November 15, 2002

TVA-SQN-TS-02-06 10 CFR 50.90

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

Gentlemen:

In the Matter of	)	Docket Nos. 50-327
Tennessee Valley Authority	)	50-328

SEQUOYAH NUCLEAR PLANT (SQN) - UNITS 1 AND 2 - TECHNICAL SPECIFICATION (TS) CHANGE 02-06, "INCREASED CONDENSATE STOARAGE TANK (CST) MINIMUM VOLUME"

Pursuant to 10 CFR 50.90, TVA is submitting a request for a TS change (TSC 02-06) to licenses DPR-77 and DPR-79 for Units 1 and 2. The proposed change will revise TS 3.7.1.3, "Condensate Storage Water," Limiting Condition for Operation for SQN Units 1 and 2 by increasing the required minimum amount of stored water from 190,000 gallons to 240,000 gallons. TVA is requesting this change to support the replacement steam generator requirements. Greater steam generator structural mass and upgraded regulatory standards were used to reevaluate the minimum CST volume. This request is similar to the approved license amendment request by South Carolina Electric & Gas Company's (SCE&G) Virgil C. Summer Nuclear Station, Amendment Number 145 issued July 7, 2000.

TVA has determined that there are no significant hazards considerations associated with the proposed change and that the TS change qualifies for categorical exclusion from environmental review pursuant to the provisions of 10 CFR 51.22 (c)(9). The SQN Plant Operations Review Committee and the SQN Nuclear Safety Review Board have reviewed this proposed change and determined that operation of SQN Units 1 and 2 , in accordance with the proposed change, will not endanger the health and safety of the public. Additionally, in accordance with 10 CFR 50.91 (b)(1), TVA is sending a copy of this letter and attachments to the Tennessee State Department of Public Health. As part of the proposed license amendment request, no commitments have been made by TVA.

TVA requests approval of this TS change to support the Unit 1 Cycle 12 outage currently scheduled for March 2003. TVA requests that the implementation of the revised TS be within 45 days of NRC approval. This letter is being sent in accordance with NRC RIS 2001-05.

If you have any questions about this change, please telephone me at (423) 843-7170 or J. D. Smith at (423) 843-6672.

Sincerely,

Pedro Salas
Licensing and Industry Affairs Manager

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 15 day of November, 2002.

Enclosures
1. TVA Evaluation of the Proposed Changes
2. Proposed Technical Specifications Changes (mark-up)
3. Changes to Technical Specifications Bases pages
4. Framatome ANP's SQN Condensate Volume Requirement Verification

Enclosure 1

TENNESSEE VALLEY AUTHORITY
SEQUOYAH PLANT (SQN)
UNITS 1 AND 2

TVA Evaluation of the Proposed Change

1. DESCRIPTION

This letter is a request to amend Operating License(s) DPR-77 and DPR-79 for SQN Units 1 and 2. The proposed change would revise the Limiting Condition of Operation (LCO) of Technical Specification (TS) 3.7.1.3, "Condensate Storage Water (CST)," to require an additional inventory of water storage, as the preferred coolant source during credible design accidents. In addition, the associated TS Bases will be modified for clarity. This proposed change will address the requirement of additional coolant water for plant transients resulting in the need for auxiliary feedwater after replacement steam generators installation.

Enclosure 3 contains the proposed TS Bases revision associated with the proposed revised LCO.

2. PROPOSED CHANGE

This amendment request proposes to revise SQN's TS 3.7.1.3, "Condensate Storage Water," for Units 1 and 2 by increasing the minimum amount of stored water. Specifically, the minimum water volume value of 190,000 gallons will be replaced by 240,000 gallons such that the revised LCO will state:

"The condensate storage tank system (CST) shall be OPERABLE with a contained water volume of a least 240,000 gallons of water."

The associated TS Bases 3/4.7.1.3, "Condensate Storage Tank," also includes a proposed revision. This proposed revision will clarify the basis for the minimum amount of water. This revision, as can be seen in Enclosure 3, will include the statement:

"and to subsequently reduce the reactor coolant system temperature to HOT SHUTDOWN conditions in 6 hours at which time the heat removal load is transferred to the residual heat removal system."

In summary, the minimum condensate storage tank water volume of 190,000 gallons to be maintained during applicable modes will be increased to 240,000 gallons. This change reflects the necessary minimum amount of feedwater, with an additional 12,000 gallon margin, to assist in steam generator recovery of Unit 1 by removing primary stored and residual core energy for such events as loss of normal feedwater supply or secondary system pipe rupture. This proposed change is conservatively requested for both units since the Unit 1 CST is inter-connected to the Unit 2 CST.

3. BACKGROUND

Each of SQN's CST's consist of a non-seismic qualified carbon steel tank with capacity of 385,000 gallons. The CST's are connected to the condenser hotwell and hotwell pumps discharge for the addition and dumping of water, respectively, to maintain water inventory in the secondary system. Storage tank level is maintained by makeup from the water treatment plant. Each tank is equipped with an electronic level indicator which provides continuous tank level indication and provides a signal in the main control room for annunciation of abnormal tank levels. In addition, each tank is provided with a local level indicator. The current minimum water amount of 190,000 gallons in each tank is reserved for the auxiliary feedwater (AFW) Systems by means of an administrative limit based upon indicated level set points.

A CST is the preferred and primary source of clean water for the AFW. An alternate unlimited source of cooling water is supplied by the seismic Category 1 essential raw cooling water (ERCW) system. The ERCW supply can be remote-manually aligned based on CST level or automatically on a two-out-of-three low-pressure signal in the condensate suction line. In addition, the fire protection system can be aligned to supply feedwater in the event of a flood above plant grade. (Reference 1)

TS 3.7.1.3 currently requires the CST of both Unit 1 and 2 be operable by maintaining a minimum water volume of 190,000 gallons. This minimum volume of water in the CST is specified, as stated in TS Bases 3.7.1.3, to ensure sufficient water is available to the AFW system to maintain the reactor coolant system (RCS) at hot standby for two hours. (Reference 2)

Sequoyah is currently working towards replacement of its Unit 1 steam generators in the Spring of 2003. The design of the replacement steam generator provides additional structural mass over the original steam generator and consequently an increase in stored energy content. TVA has chosen to reevaluate the minimum CST volume using a newer standard for decay heat generation and associated conservative input parameters. These changes have resulted in an increase in the minimum CST inventory. In addition to this proposed TS LCO change, a TS Bases change is proposed to clarify that the CST minimum volume includes capacity to reduce the RCS temperature to hot shutdown conditions within 8 hours of reactor trip.

There is precedence for allowing an increase in the minimum required water volume in the CST as a result of replacement steam generators. The South Carolina Electric & Gas Company (SCE&G) operating license for the Virgil C. Summer Nuclear Station, has been amended to allow an increase in the required minimum water volume of the CST as a result of replacement steam generators, uprate, and recalculated value of the unusable volume of the CST. This amendment, Number 145, was issued on July 7, 2000.

4. TECHNICAL ANALYSIS

The minimum required volume of water in the CST, as specified by LCO 3.7.1.3, is being changed from 190,000 gallons to 240,000 gallons. This change is based on the increased requirements created by installing replacement steam generators on Unit 1, newer standard for modeling decay heat generation (Reference 3), and revised input assumptions for the calculation to determine the minimum water volume necessary during plant transients.

The previous required inventory of 190,000 gallons was originally based on a very conservative decay heat model and the time from a reactor trip to placing the residual heat removal (RHR) system in service (References 4 and 5). The core decay heat model for the original CST inventory determination was based on the conservative Westinghouse Electric Company decay heat model (circa 1970), a precursor to ANS 5.1-1971. To determine the new CST inventory requirements, the core heat production associated with decay heat is based on the 1994 ANS standard with B&W heavy actinide contribution.

Several of the original assumptions were incorporated into the calculation. These assumption are as follows:

1. Following reactor trip, no reactor coolant pumps are operating,

2. Following the reactor trip, the RCS temperature is reduced to 350 degrees Fahrenheit (°F) over a period of 8 hours, at which time the heat removal load is transferred to the RHR system,

   (NOTE: The sequence and length of time at hot standby and for cooldown do not affect the water requirement; rather, the time from reactor trip to RHR operation determines the water requirement.)

3. All feedwater is assumed to be delivered to the steam generator for heat removal by evaporation and released through the main steam safety valves. Release of feedwater other than through the main steam safety valves, such as spillage due to a feedline break, is not considered.

The following assumptions have been changed from the original CST inventory calculations to allow greater operation freedom and support emergency response guidelines:.

1. The original AFW temperature assumption of 100°F used by Westinghouse Electric Company in 1971 was increased by 20 degrees for an AFW temperature input value of 120°F,

2. The original AFW requirement did not include the quantity of water needed to refill the steam generators; whereas this calculation considered steam generator refill to the normal zero load level, and

3. The assumption of the reactor operating at 102% of the power level (corresponding to the turbine-generator unit maximum calculated heat balance) was changed to 100.7%. This is the result of the recent installation of a new main feedwater leading edge flow measurement system which provided a 1.3% reduction in the calorimetric uncertainty of the secondary side power measurement.

