatures less than 95°F are readily achievable with the existing margin and flow rates that exist in the ERCW system which cools the CCS Heat Exchanger.

The Holtec analysis fixed the CCS temperature at a single value of 95°F. The Alternate SFP Decay Heat Analysis allows fixing this parameter at different values as an input parameter, within the following restriction. Since discreet equations were developed for heat exchanger effectiveness values at CCS temperatures of 95, 93, 90, 85, and 80°F, CCS Temperature input was also restricted to these CCS temperature values within the spreadsheet based model. The CCS temperature is held constant at the fixed value throughout the off-load period. Actual experience would suggest the CCS temperature would decrease during this time period, since the primary heat load on CCS is decaying with time. Keeping this input parameter fixed with time allowed overall spreadsheet based model simplification, while generating overall conservative results.

ANALYSIS AND RESULTS

Design Basis Benchmark Evaluations

The original thermal hydraulic analysis was based on design limiting values for fouling and CCS temperature of 0.0005 $hr*ft^2*°F/Btu$ and 95°F, respectively. In order to validate the Excel spreadsheet based methodology as an acceptable substitute in predicting SFP thermal response, two cases were performed using the design values for fouling and CCS temperatures. The cases were set up to allow direct comparison of spreadsheet mode results to previous results developed by Holtec. Table 1 below summarizes the design basis results from both the existing Holtec analysis and those calculated with the Excel spreadsheet based model.

TABLE 1 -Fouling = 0.0005 hr*ft^2*°F/Btu (Design Case)				
Case	Description	CCS Temp °F	SFP Qmax MBtu/hr	SFP Tmax °F
Holtec -1T	Single Train Analysis by Holtec	95	32.42	159.24
Holtec -2T	Two Train Analysis by Holtec	95	32.60	129.30
7.2-1T	Single Train Analysis by TVA	95	32.42	159.34
7.2-2T	Two Train Analysis by TVA	95	32.60	129.37

The values tabulated above for SFP Tmax and SFP Qmax agree well with those determined by the Holtec thermal Hydraulic Analysis, thus validating the use of the Excel spreadsheet model to predict SFP transient thermal response.

Specific SFP Thermal Analysis

The spreadsheet model was utilized to develop numerous evaluations of SFP performance at off-design conditions. The purpose of the analysis was to develop data which determined maximum allowable SFP heat load at off-design condition of Hx fouling and CCS temperature. The limiting criteria was to not exceed the 1 train SFP temperature limit of 159.24 °F. Validation of one train being the limiting case over two train operation was provided in the analysis. Since one train operation has been shown to be limiting, any decay heat value imposed on the SFP which does not exceed the one train SFP temperature limit of 159.24°F will not exceed the existing two train SFP temperature design limit of 129.30°F. Multiple iterations were performed with the spreadsheet until some combination of initial SFP decay heat and adjustments to off-load start time resulted in a maximum heat load which would not exceed the upper 1-Train SFP temperature limit of 159.24°F.

The spreadsheet based Alternate SFP Decay Heat Analysis also evaluated the following additional cases:

1. Validation of Maximum Allowable SFP Heat Load Dependency on Off-Load Start Time
2. Validation of Maximum Allowable SFP Heat Load Dependency on 1-Train Operation
3. Limiting Maximum Heat Rejection to CCS During Refueling: Fouling at 0, CCS Temp at 95°F
4. Maximum Heat Rejection to CCS: Steady State Equilibrium SFP Decay Heat - Non-Refueling

Maximum Allowable Decay Heat in SFP for Off-Design Conditions

Table 2 below provides a summary of the values calculated in the spreadsheet based model. Table 2 data is shown graphically in Figure 1. The actual data values for allowable heat load were reduced by 2% to ensure maximum values are not exceeded based on reading error of the allowable decay heat graph, and to ensure conservative values result from the development of the spreadsheet model. The lowest CCS temperature used for analysis is 80°F, but the value could be much lower, since the ERCW can reach 40°F during winter. Therefore, an upper limit of maximum decay heat was established. Based on the data below, the value of 47.4 MBtu/hr was chosen to represent the maximum allowable decay heat that can be placed in the SFP regardless of CCS temperatures less than 80°F. This maximum value established the basis for other evaluations such as time-to-boil, heat-up-rate, etc.

Table 2 - Maximum Allowable SFP Decay Heat - With 2% Reduction [Mbtu/hr]					
Tccs	Fouling= .0005 hr*ft²*°F /Btu	Fouling= .0004 hr*ft²*°F /Btu	Fouling= .0003 hr*ft²*°F /Btu	Fouling= .0002 hr*ft²*°F /Btu	Fouling= .0001 hr*ft²*°F /Btu
95	32.600 (Note 1)	34.323	35.866	37.524	39.103
93	33.858	35.389	37.060	38.611	40.240
90	35.389	37.026	38.575	40.200	41.902
85	37.896	39.447	41.109	42.851	44.677
80	40.173	41.828	43.600	45.452	47.399
Note 1: This value has been further reduced to match the existing design allowable decay heat value.					

2. **TVA refers to "an alternate method", which allows varying heat exchanger fouling and varying SFP heat exchanger coolant (CCS) temperature to perform thermal balance on the SFP. Please provide the following additional information regarding this method:**

   a) **In Sections 1.5.8 and 1.5.9, TVA states that the increase in allowable decay heat associated with the reduced SFP heat exchanger fouling factors and lower CCS temperatures is approximately 10 MBTU/hr. However, Table 1.5.11-1 shows the maximum allowable decay heat load is varied by 14.8 MBTU/hr. (32.6 - 47.4). Please explain this discrepancy.**

RESPONSE

The number "approximately 10 MBtu/hr" was incorrectly stated. The value should have been "approximately 14 MBtu/hr" (14.8 MBtu/hr is the actual difference, with approximately 1 MBtu/hr attributable to the tritium program increase and 13.8 Mbtu/hr attributable to earlier offloads). The value stated in these paragraphs is used only to provide a general understanding of tritium related impacts relative to the total increase requested by TVA to allow core off-loading as early as 100 hours after shutdown. Note also that the 14.8 increase (to 47.4 MBtu/hr) can only be achieved at CCS temperatures of 80°F or less (see attached graph, response to RAI 2.c). CCS temperatures of 80°F or

less are only achievable with UHS temperatures much less than the design maximum of 85°F. The actual impact on the UHS and ERCW analyses due to the additional heat load would be less than the 14.8 MBtu/hr, since some portion of the additional heat load is only allowed under conditions of sub-design (<85°F) UHS temperatures. Therefore the value of 14.8 MBtu/hr is clearly a conservative, limiting value regarding impacts on downstream heat removal systems.

b) **Is the maximum allowable decay heat load shown in Table 1.5.11-1 (e.g., 47.4 MBTU/hr) the decay heat at the beginning of core offload, or is it the peak decay heat in the SFP during the core offload operation?**

RESPONSE

The maximum allowable SFP decay heat load is the maximum allowable decay heat allowed in the SFP at the completion of off-loading the last fuel assembly from the core to the SFP.

c) **In the subsection "Results of Alternate Analysis", TVA states that "series of curves have been developed to provide operator guidance for an increase in allowable SFP decay heat." What criteria were used to determine the allowable decay heat for the given heat exchanger fouling and CCS temperature when preparing the curves? Is each point in the curves the maximum decay heat which would maintain the SFP temperature below 159.24°F for the given heat exchanger fouling and CCS temperature? Please provide this graph.**

RESPONSE

The Alternate Analysis developed data for the curves by placing just enough decay heat load into the SFP that would result in a maximum SFP temperature of 159.24°F, assuming one failed train of SFP cooling. Multiple analyses were performed at varying fouling factors, ranging from 0.0001 to 0.0005 and varying CCS Temperatures between 95°F to 80°F. As expected, at lower fouling and lower CCS temperature, a higher quantity of SFP decay heat could be input without exceeding the design limiting SFP temperature of 159.24°F. The resulting data was reduced by 2% to include margin, and the reduced data points were subsequently graphed (See attached Figure 1.) to allow a varying maximum SFP decay heat based on actual fouling and CCS temperatures.