The calculation to determined the minimum volume requirements of the CST is included in Enclosure 4.

The proposed increase in the minimum water volume of the CST ensures that a sufficient quantity of the preferred source of clean feedwater is available for use during plant transients that require use of the AFW system. However, the CST's are not seismically qualified and NRC Branch Technical Position (RSB 5-1) Section G, "Auxiliary Feedwater Supply," states:

> *The Seismic Category 1 water supply for the auxiliary feedwater system for a PWR (pressure water reactor) shall have sufficient inventory to permit operation at hot shutdown for at least 4 hours, followed by cooldown to the conditions permitting operation of the residual heat removal (RHR) system. The inventory needed for cooldown shall be based on the longest cooldown time needed with either only onsite or only offsite power available with an assumed single failure.*

The AFW system is backed by an unlimited supply of water from the ERCW system, which is designed for seismic conditions (i.e., seismic Category 1) and meets single failure requirements (References 6 and 7). Hence, Sequoyah meets RSB 5-1 Section G.

In summary, the proposed revision to TS 3.7.1.3, "Condensate Storage Tank," minimum water volume from 190,000 gallons to 240,000 gallons reflects the additional amount of water necessary to cool the replacement steam generators of Unit 1 with the revised assumptions. TVA has proposed that both the Unit 1 and 2 TSs be revised because Unit 1 and Unit 2 CSTs are inter-connected. The proposed minimum water volume increase is the result of calculations performed by Framatome ANP. These calculations took into consideration the original calculations basis for the LCO for TS 3.7.1.3; the increase in structural mass of the new steam generators; a more limiting AFW temperature of 120°F, refill to the normal steam generator zero load level, and the recent upgrade in rated thermal power. Since the calculations were performed with a more limiting replacement steam generator for Unit 1, they are also applicable to the original Unit 2 steam generators.

5. REGULATORY SAFETY ANALYSIS

This license amendment request proposes to revise SQN's TS 3.7.1.3, "Condensate Storage Water," for Units 1 and 2 by increasing the minimum amount of stored water. Specifically, the minimum water volume value of 190,000 gallons will be replaced by 240,000 gallons such that the revised LCO will state:

"The condensate storage tank system (CST) shall be OPERABLE with a contained water volume of a least 240,000 gallons of water."

The associated TS Bases 3/4.7.1.3, "Condensate Storage Tank," also includes a proposed revision. This proposed revision will clarify the base for the minimum amount of water. This revision, as can be seen in Enclosure 3, will include the statement:

"and to subsequently reduce the reactor coolant system temperature to HOT SHUTDOWN conditions within 6 hours at which time the heat removal load is transferred to the residual heat removal system."

In summary, the minimum CST water volume of 190,000 gallons to be maintained during applicable modes will be increased to 240,000 gallons. This change reflects the necessary minimum amount of feedwater, with administrative margin, to assist in steam generator recovery of Unit 1 by removing primary stored and residual core energy for such events as loss of normal feedwater supply or secondary system pipe rupture. Because Unit 1 CST is inter-connected to the Unit 2 CST, this proposed change is conservatively requested for both units.

5.1 <u>No Significant Hazards Consideration</u>

TVA has evaluated whether or not a significant hazards consideration is involved with the proposed amendment(s) by focusing on the three standards set forth in 10 CFR 50.92, "Issuance of amendment," as discussed below:

1. Does the proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?

   Response: No.

   The proposed change does not change the physical design and construction of the condensate storage tank (CST). The purpose of the increased water volume is to ensure that the required volume of water, preserved by the technical specification (TS), is sufficient to meet Sequoyah Nuclear Plant (SQN) Licensing and Design Basis after installation of the replacement steam generators. The change in the administratively controlled inventory of the CST will not increase the probability of an accident. Therefore, the proposed change does not involve a significant increase in the probability of consequences of an accident previously evaluated.

2. Does the proposed change create the possibility of a new or different kind of accident from any accident previously evaluated?

   Response: No.

   This change increases the minimum required volume of water in the CST, thus ensuring that the auxiliary feedwater (AFW) system can perform its required safety function, using a preferred water source for plant transient mitigation. The maximum and normal water levels in the CST are not being changed. Additionally, increasing the minimum water volume requirement will not initiate any accident. Therefore, the proposed change does not create the possibility of a new or different kind of accident from any previously evaluated.

3. Does the proposed change involve a significant reduction in a margin of safety?

   Response: No.

   This change does not reduce any margin associated with the CST inventory available to AFW. The requirement for sufficient CST volume to maintain hot standby and subsequent cooldown to hot shutdown continues to be met by the minimum volume increase. Additionally, the essential raw cooling water (ERCW) system still provides the long-term supply of safety grade cooling water to the AFW in the event that all inventory of the CST is lost. Therefore, the proposed change does not involve a significant reduction in a margin of safety.

   Based on the above, TVA concludes that the proposed amendment(s) present no significant hazards consideration under the standards set forth in 10 CFR 50.92 (c), and accordingly, a finding of “no significant hazards consideration” is justified.

5.2 Applicable Regulatory Requirements/Criteria

The regulatory basis for TS 3.7.1.3, “Condensate Storage Tank,” is to provides a safety grade source of water to the steam generators for removing decay and sensible heat from the reactor coolant system (RCS). Sequoyah CST provides the primary and preferred source of AFW during plant transients. The ERCW is the backup safety-related system which meets the basis for providing a safety grade source of water.

10 CFR Part 50 General Design Criteria (GDC) 2, “Design bases for protection against natural phenomena,” requires structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

GDC 5, “Sharing of structures, systems, and components,” requires that SSCs important to safety shall not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units.

GDC 44, “Cooling water,” describes that a system to transfer heat from SSCs important to safety, to an ultimate heat sink shall be provided.

GDC 45, “Inspection of cooling water system,” defines that the cooling water system shall be designed to permit appropriate periodic inspection of important components, such as heat exchangers and piping, to assure the integrity and capability of the system.

GDC 46, “Testing of cooling water system,” requires that the cooling water system shall be designed to permit appropriate periodic pressure and functional testing.

Regulatory Guidance 1.29, “Seismic Design Classification,” describes the acceptable method for identifying and classifying those features of a light-water-cooled nuclear power plant that should be designed to withstand the effects of a Safe Shutdown Earthquake.

NRC Branch Technical Position RSB 5-1, “Design Requirements of the Residual Heat Removal System,” dated July 1981.

NUREG -0800, “U.S. NRC Standard Review Plan,” Section 9.2.6, “Condensate Storage Facilities,” provides guidance to the NRC staff for the review and evaluation of system design features from the CST to the connections or interfaces with other systems associated with the condensate storage facilities, which may or may not be safety related.

The CST is aligned to the AFW system as the primary and preferred source of cooling water for plant transients that result in a need for AFW. NUREG-0800, Standard Review Plan, Section 9.2.6, “Condensate Storage Facility,” provides guidelines to assure conformance with the requirements of General Design Criteria 2, 5, 44, 45, and 46. A condensate storage facility may not be safety related as in the case of Sequoyah’s CST, but it is recognized that a CST may have provisions to automatically transfer to a seismic Category I source. Sequoyah conforms with these requirements.

The TSs for the CST has once been amended to extend the limiting condition for operation of the CSTs to Mode 4 when steam generators are relied upon for heat removal. In the accompanying NRC safety evaluation report (SER) it was written that following a reactor trip, decay heat is dissipated by evaporating water in the steam generator and venting the steam either to the condensers or to the atmosphere. In such situations, steam generator water inventory must be maintained at a level sufficient to ensure adequate heat transfer and decay heat removal. The AFW system pumps deliver this emergency water supply to the steam generators. The AFW system provides emergency water to the steam generators until either normal feed water flow is established or the residual heat removal (RHR) system can assume the decay heat removal function. The primary sources of water for the AFW system pumps are the CSTs. On low suction pressure, the AFW pumps are designed to automatically swap to the ERCW.

The ERCW is a seismic Category 1 system (Reference 6). However in order to maintain our current license basis, preferred source, and an adequate amount of the primary source of cooling water, SQN has chosen to request a license amendment to increase the minimum amount of CST inventory.