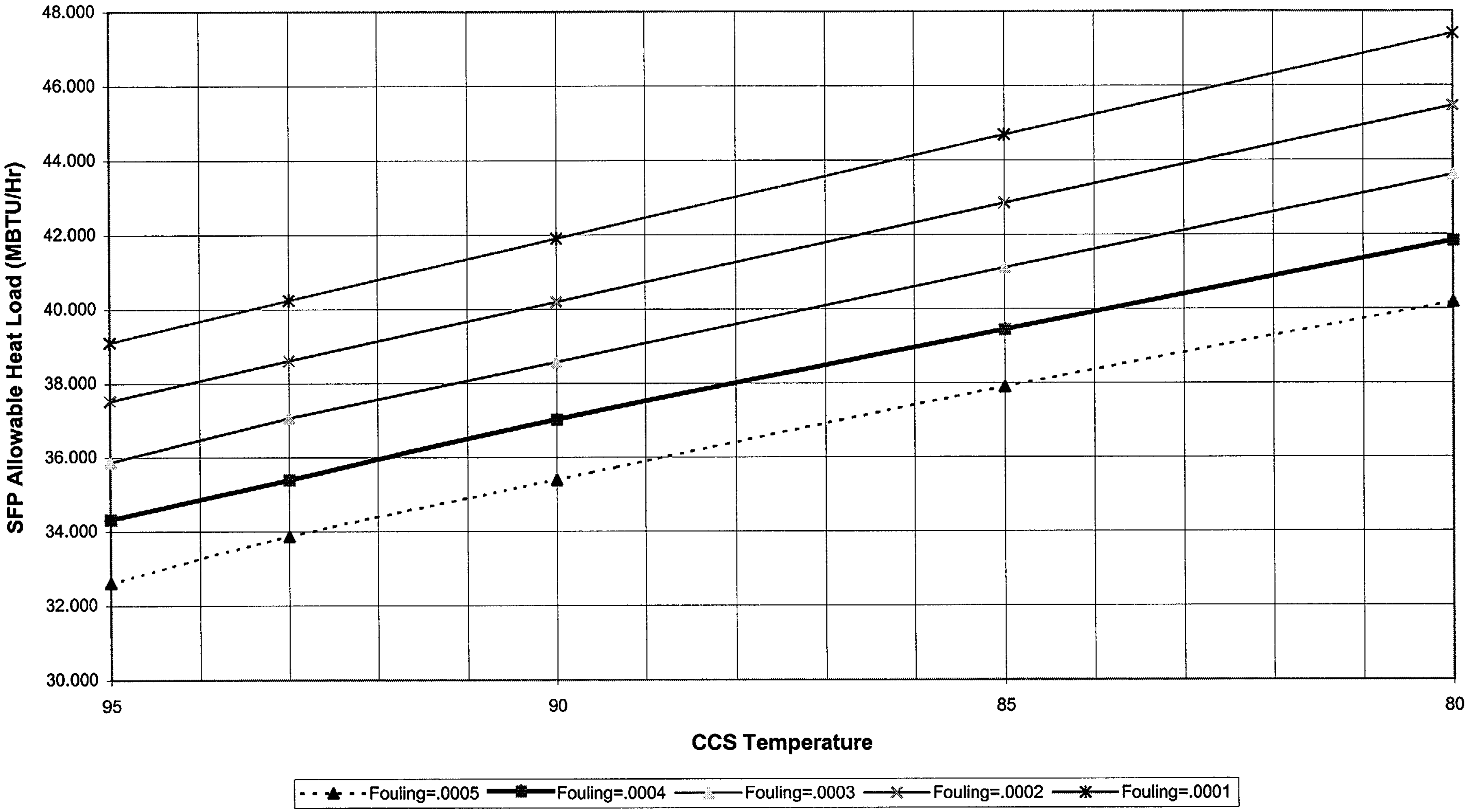


FIGURE 1
WBN ALLOWABLE SFP DECAY HEAT FOR
OFF-DESIGN SFPCS HX FOULING AND CCS TEMPERATURES

d) **Please explain the procedures for operators to determine the heat exchanger fouling and CCS temperature for each outage. Are these procedures currently in place?**

RESPONSE

TVA's plan is as follows: Heat exchanger fouling will be determined by industry accepted methodology using qualified testing equipment. Data will be collected from CCS and SFP systems (flow and temperature) and will be analyzed based on known SFP heat exchanger design data to determine fouling. Sufficient data will be generated over a period of time (several outages) to quantify any trend regarding deteriorating SFP heat exchanger conditions. Experience to date at Sequoyah Nuclear Plant suggests little to no fouling over a 20 year period without cleaning. This is an expected result, as both the SFP and CCS systems are pure water systems. Once the fouling trend has been established, routine determination of fouling prior to every outage is not warranted, but will instead be based on the trend data and specific needs of a given outage.

The CCS temperature is a function of ERCW (ultimate heat sink) temperature. For design cases, ERCW at 85°F will result in a CCS maximum temperature of 95°F or less during refueling operations. In a basic relationship, for every degree ERCW decreases, a corresponding decrease of nearly 1 degree would be seen in the CCS maximum temperature. However, within design analysis significant ERCW flow margin exists during refueling operations. TVA intends to provide operator guidance relating ERCW temperatures to CCS temperatures. Since ERCW temperatures are based on the UHS (river) temperatures and therefore change throughout the year, the design output curve will provide operations with a tool to assist decision making regarding highest expected CCS temperatures during refueling outage activities. Actual CCS temperatures are monitored in the MCR, and can be assessed relative to projected temperatures to ensure maximum CCS temperatures are not exceeded.

These procedures have not been developed to date. As part of TVA's plan for program implementation after receipt of NRC approval, the procedures will be developed and issued.

e) **How does the alternate method account for the time to boiling, SFP heat-up rate, boil-off rate, etc? How is it assured that the each point in the curve meet the NRC SRP guidelines for these parameters?**

<u>**RESPONSE**</u>

The revised values for time-to-boiling, SFP heat-up rate, and boil-off rate are all based on the maximum allowable SFP decay heat load of 47.4 MBtu/hr, which represents a limiting case. Specific values for these parameters were not determined for discreet combinations of fouling/CCS temperatures shown on the SFP allowable decay heat curve. All points on the curve are bounded by the consideration of the maximum allowable decay heat value of 47.4 MBtu/hr for the development of these parameters.

The SRP does not provide any specific quantitative parameters or limits regarding heat-up rate, time-to-boil, or boil-off rate. However, SRP Section III.1.d does require a review of such parameters consistent with the stated storage conditions. All values determined by TVA in support of the proposed change are based on the maximum heat load proposed to be placed into the SFP, since if all cooling is lost, SFP heat exchanger fouling and CCS temperature inputs have no influence on the analysis results.

3. **Table 1.5.11-1 shows the average time to SFP boiling, average SFP heat-up rate, and average boil-off rate.**

   a) **Please explain "average." (i.e., what quantities are averaged?)**

<u>**RESPONSE**</u>

The term average was used to signify that several variables are changing, however, as explained below, the values determined are conservative and are based on the highest allowable SFP heat load of 47.4 MBtu/hr.

Heat-Up Rate: The average heat-up rate analysis for the SFP was determined by dividing the maximum heat generation rate (47.4 MBtu/hr) by the heat capacity of the SFP. This methodology is conservative in that it ignores the exponentially decaying time relationship of spent fuel heat load during the time the SFP is heating up. The methodology

also ignores increased heat loss to the surrounding environment and structures as the SFP temperature increases. The term "average" was used recognizing that for the first few minutes after a loss of SFP cooling, a higher heat-up rate would be expected, compared to the final heat up rate as the pool approaches a boiling temperature. The term "average" was intended to imply average over the time period of concern, rather than an instantaneous maximum heat-up rate. Overall, the heat-up rate provides a maximum expected value to operations for their assessment of urgency, should all SFP cooling be lost.

Time-to-Boil Determination: The time-to-boil analysis is determined by dividing the difference in original (159.24°F) and final (212°F) temperatures of the event by the average heat-up rate. The energy and time required for the heat of vaporization at 212°F was conservatively ignored. The starting temperature is taken as the maximum SFP temperature of 159.24°F for one train operation. The heat up rate, as discussed above, is based on maximum allowable SFP heat load (47.4 MBtu/hr). Again, conservatism is maintained by ignoring the exponentially decaying time relationship of spent fuel heat load during the time the SFP is heating up and ignoring increased heat loss to the surrounding environment and structures as the SFP temperature increases. The term "average" was used since one of the inputs to this evaluation was the "average heat-up rate," and further implies an average over the time period of concern. The results of the time-to-boil determination, based on conservative, worst case assumptions, provides information to operations regarding the time period for action to mitigate such an event, and clearly represents a maximum or worst case value for the intent of this parameter.

Boil-Off Rate Determination: Boil-off rate was determined by equating heat lost through boiling to net heat generation rate. Since the SFP surface water remains at boiling temperature, 212°F, the boil-off rate is dependent only on the amount of decay heat in the SFP. The decay heat in the SFP decreases with time during the boiling event. To ensure a conservative value for boil-off rate is determined, no credit was taken for decreasing decay heat energy with time. No credit was taken for heat lost through pool walls or other structures. The maximum boil-off rate was taken at the instant of highest decay heat (47.4MBtu/hr) in the SFP. Once the SFP reaches an equilibrium boiling temperature of

212°F, the amount of heat lost through vaporization must exactly match the heat generation within the SFP, since other heat losses are ignored. The use of the term "average" for the Boil-off rate is somewhat confusing. The use of the term "maximum" would have more appropriately described the parameter.

b) **Please explain why "average" is a more appropriate quantity to be presented in this table rather than the minimum time to SFP boiling, maximum SFP heat-up rate, and maximum boil-off rate?**

RESPONSE

TVA agrees that the use of the term "average" instead of "maximum" or "minimum", as appropriate, is confusing. The values as determined, are based on conservative, worst case input values. As discussed in the response to question 3a above, it is unnecessarily complex to predict a precise heat up rate minute by minute, however an "average" but conservative heat up rate is easily determined. The methodology used to determine these parameters was consistent with previous determinations, and the analysis results were consistent with the changes to the inputs. The resulting values for all three of these parameters are conservative, worst case values for their intended purpose. The use of "maximum" and "minimum" would have been a better choice of terminology. Regardless of the terminology used however, no change in methodology for determining these three parameters would have resulted.

c) **When is time zero when the "time to boiling" and "time until 10 feet of water" are calculated (e.g., are they calculated from the time of loss of cooling)?**

RESPONSE

Time zero is taken at the moment cooling is lost.

d) **When is the loss of cooling assumed to occur (e.g., at the peak SFP temperature)?**

RESPONSE

Loss of cooling is assumed to occur at the time of maximum (peak) heat load in the SFP, which occurs just after the

last fuel assembly is removed from the core into the SFP. The prior design analysis assumed cooling was lost at peak SFP temperature. However, for model simplification, the Alternate Analysis is based on loss of cooling at peak heat load. This is a more conservative approach, in that the earlier cooling is lost, the higher the start point is on the decay heat curve for the loss of cooling period. Waiting for peak temperature requires an additional 6 to 8 hours to elapse while the SFP increases to the highest temperature required to compensate for the heat load from the last fuel bundles. This delay results in a lower calculated maximum SFP temperature due to the lower decay heat load.