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

6. ENVIRONMENTAL CONSIDERATION

A review has determined that the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, or would change an inspection or surveillance requirement. However, the proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 50.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

7. REFERENCES

1. Sequoyah Nuclear Plant, Final Safety Analysis Report (As Updated) Revision 17, Section 10.4.7.2.2, "System Description"
2. Sequoyah Nuclear Plant, Technical Specification Bases 3/4.7.1.3, "Condensate Storage Tank"
3. American Nuclear Society Document ANSI/ANS-5.1-1994, "American National Standard for Removing Decay Heat Power in Light Water Reactors," dated August 23, 1994

4. Letter to TVA from Westinghouse Electric Corporation, “AFW Flows and Condensate Storage Tank Volume,” dated May 23, 1993 (B38930607811)
5. Letter to TVA from Westinghouse Electric Corporation, “Required Auxiliary Feedwater Storage Quantity,” dated November 20, 1981 (811218F0714)
6. Sequoyah Nuclear Plant, Final Safety Analysis Report (As Updated) Revision 17, Section 9.2.2, “Essential Raw Cooling Water (ERCW)”
7. NUREG 0011 - Safety Evaluation Report for Sequoyah Nuclear Plant dated March 1979, Section 10.4.2, “Auxiliary Feedwater System”

ENCLOSURE 2

TENNESSEE VALLEY AUTHORITY
SEQUOYAH PLANT (SQN)
UNITS 1 AND 2

Proposed Technical Specification Changes (mark-up)

I. AFFECTED PAGE LIST

Unit 1

3/4 7-7

Unit 2

3/4 7-7

II. MARKED PAGES

See attached.

CONDENSATE STORAGE TANK

LIMITING CONDITION FOR OPERATION

3.7.1.3 A condensate storage tank system (CST) shall be OPERABLE with a contained water volume of at least ~~190,000~~ 240,000 gallons of water.

APPLICABILITY: MODES 1, 2 and 3,
MODE 4 when steam generator is relied upon for heat removal.

ACTION:

With the condensate storage tank system inoperable, within 4 hours either:

a. Restore the CST to OPERABLE status or be in at least HOT STANDBY within the next 6 hours and in HOT SHUTDOWN within the following 12 hours without reliance on steam generator for heat removal, or

b. Verify by administrative means OPERABILITY of the Essential Raw Cooling Water System as a backup supply to the auxiliary feedwater pumps* and restore the condensate storage tank to OPERABLE status within 7 days or be in at least HOT STANDBY within the next 6 hours and in HOT SHUTDOWN within the following 12 hours without reliance on steam generator for heat removal.

SURVEILLANCE REQUIREMENTS

4.7.1.3.1 The condensate storage tank system shall be demonstrated OPERABLE at least once per 12 hours by verifying the contained water volume is within its limits when the tank is the supply source for the auxiliary feedwater pumps.

* OPERABILITY shall be verified once per 12 hours following initial verification.

CONDENSATE STORAGE TANK

LIMITING CONDITION FOR OPERATION

3.7.1.3 The condensate storage tank system (CST) shall be OPERABLE with a contained water volume of at least ~~190,000~~ 240,000 gallons of water.

APPLICABILITY: MODES 1, 2 and 3,
MODE 4 when steam generator is relied upon for heat removal.

ACTION:

With the condensate storage tank system inoperable, within 4 hours either:

a. Restore the CST to OPERABLE status or be in at least HOT STANDBY within the next 6 hours and in HOT SHUTDOWN within the following 12 hours without reliance on steam generator for heat removal, or

b. Verify by administrative means OPERABILITY of the Essential Raw Cooling Water System as a backup supply to the auxiliary feedwater pumps* and restore the condensate storage tank to OPERABLE status within 7 days or be in at least HOT STANDBY within the next 6 hours and in HOT SHUTDOWN within the following 12 hours without reliance on steam generator for heat removal.

SURVEILLANCE REQUIREMENTS

4.7.1.3.1 The condensate storage tank system shall be demonstrated OPERABLE at least once per 12 hours by verifying the contained water volume is within its limits when the system is the supply source for the auxiliary feedwater pumps.

* OPERABILITY shall be verified once per 12 hours following initial verification.

ENCLOSURE 3

TENNESSEE VALLEY AUTHORITY
SEQUOYAH PLANT (SQN)
UNITS 1 AND 2

Changes to Technical Specifications Bases Pages

I. AFFECTED PAGE LIST

Unit 1

B3/4 7-2b

Unit 2

B3/4 7-2b

II. MARKED PAGES

See attached.

which are designated as Train A, receive A-train air, and provide flow to the same steam generators that are supplied by the B-train motor-driven auxiliary feedwater pump. The remaining two LCVs are designated as Train B, receive B-train air, and provide flow to the same steam generators that are supplied by the A-train motor-driven pump. This design provides the required redundancy to ensure that at least two steam generators receive the necessary flow assuming any single failure. It can be seen from the description provided above that the loss of a single train of air (A or B) will not prevent the auxiliary feedwater system from performing its intended safety function and is no more severe than the loss of a single auxiliary feedwater pump. Therefore, the loss of a single train of auxiliary air only affects the capability of a single motor-driven auxiliary feedwater pump because the turbine-driven pump is still capable of providing flow to two steam generators that are separate from the other motor-driven pump.

Two redundant steam sources are required to be operable to ensure that at least one source is available for the steam-driven auxiliary feedwater (AFW) pump operation following a feedwater or main steam line break. This requirement ensures that the plant remains within its design basis (i.e., AFW to two intact steam generators) given the event of a loss of the No. 1 steam generator because of a main steam line or feedwater line break and a single failure of the B-train motor driven AFW pump. The two redundant sources must be aligned such that No. 1 steam generator source is open and operable and the No. 4 steam generator source is closed and operable.

For instances where one train of emergency raw cooling water (ERCW) is declared inoperable in accordance with technical specifications, the AFW turbine-driven pump is considered operable since it is supplied by both trains of ERCW. Similarly, the AFW turbine-driven pump is considered operable when one train of the AFW loss of power start function is declared inoperable in accordance with Technical Specifications because both 6.9 kilovolt shutdown board logic trains supply this function. This position is consistent with American National Standards Institute/ANS 58.9 requirements (i.e., postulation of the failure of the opposite train is not required while relying on the TS limiting condition for operation).

3/4.7.1.3 CONDENSATE STORAGE TANK

The OPERABILITY of the condensate storage tank with the minimum water volume ensures that sufficient water is available to maintain the RCS at HOT STANDBY conditions for 2 hours with steam discharge to the atmosphere concurrent with total loss of off-site power. The contained water volume limit includes an allowance for water not useable because of tank discharge line location or other physical characteristics.

SENTENCE INSERT

and to subsequently reduce the reactor coolant system temperature to HOT SHUTDOWN conditions in 6 hours at which time the heat removal load is transferred to the residual heat removal system train air, and provide flow to the same steam generators that are supplied by the A-train motor-driven pump. This design provides the required redundancy to ensure that at least two steam generators receive the necessary flow assuming any single failure. It can be seen from the description provided above that the loss of a single train of air (A or B) will not prevent the auxiliary feedwater system from performing its intended safety function and is no more severe than the loss of a single auxiliary feedwater pump. Therefore, the loss of a single train of auxiliary air only affects the capability of a single motor-driven auxiliary feedwater pump because the turbine-driven pump is still capable of providing flow to two steam generators that are separate from the other motor-driven pump.

Two redundant steam sources are required to be operable to ensure that at least one source is available for the steam-driven auxiliary feedwater (AFW) pump operation following a feedwater or main steam line break. This requirement ensures that the plant remains within its design basis (i.e., AFW to two intact steam generators) given the event of a loss of the No. 1 steam generator because of a main steam line or feedwater line break and a single failure of the B-train motor driven AFW pump. The two redundant sources must be aligned such that No. 1 steam generator source is open and operable and the No. 4 steam generator source is closed and operable.

For instances where one train of emergency raw cooling water (ERCW) is declared inoperable in accordance with technical specifications, the AFW turbine-driven pump is considered operable since it is supplied by both trains of ERCW. Similarly, the AFW turbine-driven pump is considered operable when one train of the AFW loss of power start function is declared inoperable in accordance with technical specifications because both 6.9 kilovolt shutdown board logic trains supply this function. Similarly, the AFW turbine-driven pump is considered operable when one train of the AFW loss of power start function is declared inoperable in accordance with Technical Specifications because both 6.9 kilovolt shutdown board logic trains supply this function. This position is consistent with American National Standards Institute/ANS 58.9 requirements (i.e., postulation of the failure of the opposite train is not required while relying on the TS limiting condition for operation).

3/4.7.1.3 CONDENSATE STORAGE TANK

The OPERABILITY of the condensate storage tank with the minimum water volume ensures that sufficient water is available to maintain the RCS at HOT STANDBY conditions for 2 hours with steam discharge to the atmosphere concurrent with total loss of off-site power. The contained water volume limit includes an allowance for water not usable because of tank discharge line location or other physical characteristics.

SENTENCE INSERT

and to subsequently reduce the reactor coolant system temperature to HOT SHUTDOWN conditions in 6 hours at which time the heat removal load is transferred to the residual heat removal system

ENCLOSURE 4

TENNESSEE VALLEY AUTHORITY
SEQUOYAH PLANT (SQN)
UNITS 1 AND 2

Framatome ANP, SQN Condensate Volume Requirement Verification

B38 021104 802

QA Record

NOV 04 2002

Framatome Advanced Nuclear Power (FANP)
P. O. Box 10935
Lynchburg, Virginia 24506-0935

Attention: Mr. W. L. Redd

Gentlemen:

SEQUOYAH NUCLEAR PLANT UNITS 1 AND 2 - ENGINEERING AND ANALYSIS SUPPORT SERVICES - CONTRACT 99NNQ-256540 - LETTER TVFTI-071

CONTRACT WORK AUTHORIZATION NO. N2000-001 - DOCUMENT SUBMITTAL - CONDENSATE STORAGE TANK MINIMUM CONTAINTED VOLUME EVALUATION - N2N-057

We acknowledge receipt of the document listed below submitted by Letter FANP-02-2442 and return herewith one copy marked (A), "Approved".