4. **Table 1.5.11-1 refers to the make-up rate of 55 gpm, while the calculated boil-off rate is 102 gpm. In view that the boil-off rate exceeds the make-up rate, please list various sources of other make-up water available which can be aligned to the SFP, their make-up rates, and time required to align them to the SFP. Please also explain whether any operating procedures are in place to align these water sources to the SFP under this circumstance.**

RESPONSE

The following provides the requested information.

- High Pressure Fire Protection Hoses - Endless supply from river, flow rate is minimum of 55 gpm. High pressure fire protection hose station connections are located at each end of the SFP. Time Required to align - <1 Hour.

- Refueling Water Storage Tank - 375,000 gallon RWST via two refueling purification pumps, rated at 200 gpm. - Time Required to Align - < 1 hour See Note A below.

- Demineralized Water - Total of 25,000 gallons initial supply from Demineralized Water Head Tank, and Cask Decon Head Tank. These tanks can be replenished from yard makeup pumps. Supply is via system static head supplied from head tanks. Flow rate unknown. Demineralized water is directly connected to SFPCCS piping. SFP Makeup could also be supplied from service connections located nearby via hoses. Time Required to align - <1 Hour. See Note A below.

- Primary Water - 187,000 gallon Primary Water Storage Tank, supplied via 150 gpm rated pumps. Primary Water is directly connected to SFPCCS piping. Time Required to align - <1 Hour. See Note A below.

  Note A - System Operating Instruction, SOI-18.01 provides instructions for utilizing the RWST, PW, and DW systems for normal make-up purposes. These instructions provide adequate guidance for aligning these water sources for normal or emergency conditions. There are no "Emergency Operation" procedures in place to establish these water supplies, as a loss of two independent cooling trains must be postulated to result in such a condition. Sufficient time exist to align these makeup sources following the normal operating procedures.

The list above provides the sources of water available for immediate and longer term use as SFP makeup should coolant inventory in the SFP be lost due to boiling. The rated pump capacities have been provided in lieu of specific flow rates due to lack of specific quantifiable test data or analyses. While flows may be less than the stated pump capacity due to system losses, the values provide an indication of approximate flow rates and multiple sources of water that is available for SFP makeup, should mitigation of such an event be required. Normal operating procedures would be used to align these water sources.

5. **On page 1-37 ("Component Cooling System Maximum Water Temperature"), TVA states that "By the time the core will be completely off-loaded (about 136 hours after shutdown), the residual heat removal heat load is essentially zero, and that the CCS temperature would be less than the maximum design temperature, 95°F." What value of the CCS temperature is used between these times (between beginning and end of the core off-load) - is the CCS temperature varied or constant during this period?**

RESPONSE

The CCS temperature is not varied in the Alternate Analysis methodology. The temperature used at the start of off-load for CCS is used through the time period of the analysis. This is a model simplification and is consistent with the existing design analysis of record issued in support of the WBN re-rack project. In actual SFP cooling performance, as

the fuel decay heat load continues to decrease with time, the CCS temperature will correspondingly decrease.

Section 1.5.12, Interface Issue 12, Component Cooling Water System

1. **In the sub-sections "Tritium Impact on Spent Fuel Pool Decay Heat" of Section 1.5.8 (Station Service Water System) and Section 1.5.12 (Component Cooling Water System [CCS]), TVA referred to "a quantitative analysis of expected spent fuel decay heat." Please provide this analysis or a summary of the analysis, which should include the scenarios evaluated, the methodology, the code used, important assumptions and results.**

   RESPONSE

   The following provides a summary of TVA Calculation MDQ0078-000059 Revision 0, Tritium Production Impact on SFP Decay Heat:

   The production of Tritium at WBN results in both higher fuel decay heat loads during the outage as well as higher residual Spent Fuel Pool (SFP) heat loads remaining in the pool which affect future outages. The purpose of this analysis was to examine the decay heat loads for two Tritium assembly feed cases, an 80-Feed Tritium core, and a 96-Feed Tritium core, and compare them to the decay heat loads for a normal (Base Case) core heat load.

   An assumption used in the analysis was that the use of a specific outage decay heat curve is acceptable. The Technical Justification for this assumption is based on the fact that the intent of the analysis was to determine relative impacts of Tritium Producing Cores (TPC) on the plant. Since relative values are being developed, the use of outage specific decay heat data combined with conservative rounding of results provided bounding results.

   Heat Generation

   The SFP decay heat generation values consist of heat from both the current core and residual (old) fuel that is in the SFP. The core decay heat generation values were taken from data developed. The computer code DEHEAT is utilized to predict post shutdown core decay heat and decay heat from

older stored fuel. DEHEAT is based on methodology contained in ANSI/ANS-5.1-1994, REG GUIDE 3.54, and NUREG/CR-2397. All data utilized in the analysis was based on results from DEHEAT generated data sets for a Base (existing), 80-Feed, and 96-Feed cores.