Document No.	Revision	Title
32-5014532	00	Condensate Storage Tank (CST) Minimum Contained Volume Calculation, Unit 1 and 2

The subject calculation evaluates the Sequoyah replacement steam generators with respect to the minimum contained CST volume requirement in Section 3.7.1.3 of the Sequoyah Technical Specifications. The calculation models the changes in the steam generator tube heat transfer surface area and heat transfer coefficient and establishes the minimum CST volume requirements for plant cooldown following a full power reactor trip to residual heat removal operating conditions. The calculation also evaluates the effect of assumed condensate temperature and steam generator level on the minimum volume requirements.

We have reviewed the subject calculation and note that the minimum required CST volume for the replacement steam generators using the currently assumed nominal condensate temperature (100°F) and post-trip steam generator level (no refill) is 188,700 gallons. However, we also note that the calculation is based on decay heat calculated using the 1994 American Nuclear Society (ANS) decay heat standard. Since the current condensate temperature and steam generator refill assumptions are predicated on the use of a conservative decay heat generation model (i.e., the 1970 Westinghouse Electric Company decay heat model), we do not consider continued use of these assumptions to be appropriate for use with the 1994 ANS decay heat standard. Based on a bounding condensate temperature of 120°F and a steam generator post-trip refill level assumption consistent with current operating practice (i.e., 39 percent of the narrow range instrument span), the subject calculation establishes a minimum CST contained volume requirement of 228,000 gallons. We plan to adopt this value as the revised safety analysis limit for operation with the replacement steam generators. Since this value exceeds the 190,000 gallon minimum contained volume requirement in Section 3.7.1.3 of the Sequoyah Technical Specifications, we have initiated Sequoyah Technical Specification Change Request No. TVA-SQN-TS-02-06 to increase the current CST contained volume operability limit from 190,000 gallons to 240,000 gallons. Because the Sequoyah Unit 1 and Unit 2 condensate storage tanks are interconnected, this change will be made to the Unit 2 Technical Specifications as well as the Unit 1 Specifications.

Please note we have made the following annotations to the TVA approved copies of the subject document.

1. Page 4 - To be consistent with the operating mode definitions given in Table 1.1 of the Sequoyah Technical Specifications, we have annotated the second paragraph in Section 1.1 on this page to read, "The reactor is tripped and the plant is cooled in hot standby conditions for a 2 hour time frame. In the following 6 hours, the plant is cooled from hot standby to hot shutdown (i.e., residual heat removal cut-in conditions)."

2. Page 85 - To be consistent with Section 1.1, we have annotated Section 8.1 on this page to read, "...the plant is tripped from full power and cooled in hot standby conditions over a 2-hour period followed by a cool down to RHR cut-in conditions in 6 hours; a total of 8 hours."

Please adjust your records as necessary to reflect these annotations. Please incorporate these annotations in the text of the document should it be revised for any other reason.

The above document was prepared as part of the nuclear steam supply and balance-of-plant systems review performed by FANP under Section 2.7 of the proposal submitted by Letter FTI-99-2241. The calculation is based on design input information provided by Letter TVFTI-057 concerning the technical basis for the current CST contained volume requirement.

Please contact D. M. Lafever at Sequoyah (423-843-8377) if you have any questions or comments regarding the content of this submittal.

Sincerely,

for P. G. Trudel, Project Engineer
Steam Generator Replacement Project

Enclosure

JMO 11/4

DML:JS

cc: Framatome Advanced Nuclear Power
Attn: Mr. F. X. Masseth
P. O. Box 10935
Lynchburg, Virginia 24506-0935

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P. C. Askins, OPS 1A-SQN
R. H. Bryan, LP 4J-C
C. Carey, OPS 2B-SQN, w/1
R. E. Griffith, OPS 2B-SQN, w/1
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J. F. Thomas, OPS 2B-SQN
P. G. Trudel, MPB 1A-SQN, w/1
*RIMS, WTC A-K, w/1

*B38 021014 804, B38 990930 805, B38 011220 802

Attachment

B88 021104 800

QA Record B88 021104 800

FRAMATOME ADVANCED NUCLEAR POWER

CONDENSATE STORAGE TANK MINIMUM CONTAINED VOLUME CALCULATION FOR STEAM GENERATOR REPLACEMENT

SEQUOYAH UNIT 1 AND 2

DOCUMENT NO. 32-5014532
REVISION 00

APPROVED

This approval does not release the Contractor from any part of his responsibility for the correctness of design, details and dimensions.

Letter No. TVFTI-071

Date: November 04, 2002

TENNESSEE VALLEY AUTHORITY

SQEP (N) BY P.G. Trudel

PROJECT Sequoyah DISCIPLINE N
CONTRACT 99NNQ-256540 UNIT 1 and 2
DESC. SG Replacement CST Minimum Volume
DWG/DOC NO. 32-5014532
SHEET - OF - REV. 00
DATE 11/04/02 ECN/DCN - FILE N2N-057

RIMS, WTC A-K

FRAMATOME ANP

CALCULATION SUMMARY SHEET (CSS)

Document Identifier 32 - 5014532 - 00

Title SQN CONDENSATE VOLUME REQUIREMENT VERIFICATION

PREPARED BY:

NAME MARK L. MILLER

SIGNATURE [signature]

TITLE PE DATE 6/7/02

COST CENTER 41016 REF. PAGE(S) 86

REVIEWED BY:

METHOD: ☒ DETAILED CHECK ☐ INDEPENDENT CALCULATION

NAME SD Blair

SIGNATURE [signature]

TITLE ENG III DATE 6/7/02

TM STATEMENT: REVIEWER INDEPENDENCE [signature]

PURPOSE AND SUMMARY OF RESULTS:

TVA will replace steam generators at SQN, Unit 1. Scoping calculations reveal that slightly more auxiliary feedwater (AFW) is required to cool the replacements (RSGs) from normal operation to RHR cut-in than it would to cool the original steam generators (OSGs). This file provides verification that the plant cooldown with RSGs can be accommodated within the existing Technical Specification requirement of 190,000 gallons of condensate storage tank (CST) water, given the current calculational basis.

The calculations of this file were extended beyond a simple verification of existing Technical Specification. CST volume requirements were defined for (1) a more limiting AFW temperature of 120 F - the original calculations were performed with an AFW temperature of 100 F and (2) for varied final "re-filled" steam generator secondary states at RHR cut-in - current calculational bases do not account for re-fill. Since the calculations were performed with the more limiting RSGs, they are applicable to the OSGs as well and allow TVA the flexibility of improving plant margins commensurate with a Technical Specification change with regards to the CST volume requirement.

CST volume requirements were generated with a special formulation of the First Law of Thermodynamics. Calculations consider the removal of decay heat, the cooling of primary and secondary metals and contained fluids, and accounts for the normal makeup required to balance the shrinkage of the primary system fluid owing to the cooldown. The following CST requirements were generated in this file:

CST Requirement, Cooldown from Full Power to RHR Cut-In, Gallons

	100 F AFW	120 F AFW
Initial SG Mass at RHR Cut-In	188,700	193,000
SG Tubes Covered by Liquid at RHR Cut-In	195,200	199,600
0% NRL at RHR Cut-In	207,400	212,000
39% NRL at RHR Cutin	223,000	228,000

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV
RELAP5/Mod2-BW v. 24.0HP	

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

☐ YES ☒ NO

1.1 Introduction

This calculation seeks to establish a basis for the Sequoyah Technical Specification condensate storage tank (CST) inventory requirement. The work herein is performed as part of the SG replacement program. Although the replacement steam generator is used in these calculations the difference in energy content between the original and the replacement steam generator is minimal. The calculations in this file are applicable to both generator designs - to both Units 1 and 2.

Inputs to the original calculations related to the existing CST inventory requirement were examined and the cooldown associated with the original calculation was adapted for this work. The reactor is tripped and the plant is cooled ~~to hot shutdown conditions within~~ in hot standby conditions for a 2-hour time frame. In the following 6 hours, the plant is cooled from hot ~~shutdown to~~ standby to hot shutdown (i.e., residual heat removal (RHR) cut-in conditions).

Plant parameters are initially based on a RELAP5 steady-state run conducted in Reference1. The energy content associated with the heat structures and fluid content contained in the reactor coolant system (RCS) pressure boundary and the SG secondary from the main feedwater piping (at the point of auxiliary feedwater (AFW) entry) to the steam lines (at the turbine) are considered. Core heat production associated with decay heat is simulated with the 1994 ANS standard with B&W heavy actinide contribution.