Projected Core Decay Heat Impact

The earliest time in which core off-load can be initiated is at 100 hours after core shutdown. From plant experience, the latest time in which core off-load is likely to begin is at approximately 10 days after core shutdown. The period from 100 hours, Day 4, to Day 10, represents the time frame in which core off-load is most likely to begin. Since for any given outage, start of off-load is predicated on outage management efficiencies, not design parameters, the estimated impact was taken as the average between the Day 4 and Day 10 affects. By utilizing DEHEAT generated data (Day 4 and Day 10) for the 80- and 96-Feed cores, and comparing this data to the equivalent data of the Base core, the following results were determined, after averaging the Day 4 and Day 10 results:

TABLE 1 - Increase Heat Load over Base Case

Feed Case	Day 4 (MWt)	Day 10 (MWt)	Average (MWt)
TPBAR 80-Feed Case	0.1818	0.2054	0.1936
TPBAR 96-Feed Case	0.0994	0.1304	0.1149

Projected SFP Residual Heat Impact

For every refueling outage, there is an increase in residual heat in the SFP resulting from the addition of spent fuel to the pool. From inspection of the DECAY generated data for the multiple feed cases, the 96-Feed case residual decay heat values ("Discharge Batch") were found to be the greatest when compared to the other cases. This was expected since a 96-Feed core requires more fuel assemblies to be placed in the SFP each outage.

In addition to using the most conservative SFP residual decay heat values, the capacity of the pool was considered.

For WBN, the maximum design SFP capacity is 1835 cells. (See response to Section, 1.5.1, question 7 for maximum licensing capacity.) A full core off-load requires enough SFP area to store 193 fuel assemblies, therefore the maximum amount of cells allowed for general fuel storage is 1642 cells. The total number of fuel assemblies added to the pool cannot exceed 1642 cells. Using the specified residual decay heat values for the 96-Feed case (limiting) and comparing to the Base Case, considering the pool's storage limitations, the analysis tabulated the amount of heat, MWt, added to the pool for every cycle until the pool reached its capacity.

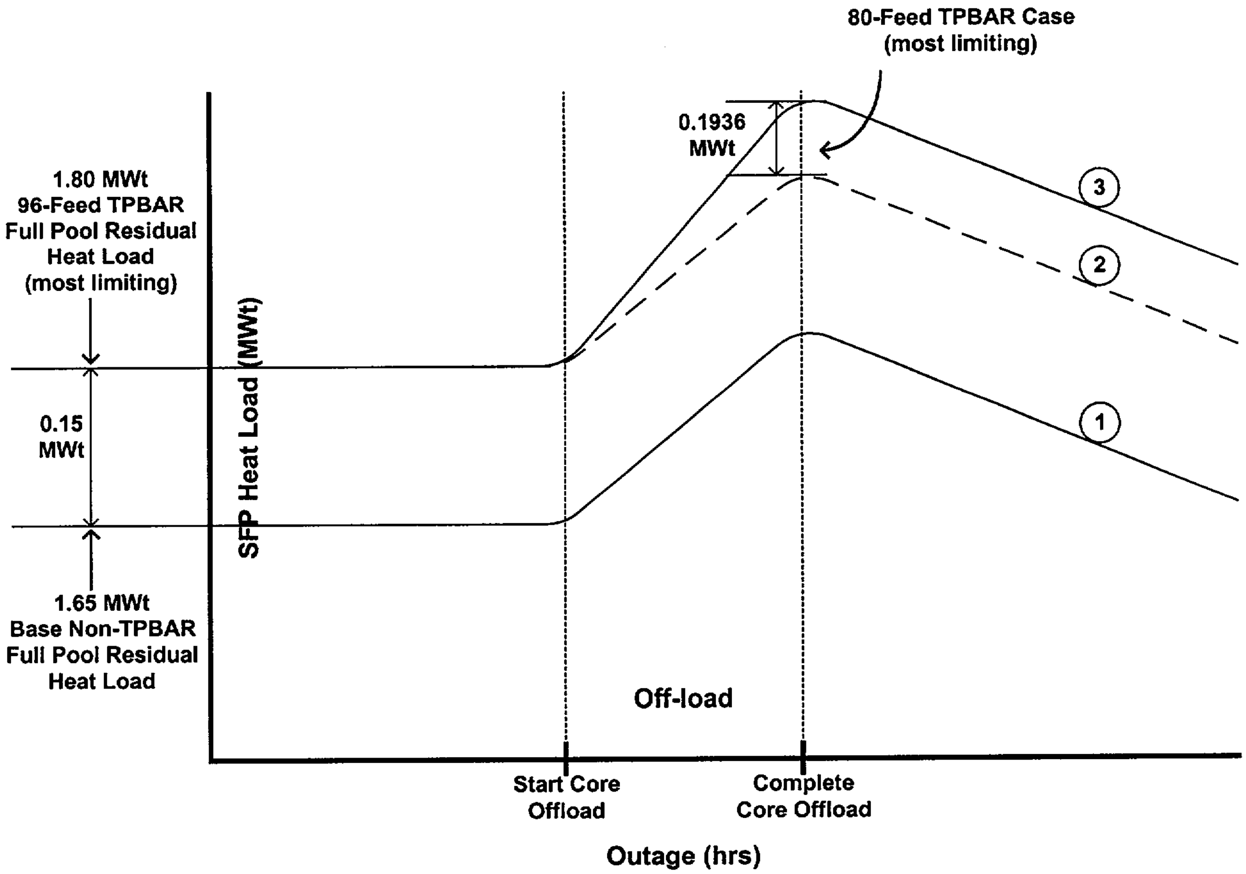
To remain under the maximum allowable fuel cells that can be stored in the SFP, the Base Non-TPBAR Case resulted in the SFP reaching capacity at Cycle 20. The total amount of Base Non-TPBAR Case residual heat at the end of Cycle 20 was determined to be 1.6269 MWt, approximately 1.65 MWt. To remain under the maximum allowable fuel cells that can be stored in the SFP, the 96-Feed TPBAR case resulted in the SFP reaching capacity at Cycle 17. The total amount of 96-Feed TPBAR case residual heat at the end of Cycle 17 was determined to be 1.7795 MWt, approximately 1.80 MWt. Therefore, by comparing the Base case to the 96-Feed Case (limiting), the affect of Tritium on the SFP at full pool conditions was determined to be an increase in residual heat of 0.1526 MWt.

<u>Net SFP Decay Heat Impact Related to Tritium Production Activities</u>

The net SFP decay heat impact related to Tritium production activities was obtained by adding the Tritium impacts on core decay heat (both 80-Feed and 96-Feed TPBAR cases) and the limiting 96-Feed case value for the SFP residual decay heat:

TPBAR 96-Feed Case → 0.1149 MWt + 0.1526 MWt = 0.2675 MWt
TPBAR 80-Feed Case → 0.1936 MWt + 0.1526 MWt = 0.3462 MWt

A graphical representation of the limiting 80-Feed TPBAR core decay heat case and the limiting 96-Feed TPBAR SFP residual decay heat case is found in Figure 2. This diagram shows Tritium's impact on off-loading activities.



1. Current Trajectory with out Tritium - Starting at 1.65 MWt
2. Trajectory on Non-TPBAR Core During Off-load, if Starting @ 1.80 MWt
3. Trajectory of the 80-Feed TPBAR Case Starting at Full SFP Condition

FIGURE 2

TRITIUM IMPACT ON OFF-LOADING DECAY HEAT

Results / Conclusions

Based on the analysis, it was shown that Tritium production activities will have an impact on SFP decay heat loads. Due to this impact, the critical path time related to required hold time prior to off-loading the core will also be affected. Below are the expected bounding ranges of impacts, based on multiple variables. The overall conclusion of the analysis is that Tritium production activities at WBN will have a small but measurable negative impact on SFP decay heat. The increase in SFP decay heat will impact outage critical path time, due to a delay in commencement of off-load activities.

Net SFP Decay Heat Impact = 0.27 to 0.35 MWt
Full Pool Residual Decay Heat = 1.8 MWt

2. **In the sub-sections "Increased Spent Fuel Pool Cooling Heat Rejection" of Section 1.5.8 and Section 1.5.9 (Ultimate Heat Sink [UHS]), TVA says that "the increase in decay heat load is well within the design bases limiting heat load imposed on the ERCW [Essential Raw Cooling Water] (UHS) during other modes of operation," and "the increased heat load rejection to the CCS will not result in a significant temperature increase in ERCW (UHS)."**

   a) **Please provide the design heat load of the ERCW, UHS and CCWS.**

RESPONSE

For the purpose of this discussion, the UHS is considered synonymous with ERCW. Note that UHS also provides heat removal for other non-safety related systems, including Raw Cooling Water (RCW), and the Supplemental Condenser Circulating Water (SCCW). Safety related system heat loads on the UHS are the only impacts related to the requested change, therefore the UHS discussion below has been combined with ERCW. (The ERCW discharges into the Cooling Tower Basin; however, the impact on the SCCW system is negligible.) The use of "nominal" values is used in the responses to Questions 2.a and 2.b below, since there are some variations in heat loads between independent trains of cooling in the CCS and ERCW systems.

The limiting design heat load of the CCS system is nominally 120 MBtu/hr. This heat load is based on Unit 1 in Hot Shutdown mode, Loss-of-offsite-power (LOOP), loss of a single train of components, and Unit 2 in "Construction" mode. The primary contributor to this heat load is the RHR heat load taken at 4 hours after shutdown, with all core decay heat being removed by one train of RHR.