Thermodynamic "first law" formulation was ultimately applied to determine the needed volume of AFW needed to cool the plant to each operational statepoint. Parametric studies are included in these calculations, allowing TVA to make decisions regarding AFW temperature and final, RHR cut-in, SG secondary inventory.

1.2 Important Inputs

- Full power core energy content is accounted for in these calculations. Only decay heat is modeled, however, and the initial core heat generated during the reactor trip is ignored in these calculations. The coastdown and isolation of the main feedwater system - also not modeled - is sufficiently delayed to provide the inventory needed to accommodate the rapidly decaying core power.

- All steel heat structures, stainless and carbon-, are combined for simplification. Material properties are compared and those properties resulting in the maximum heat content difference between operational modes (maximized AFW requirement) are applied.

- The original calculations performed as the basis for the existing CST volume Technical Specification requirement do not account for the operation of reactor coolant pumps. The plant is, therefore, cooled by natural circulation. As a result, there is a measurable difference between the hot and cold leg fluid temperature for shut-down conditions. This difference is accounted for in the calculation of plant structure and fluid energy content via a conservative approximation of this hot - to - cold leg temperature difference.

6/7/02

8.1 Results and Conclusions

The condensate storage tank inventory requirement was examined in this calculation. The original ~~basis~~ regarding cooldown is adapted -- the plant is tripped from full power and cooled (in) hot ~~shutdown~~ standby conditions over a 2-hour period followed by a cool-down to RHR cut-in conditions in ~~8~~ (6) hours; a total of 8 hours. Parametric studies regarding the auxiliary feedwater temperature and SG secondary inventory conditions - at RHR cut-in - were performed. Results of the study are detailed in Table 15.

Table 15
Condensate Storage Tank Inventory Requirement

Cooldown from full-power to hot shutdown conditions:	
100 F AFW temperature	68,400 gal
120 F AFW temperature	70,000 gal
Cooldown from full-power to RHR cut-in conditions:	
No change in SG secondary inventory	
100 F AFW temperature	188,700 gal
120 F AFW temperature	193,000 gal
SG tubes covered by secondary inventory at RHR cut-in	
100 F AFW temperature	195,200 gal
120 F AFW temperature	199,600 gal
0% Narrow Range Level at RHR cut-in	
100 F AFW temperature	207,400 gal
120 F AFW temperature	212,000 gal
39% Narrow Range Level at RHR cut-in	
100 F AFW temperature	223,000 gal
120 F AFW temperature	228,000 gal

[signature] 6/7/02

FRAMATOME ANP

CALCULATION SUMMARY SHEET (CSS)

Document Identifier 32 - 5014532 - 00

Title SQN CONDENSATE VOLUME REQUIREMENT VERIFICATION

PREPARED BY:		REVIEWED BY:	
		METHOD: ☒ DETAILED CHECK ☐ INDEPENDENT CALCULATION	
NAME MARK L. MILLER		NAME SD Blair	
SIGNATURE [signature]		SIGNATURE [signature]	
TITLE PE	DATE 6/7/02	TITLE ENG III	DATE 6/7/02
COST CENTER 41016	REF. PAGE(S) 86	TM STATEMENT: REVIEWER INDEPENDENCE [signature]	

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THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

☐ YES ☒ NO

Revision Log

Revision Level	Description
00	Original Issue

6/7/02

Table of Contents **Page**

6/7/02

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6/7/02

2.1 Primary and Secondary Heat Structures

The primary and secondary heat structure inputs are compiled from an examination of the Reference 1 RELAP5 input deck for run **sqslbocnul/XVDG, dated 10/17/00**. This deck is the null transient deck used in the preparation of the steam line break outside containment RELAP5 model in Reference 1 and includes the W/CE replacement steam generator. The deck is retrieved and exercised over a period of 0.5 seconds to give a good copy of the input summary for the compilation of heat structure data. This "short" run is identified as **sqss/XWEL, dated 2/7/02**.

Table 1 lists all of the heat structures associated with the reactor coolant system, core, and steam generator secondary model components. Geometric data is included in Table 1: structure geometries, the inside dimensions, outside dimensions, and surface area factors. Structure volume is not available in the short run output but is calculated in Table 1 as follows:

Slab:

$$V_{Slab} = (R_o - R_i) \bullet A_{SF}$$

Cylinder:

$$V_{Cylinder} = \pi\left(R_o^{\,2} - R_i^{\,2}\right) \bullet A_{SF}$$

Sphere:

$$V_{Sphere} = \frac{4}{3}\pi\left(R_o^{\,3} - R_i^{\,3}\right) \bullet A_{SF}$$

where,

V = structure volume
R_o = outside dimension
R_i = inside dimension
A_{SF} = surface area factor

Structure volumes are summed for each major model structure component in Table 1.

SDR. Sr 4/7/02

Table 1
RELAP5 Model Heat Structure Geometry Compilation

	structure number	description	geometry	left dimension, ft	right dimension, ft	surface area entry	structure volume, ft^3
RCS	1001001	3x hot leg noz	cyl	1.2098	1.473	1.0017E+01	22.22
	1051001	3x hot leg	cyl	1.2098	1.4136	1.5285E+01	25.67
	1051002	3x hot leg	cyl	1.2098	1.4136	2.3490E+01	39.45
	1051003	3x hot leg	cyl	1.2098	1.4136	1.9107E+01	32.09
	1201001	3x rsg in	sph	5.2342	5.7925	7.5000E-01	160.08
	1202001	3x rsg div plate	rec	0	0.16667	1.2910E+02	21.52
	1211001	3x rsg in ts	rec	0	2.10413	1.1312E+02	238.02
	1251001	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251002	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251003	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251004	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251005	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251006	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251007	3x rsg tubes	cyl	0.02767	0.03125	3.4673E+04	22.98
	1251008	3x rsg tubes	cyl	0.02767	0.03125	3.4673E+04	22.98
	1251009	3x rsg tubes	cyl	0.02767	0.03125	3.4673E+04	22.98
	1251010	3x rsg tubes	cyl	0.02767	0.03125	3.4673E+04	22.98
	1251011	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251012	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251013	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251014	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251015	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1251016	3x rsg tubes	cyl	0.02767	0.03125	6.1017E+04	40.43
	1291001	3x rsg out ts	rec	0	2.10413	1.1312E+02	238.02
	1301001	3x rsg out	sph	5.2342	5.7925	7.5000E-01	160.08
	1351001	3x cold leg ps	cyl	1.2927	1.5094	1.4631E+01	27.91
	1351002	3x cold leg ps	cyl	1.2927	1.5094	1.3584E+01	25.91
	1351003	3x cold leg ps	cyl	1.2927	1.5094	2.1207E+01	40.45
	1351004	3x cold leg ps	cyl	1.2927	1.5094	1.0560E+01	20.14
	1351005	3x cold leg ps	cyl	1.2927	1.5094	2.1207E+01	40.45
	1601001	3x pump metal	cyl	4.3315	4.8405	7.2034E+02	10564.98
	1651001	3x cold leg	cyl	1.1475	1.34125	1.1688E+01	17.71
	1651002	3x cold leg	cyl	1.1475	1.34125	4.5597E+01	69.07
	1701001	3x cold leg noz	cyl	1.1475	1.476	1.4475E+01	39.19
	2001001	1x hot leg	cyl	1.2098	1.473	3.3390E+00	7.41
	2051001	1x hot leg	cyl	1.2098	1.4136	5.0950E+00	8.56
	2051002	1x hot leg	cyl	1.2098	1.4136	7.8300E+00	13.15
	2051003	1x hot leg	cyl	1.2098	1.4136	6.3690E+00	10.70
	2201001	1x rsg in	sph	5.2342	5.7925	2.5000E-01	53.36
	2202001	1x rsg div plate	rec	0	0.16667	4.3034E+01	7.17
	2211001	1x rsg in ts	rec	0	2.10413	3.7705E+01	79.34
	2251001	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2251002	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2251003	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2251004	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48

[signature] 6/7/02

Table 1
RELAP5 Model Heat Structure Geometry Compilation

	structure number	description	geometry	left dimension, ft	right dimension, ft	surface area entry	structure volume, ft^3
	2251005	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2251006	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2251007	1x rsg tubes	cyl	0.02767	0.03125	1.1558E+04	7.66
	2251008	1x rsg tubes	cyl	0.02767	0.03125	1.1558E+04	7.66
	2251009	1x rsg tubes	cyl	0.02767	0.03125	1.1558E+04	7.66
	2251010	1x rsg tubes	cyl	0.02767	0.03125	1.1558E+04	7.66
	2251011	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2251012	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2251013	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2251014	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2251015	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2251016	1x rsg tubes	cyl	0.02767	0.03125	2.0339E+04	13.48
	2291001	1x rsg out ts	rec	0	2.10413	3.7705E+01	79.34
	2301001	1x rsg out	sph	5.2342	5.7925	2.5000E-01	53.36
	2351001	1x cold leg ps	cyl	1.2927	1.5094	4.8770E+00	9.30
	2351002	1x cold leg ps	cyl	1.2927	1.5094	4.5280E+00	8.64
	2351003	1x cold leg ps	cyl	1.2927	1.5094	7.0690E+00	13.48
	2351004	1x cold leg ps	cyl	1.2927	1.5094	3.5200E+00	6.71
	2351005	1x cold leg ps	cyl	1.2927	1.5094	7.0690E+00	13.48
	2601001	1x pump metal	cyl	4.3315	4.8405	2.4011E+02	3521.66
	2651001	1x cold leg	cyl	1.1475	1.34125	3.8960E+00	5.90
	2651002	1x cold leg	cyl	1.1475	1.34125	1.5199E+01	23.02
	2701001	1x cold leg noz	cyl	1.1475	1.476	4.8250E+00	13.06
	3001001	3x dc shell	cyl	7.2083	8.0838	5.2500E+00	220.82
	3001002	3x dc shell	cyl	7.2083	8.0838	2.9380E+00	123.57
	3001003	3x dc shell	cyl	7.2083	8.0838	4.9630E+00	208.75
	3001004	3x dc shell	cyl	7.2083	8.0838	4.9630E+00	208.75
	3021001	3x therm sh	cyl	6.604	6.837	2.4375E+00	23.98
	3021002	3x therm sh	cyl	6.604	6.837	2.5425E+00	25.01
	3021003	3x therm sh	cyl	6.604	6.837	3.1350E+00	30.84
	3021004	3x therm sh	cyl	6.604	6.837	3.3975E+00	33.43
	3081001	3x rv shell	cyl	7.2083	7.9064	5.6070E+00	185.86
	3101001	rv bottom	sph	7.346	8.01235	1.9810E-01	97.88
	3121001	3x bh internals	rec	0	0.04167	9.6940E+02	40.39
	3121002	3x bh internals	rec	0	0.04167	1.2081E+03	50.34
	3121003	3x bh internals	rec	0	0.04167	1.4699E+03	61.25
	3131001	1x bh internals	rec	0	0.04167	4.0270E+02	16.78
	3131002	1x bh internals	rec	0	0.04167	4.9000E+02	20.42
	3401001	3x baf pl	rec	0	0.09375	1.6012E+02	15.01
	3401002	3x baf pl	rec	0	0.09375	1.6012E+02	15.01
	3401003	3x baf pl	rec	0	0.09375	1.6012E+02	15.01
	3411001	1x baf pl	rec	0	0.09375	5.3370E+01	5.00
	3411002	1x baf pl	rec	0	0.09375	5.3370E+01	5.00
	3411003	1x baf pl	rec	0	0.09375	5.3370E+01	5.00
	3481001	3x n shield	cyl	6.1667	6.3542	1.5000E+00	11.06
	3481002	3x n shield	cyl	6.1667	6.3542	1.5000E+00	11.06

[signature] 6/7/02

Table 1
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	structure number	description	geometry	left dimension, ft	right dimension, ft	surface area entry	structure volume, ft^3
	3481003	3x n shield	cyl	6.1667	6.3542	1.5000E+00	11.06
	3481004	3x n shield	cyl	6.1667	6.3542	1.5000E+00	11.06
	3481005	3x n shield	cyl	6.1667	6.3542	1.5000E+00	11.06
	3481006	3x n shield	cyl	6.1667	6.3542	1.5000E+00	11.06
	3491001	1x n shield	cyl	6.1667	6.3542	5.0000E-01	3.69
	3491002	1x n shield	cyl	6.1667	6.3542	5.0000E-01	3.69
	3491003	1x n shield	cyl	6.1667	6.3542	5.0000E-01	3.69
	3491004	1x n shield	cyl	6.1667	6.3542	5.0000E-01	3.69
	3491005	1x n shield	cyl	6.1667	6.3542	5.0000E-01	3.69
	3491006	1x n shield	cyl	6.1667	6.3542	5.0000E-01	3.69
	3531001	1x up internals	rec	0	0.04167	4.9400E+02	20.58
	3551001	core barrel	cyl	6.1667	6.3542	3.1220E+00	23.03
	3551002	core barrel	cyl	6.1667	6.3542	3.8630E+00	28.49
	3551003	core barrel	cyl	6.1667	6.3542	3.0620E+00	22.58
	3551004	core barrel	cyl	6.1667	6.3542	3.4430E+00	25.39
	3551005	core barrel	cyl	6.1667	6.3542	1.0410E+00	7.68
	3551006	core barrel	cyl	6.1667	6.3542	1.2880E+00	9.50
	3551007	core barrel	cyl	6.1667	6.3542	1.0210E+00	7.53
	3551008	core barrel	cyl	6.1667	6.3542	1.1480E+00	8.47
	3601001	3x up internals	rec	0	0.04167	1.4820E+03	61.75
	3601002	3x up internals	rec	0	0.04167	1.0650E+03	44.38
	3601003	3x up internals	rec	0	0.04167	1.4800E+03	61.67
	3601004	3x up internals	rec	0	0.04167	7.7200E+02	32.17
	3601005	3x up internals	rec	0	0.04167	1.8210E+03	75.88
	3601006	3x up internals	rec	0	0.04167	1.0160E+03	42.34
	3641001	rv head	sph	6.9583	7.8918	2.5000E-01	161.90
	3641002	rv head	sph	6.9583	7.8918	2.5000E-01	161.90
	3661001	1x dc shell	cyl	7.2083	8.0838	1.7500E+00	73.61
	3661002	1x dc shell	cyl	7.2083	8.0838	9.7900E-01	41.18
	3661003	1x dc shell	cyl	7.2083	8.0838	1.6540E+00	69.57
	3661004	1x dc shell	cyl	7.2083	8.0838	1.6540E+00	69.57
	3681001	1x therm sh	cyl	6.604	6.837	8.1250E-01	7.99
	3681002	1x therm sh	cyl	6.604	6.837	8.4750E-01	8.34
	3681003	1x therm sh	cyl	6.604	6.837	1.0450E+00	10.28
	3681004	1x therm sh	cyl	6.604	6.837	1.1325E+00	11.14
	3741001	1x rv shell	cyl	7.2083	7.9064	1.8690E+00	61.95
	4001001	surge line	cyl	0.4662	0.5833	5.9120E+01	22.83
	4101001	pzr	cyl	3.5	3.8073	6.5318E+00	46.08
	4101002	pzr	cyl	3.5	3.8073	6.5318E+00	46.08
	4101003	pzr	cyl	3.5	3.8073	6.5318E+00	46.08
	4101004	pzr	cyl	3.5	3.8073	6.5318E+00	46.08
	4101005	pzr	cyl	3.5	3.8073	6.5318E+00	46.08
	4101006	pzr	cyl	3.5	3.8073	6.5318E+00	46.08
	4101007	pzr	cyl	3.5	3.8073	6.5318E+00	46.08
	4101008	pzr	cyl	3.5	3.8073	6.5318E+00	46.08
				RCS Metal Volume, ft^3 =			**19517.1**

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Table 1
RELAP5 Model Heat Structure Geometry Compilation

	structure number	description	geometry	left dimension, ft	right dimension, ft	surface area entry	structure volume, ft^3
Core	3301001	3x clad	cyl	0.0135833	0.0155833	7.6428E+04	14.01
	3301002	3x clad	cyl	0.0135833	0.0155833	7.6428E+04	14.01
	3301003	3x clad	cyl	0.0135833	0.0155833	7.6428E+04	14.01
	3301004	3x clad	cyl	0.0135833	0.0155833	7.6428E+04	14.01
	3301005	3x clad	cyl	0.0135833	0.0155833	7.6428E+04	14.01
	3301006	3x clad	cyl	0.0135833	0.0155833	7.6428E+04	14.01
	3301001	3x fuel	cyl	0	0.0133125	7.6428E+04	42.55
	3301002	3x fuel	cyl	0	0.0133125	7.6428E+04	42.55
	3301003	3x fuel	cyl	0	0.0133125	7.6428E+04	42.55
	3301004	3x fuel	cyl	0	0.0133125	7.6428E+04	42.55
	3301005	3x fuel	cyl	0	0.0133125	7.6428E+04	42.55
	3301006	3x fuel	cyl	0	0.0133125	7.6428E+04	42.55
	3311001	1x clad	cyl	0.0135833	0.0155833	2.5476E+04	4.67
	3311002	1x clad	cyl	0.0135833	0.0155833	2.5476E+04	4.67
	3311003	1x clad	cyl	0.0135833	0.0155833	2.5476E+04	4.67
	3311004	1x clad	cyl	0.0135833	0.0155833	2.5476E+04	4.67
	3311005	1x clad	cyl	0.0135833	0.0155833	2.5476E+04	4.67
	3311006	1x clad	cyl	0.0135833	0.0155833	2.5476E+04	4.67
	3311001	1x fuel	cyl	0	0.0133125	2.5476E+04	14.18
	3311002	1x fuel	cyl	0	0.0133125	2.5476E+04	14.18
	3311003	1x fuel	cyl	0	0.0133125	2.5476E+04	14.18
	3311004	1x fuel	cyl	0	0.0133125	2.5476E+04	14.18
	3311005	1x fuel	cyl	0	0.0133125	2.5476E+04	14.18
	3311006	1x fuel	cyl	0	0.0133125	2.5476E+04	14.18
				clad volume, ft^3 =			**112.0**
				fuel volume, ft^3 =			**340.4**