The limiting design heat load of the ERCW system (rejected to the Cooling Tower Basin) is nominally 236 MBtu/hr. This heat load is based on Unit 1 in LOCA / Recirculation mode, Loss-of-offsite-power (LOOP), loss of a single train of components, and Unit 2 in "Construction" mode. The primary contributors to this heat load are the Containment Spray System (CSS) and the RHR heat exchangers, with all core decay heat being removed by one train of RHR and CSS, and the cooling requirements of two diesel generators on the active train.

b) **Please provide the overall heat load to the ERCW, UHS and CCS from all sources during the refueling outage period for the tritium production cores (TPCs) and non-TPCs (peak heat load or as a function of time) with the proposed increase of heat load associated with the reduced heat exchanger fouling and lower CCS temperature.**

RESPONSE

The peak heat loads provided below for the proposed change include the additional heat loads that CCS or ERCW/UHS would see based on the combined affect of Tritium Production Cores, and reduced fouling of the SFPCCS heat exchangers. All existing design values and analyses are based on maximum CCS and ERCW temperatures, as these maximum temperatures result in maximum piping temperatures used in piping/support analyses. For these reasons, the following discussions of changes in heat load do not reflect additional heat loads that can be gained by taking credit for lower CCS temperatures. This approach is acceptable, however, since higher heat loads can only be achieved by lower CCS temperatures which are achieved by lower ERCW temperatures, and assuring that the final analyses for piping and support thermal analyses remain bounding, since they have been based on maximum temperatures.

As an example, the proposed maximum allowable decay heat load that can be placed in the SFP is 47.4 MBtu/hr. However, the maximum allowable heat load that will be rejected to CCS was determined to be 42 MBtu/hr. The difference between 47.4 and 42 MBtu/hr is the additional heat load that can only be allowed based on sub-design CCS temperatures. While the actual heat load rejected from the SFP to CCS and ERCW at 47.4 MBtu/hr and 80°F CCS will be greater than the heat load at 42 MBtu/hr and 95°F CCS, the resulting piping temperatures and related analyses are maximized and bounding at the 42 MBtu/hr and 95°F CCS temperature design points.

The effects on SFP heat load impacts from the Tritium Production Core and the methodology using lower CCS temperatures and credit for reduced SFP heat exchanger fouling have not been independently determined. The reason for this approach is that the Tritium Production Core impacts are very low (nominal 1 MBtu/hr). Since existing FSAR statements allow the use of analysis based inputs to determine commencement of off-load time, compensation for higher heat load impacts from the Tritium Production Core alone could have been achieved by delaying the commencement of core off-loads by 15 to 20 hours, which would have resulted in no net impact on CCS or ERCW/UHS heat loads. Therefore, all discussions below, consistent with supporting analyses, are based on combining the heat load affects of the Tritium Production Core with the proposed revised methodology for taking credit for reduced CCS temperatures and reduced fouling of the SFPCCS heat exchangers.

The CCS load list calculation currently defines two different refueling periods. The first period termed "initial refueling" is defined at peak RHR heat load at the initiation of refueling activities, where all core heat is being removed by the RHR system, and the residual heat load of the SFP is conservatively determined as approximately 16 MBtu/hr from previously stored fuel a short time after the last outage. This combination results in a total RHR/SFPCCS heat load rejected to CCS of approximately 55 MBtu/hr. The second period of refueling is based on a time at completion of core off-load, where the SFP is at maximum decay heat, imposing maximum demand on SFPCCS heat exchangers, coincident with essentially no demand on the RHR heat exchangers, since the core is now empty. For the second period, peak heat load was approximately 32.5 MBtu/hr being

rejected to CCS via the SFPCCS heat exchangers. The proposed change will result in an increase of heat rejected to the CCS via the SFPCCS heat exchangers from approximately 32.5 MBtu/hr to approximately 42 MBtu/hr. The higher heat load rejected to the CCS as a result of the proposed change (42 MBtu/hr) remains bounded by the "initial refueling" case value of 55 MBtu/hr.

Similarly, the total heat load on CCS from all sources during refueling is bounded by the "initial" refueling case, with a CCS heat load of approximately 56.2 MBtu/hr. This value is not affected by the proposed change. The total heat load on CCS from all sources after the core is empty increases from approximately 33.3 MBtu/hr to approximately 42.8 MBtu/hr as a result of the proposed change.

The maximum overall heat load on ERCW which is ultimately discharged to the CCW Cooling Tower Basis is currently 152 MBtu/hr during refueling. This value represents maximum heat load rejected to ERCW Train B header during Unit 1 Refueling, Loss of offsite power, and loss of A train equipment. This value will increase to approximately 163 MBtu/hr as a result of the proposed change. The proposed higher heat load for the refueling condition is well within the overall design basis ERCW LOCA-Reirc heat load of 236 MBtu/hr discussed in 2.a above.