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Table 1
RELAP5 Model Heat Structure Geometry Compilation

	structure number	description	geometry	left dimension, ft	right dimension, ft	surface area entry	structure volume, ft^3
1x SG Sec	6001001	1x feedring	cyl	0.40625	0.4479	4.4110E+01	4.93
	6201001	1x lo shell	cyl	5.3908	5.6258	1.1500E+01	93.53
	6201002	1x lo shell	cyl	5.3908	5.6258	8.1633E+00	66.39
	6201003	1x lo shell	cyl	5.3908	5.6258	8.1633E+00	66.39
	6201004	1x lo shell	cyl	5.3908	5.6258	8.1633E+00	66.39
	6202001	1x lo shell	cyl	7.0208	7.3308	9.9000E-01	13.84
	6301001	1x shroud	cyl	5	5.0833	4.0817E+00	10.77
	6301002	1x shroud	cyl	5	5.0833	4.0817E+00	10.77
	6301003	1x shroud	cyl	5	5.0833	4.0817E+00	10.77
	6301004	1x shroud	cyl	5	5.0833	4.0817E+00	10.77
	6301005	1x shroud	cyl	5	5.0833	4.0817E+00	10.77
	6301006	1x shroud	cyl	5	5.0833	4.0817E+00	10.77
	6301007	1x shroud	cyl	5	5.0833	7.7000E+00	20.32
	6301008	1x shroud	cyl	5	5.0833	3.3500E+00	8.84
	6302001	1x tube supp	rec	0	0.04167	5.3900E+01	2.25
	6302002	1x tube supp	rec	0	0.04167	5.3900E+01	2.25
	6302003	1x tube supp	rec	0	0.04167	5.3900E+01	2.25
	6302004	1x tube supp	rec	0	0.04167	5.3900E+01	2.25
	6302005	1x tube supp	rec	0	0.04167	5.3900E+01	2.25
	6302006	1x tube supp	rec	0	0.04167	5.3900E+01	2.25
	6303001	1x u support	rec	0	0.2	1.0057E+02	20.11
	6361001	1x up shell	cyl	7.0208	7.3308	2.1800E+00	30.47
	6361002	1x up shell	cyl	7.0208	7.3308	7.6800E+00	107.34
	6361003	1x up shell	cyl	7.0208	7.3308	5.3700E+00	75.06
	6361004	1x up shell	cyl	7.0208	7.3308	3.0000E+00	41.93
	6451001	1x sep	cyl	0.48875	0.50875	3.9600E+01	2.48
	6451002	1x sep	cyl	0.48875	0.50875	8.7200E+01	5.47
	6451003	1x sep	cyl	0.48875	0.50875	3.0720E+02	19.25
	6601001	1x sec sep	rec	0	0.08333	3.2034E+02	26.69
	6701001	1x st dome	sph	12.255	12.565	1.4360E-01	86.16
				1x SG Metal Volume, ft^3 =			**833.7**

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Table 1
RELAP5 Model Heat Structure Geometry Compilation

	structure number	description	geometry	left dimension, ft	right dimension, ft	surface area entry	structure volume, ft^3
3x SG Sec	7001001	3x feedring	cyl	0.40625	0.4479	1.3233E+02	14.79
	7201001	3x lo shell	cyl	5.3908	5.6258	3.4500E+01	280.60
	7201002	3x lo shell	cyl	5.3908	5.6258	2.4490E+01	199.18
	7201003	3x lo shell	cyl	5.3908	5.6258	2.4490E+01	199.18
	7201004	3x lo shell	cyl	5.3908	5.6258	2.4490E+01	199.18
	7202001	3x lo shell	cyl	7.0208	7.3308	2.9700E+00	41.51
	7301001	3x shroud	cyl	5	5.0833	1.2250E+01	32.32
	7301002	3x shroud	cyl	5	5.0833	1.2250E+01	32.32
	7301003	3x shroud	cyl	5	5.0833	1.2250E+01	32.32
	7301004	3x shroud	cyl	5	5.0833	1.2250E+01	32.32
	7301005	3x shroud	cyl	5	5.0833	1.2250E+01	32.32
	7301006	3x shroud	cyl	5	5.0833	1.2250E+01	32.32
	7301007	3x shroud	cyl	5	5.0833	2.3100E+01	60.96
	7301008	3x shroud	cyl	5	5.0833	1.0050E+01	26.52
	7302001	3x tube supp	rec	0	0.04167	1.6170E+02	6.74
	7302002	3x tube supp	rec	0	0.04167	1.6170E+02	6.74
	7302003	3x tube supp	rec	0	0.04167	1.6170E+02	6.74
	7302004	3x tube supp	rec	0	0.04167	1.6170E+02	6.74
	7302005	3x tube supp	rec	0	0.04167	1.6170E+02	6.74
	7302006	3x tube supp	rec	0	0.04167	1.6170E+02	6.74
	7303001	3x u support	rec	0	0.2	3.0170E+02	60.34
	7361001	3x up shell	cyl	7.0208	7.3308	6.5400E+00	91.41
	7361002	3x up shell	cyl	7.0208	7.3308	2.3040E+01	322.03
	7361003	3x up shell	cyl	7.0208	7.3308	1.6110E+01	225.17
	7361004	3x up shell	cyl	7.0208	7.3308	9.0000E+00	125.79
	7451001	3x sep	cyl	0.48875	0.50875	1.1880E+02	7.45
	7451002	3x sep	cyl	0.48875	0.50875	2.6160E+02	16.40
	7451003	3x sep	cyl	0.48875	0.50875	9.2160E+02	57.76
	7601001	3x sec sep	rec	0	0.08333	9.6102E+02	80.08
	7701001	3x st dome	sph	12.255	12.565	4.3000E-01	257.99
				3x SG Metal Volume, ft^3 =			**2500.7**

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2.2 Steam Line Piping

There are no steam line piping heat structures in the RELAP5 model. However, the steam line is modeled with hydraulic control volumes and give good information regarding line lengths, flow area, etc. Table 2 includes control volume data (flow area and CV length) from the RELAP5 short run **sqss/XWEL, dated 2/7/02.**

Table 2 also includes information taken from Section 3.12 of Reference 1, the steam line model development documentation. Piping outside diameter (OD) and the number of parallel piping runs in each control volume from this section are included in Table 2. The steam line pipe structural volume for a given control volume is calculated as:

$$V_{Piping} = \left(\pi n \frac{D_o^{\,2}}{4} - A_{CV} \right) \bullet L$$

where,

V = structure volume
n = number of parallel piping runs in CV
Do = outside piping diameter
L = CV length

Structure volumes are summed for the steam lines in Table 2.

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Table 2
Steam Line Piping Structural Volume Compilation

node	designation	flow area, ft^2	length	od, inch	number parallel	pipe volume, ft^3
675010000	st line 1	4.8512	14.2321	32	1	10.44
675020000	st line 2	4.8512	8	32	1	5.87
675030000	st line 3	4.8512	44.137	32	1	32.39
675040000	st line 4	4.8512	35.555	32	1	26.09
676010000	st line 5	4.8512	25.189	32	1	18.49
677010000	st line 6	4.8512	44.401	32	1	32.58
680010000	st line 7	4.8512	19.031	32	1	13.97
680020000	st line 8	6.1509	46.343	36	1	42.53
680030000	st line 9	6.1509	46.343	36	1	42.53
680040000	st line 10	6.1509	46.343	36	1	42.53
680050000	st line 11	6.1509	46.343	36	1	42.53
680060000	st line 12	6.1509	46.343	36	1	42.53
680070000	st line 13	6.1509	46.343	36	1	42.53
680080000	st line 14	6.1509	46.343	36	1	42.53
680090000	st line 15	6.1509	46.343	36	1	42.53
680100000	st line 16	6.1509	46.343	36	1	42.53
680110000	st line 17	6.1509	46.343	36	1	42.53
681010000	st line 18	6.1509	39.779	36	1	36.50
683010000	st line 19	24.6036	16.569	36	4	60.82
683020000	st line 20	24.6036	14.647	36	4	53.77
683030000	st line 21	24.6036	15.569	36	4	57.15
683040000	st line 22	14.884	13	28	4	28.86
692010000	st line 23	6.1509	53.894	36	1	49.46
692020000	st line 24	6.1509	69.66	36	1	63.93
692030000	st line 25	6.1509	69.66	36	1	63.93
775010000	st line 26	14.5536	14.2321	32	3	31.33
775020000	st line 27	14.5536	8	32	3	17.61
775030000	st line 28	14.5536	44.137	32	3	97.17
775040000	st line 29	14.5536	31.758	32	3	69.92
776010000	st line 30	14.5536	15.073	32	3	33.18
777010000	st line 31	14.5536	44.401	32	3	97.75
780010000	st line 32	14.5536	25.296	32	3	55.69
780020000	st line 33	18.4527	55.005	36	3	151.43
780030000	st line 34	18.4527	46.343	36	3	127.58
780040000	st line 35	18.4527	46.343	36	3	127.58
780050000	st line 36	18.4527	46.343	36	3	127.58
780060000	st line 37	18.4527	46.343	36	3	127.58
780070000	st line 38	18.4527	46.343	36	3	127.58
780080000	st line 39	18.4527	46.343	36	3	127.58
			steam line metal volume, ft^3=			2299.12

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2.3 Main Feedwater Line Piping

Only the volume of main feedwater piping from the entry-point of the auxiliary feedwater line is considered in calculations leading to the condensate storage tank water volume requirement. Table 3 shows the estimation process. Fluid volumes are taken from Reference 2, Figure 1 for each steam generator, attached as Appendix A for ease of reference. Reference 3 indicates that the feedwater piping is 16-inch pipe. Reference 4, Section 3.7.2.1 indicates that the pipe is Schedule 80. For Schedule 80 pipe:

D_i = 14.312 inches

A_f = flow area = 1.1172 ft^2

A_x = pipe x-section area = 0.27907 ft^2

Using these parameters and the volume information from Reference 2, Table 3 shows the calculation of main feedwater piping length and piping volume from the auxiliary feedwater entry to the steam generator:

$$L = V/A_f$$

$$V_x = A_x \bullet L$$

where V_x = pipe structure volume

The total structure volume of the main feedwater piping from the auxiliary feedwater entry is shown in Table 3.

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Table 3
Main Feedwater Piping Structural Compilation

Fluid Volumes, ft^3	
MFW piping from AFW entry	
sg 1	93.55
sg 2	31.56
sg 3	33.67
sg 4	98.61
Total:	257.39
Lengths, ft	
sg 1	83.74
sg 2	28.25
sg 3	30.14
sg 4	88.27
Pipe Volumes, ft^3	
sg 1	23.37
sg 2	7.88
sg 3	8.41
sg 4	24.63
Total:	**64.30**

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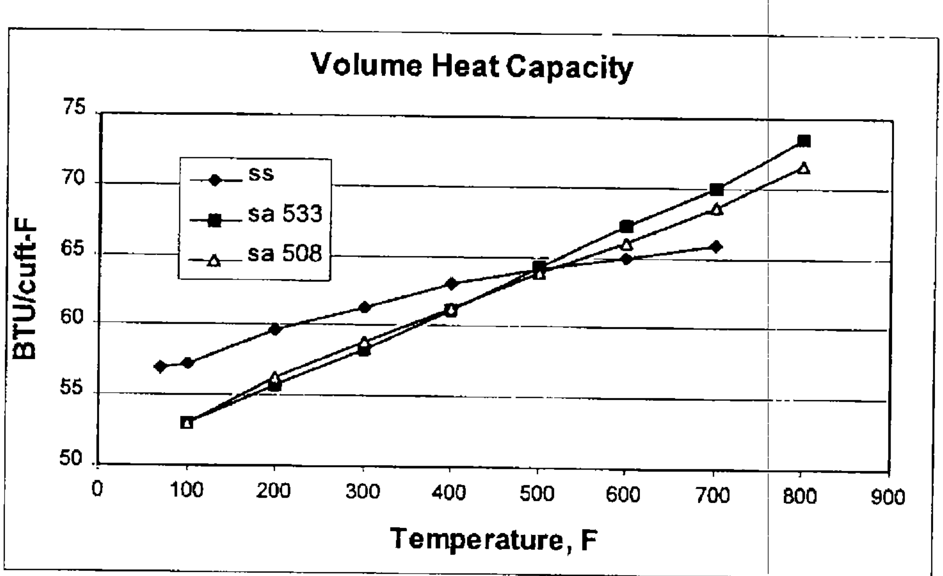
2.4 Material Properties

Material properties, specifically volumetric heat capacities for the materials comprising the RELAP5 model heat structures are compiled in Table 4. The heat capacities are taken from the RELAP5 short run **sqss/XWEL, dated 2/7/02** and are shown as a function of material temperature for stainless steel (ss), SA 533 steel, SA 508 steel, fuel - Uranium dioxide, clad - Zircaloy IV, and Inconel 690 (inc).

Volumetric heat capacity is plotted for steel below from the data of Table 4. To simplify the heat balance process, all steel structures are combined, lumping stainless steel cladding and structural steel. A conservative application of the material properties is proposed by picking the *maximum* volumetric heat capacity for initial, full power conditions.



Minimum heat capacities are conservatively applied to the heat structures for calculation of the mode 2 energy content. This maximizes the ΔU calculation for heat structures between initial conditions and mode 2 conditions. The only exception is associated with the pressurizer and surge line structural components. In mode 2, it is assumed that the pressurizer remains at saturated conditions with a pressure equivalent to the initial conditions (2250 psia). Structural heat capacities in the pressurizer and surge line at mode 2 are maintained at the *maximum* of the stainless and structural steel heat capacity to maintain equivalent structural energy both initially and in mode 2.

Minimum heat capacities are conservatively applied to the heat structures for calculation of the mode 2 energy content. This maximizes the ΔU calculation for heat structures between initial conditions and mode 3 conditions.

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Table 4
RELAP5 Model Structure Material Volumetric Heat Capacity

ss	Temp, F	C, BTU/ft^{3}F		sa 533	Temp, F	C, BTU/ft^{3}F
	70	56.95			100	52.93
	100	57.24			200	55.71
	200	59.62			300	58.33
	300	61.25			400	61.18
	400	63.03			500	64.21
	500	64.12			600	67.25
	600	64.94			700	69.91
	700	65.92			800	73.56
sa 508	Temp, F	C, BTU/ft^{3}F		inc	Temp, F	C, BTU/ft^{3}F
	100	53.02			200	57.3
	200	56.21			400	60.9
	300	58.87			600	64.4
	400	61.3			800	68
	500	63.81			1000	71.6
	600	66.08			1200	75.7
	700	68.67			1400	79.3
	800	71.67			1600	82.9
					1800	86.4
clad	Temp, F	C, BTU/ft^{3}F		fuel	Temp, F	C, BTU/ft^{3}F
	32	28.346			77	33.8
	1062	33.232			200	40.62
	1140	35.432			400	43.87
	1480	35.432			600	45.82
	1510	49.44			800	47.12
	1530	56.444			1000	48.1
	1560	58.916			1200	48.88
	1590	61.8			1600	49.92
	1610	66.332			2000	50.37
	1620	76.22			2400	51.35
	1650	80.34			2800	53.62
	1680	78.28			3200	58.17
	1700	74.16			3600	66.3
	1780	35.432			4000	78.97
	3000	35.432			4400	90.8
					4800	99.12
					5100	101.4

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2.5 Structure Initial Internal Energy Content

Table 5 shows the calculation of the initial internal energy for each, of many, model heat structures and summarizes the total energy associated with the plant metal mass at full power operation.

The identification number in Table5 refers to either (1) the structure number if the structure is simulated in the short RELAP5 run **sqss/XWEL, dated 2/7/02**, or (2) the adjacent fluid control volume number. The portion of the main feedwater piping considered in this calculation has no related component in the RELAP5 model.

The material of the relevant structure is indicated in Table 5. Initial "average" temperatures of each heat structure is taken from the RELAP5 run **sqss/XWEL, dated 2/7/02** major edit at time = 0 seconds (in the case of the steam piping, the control volume temperature is used - feedwater temperature is used to initialize the main feedwater piping). Given the material and the structure temperature volumetric heat capacity is determined, by interpolation, from Table 4. Note that, as mentioned above, if the material is steel the initial volumetric heat capacity is the maximum value of all the steels.

The initial internal energy is then estimated for each heat structure in the following manner:

$$U_i \approx c_i V T_i$$

where,

c_i = volumetric heat capacity, BTU/ft^3-F, based on structure material and temperature, Table 4

V = structure volume in ft^3, taken from Table 1 for model heat structures, Table 2 for steam line piping, and Table 3 for main feedwater piping.

T_i = structure temperature, F.

A summary of the structure internal energies is included at the bottom of Table 5. The summary indicates structure volume and internal energy for the RCS metal, clad and fuel, steam generator secondary metal, steam line piping, and main feedwater piping. The sum of all the internal energies of all the plant structures considered:

$$\sum_{metal} U_i \approx 9.3030E8 \text{ BTU}$$

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Table 5
Initial Metal Internal Energy

				<------Volumetric Heat Capacity, BTU/ft^3------>								
Identification Number	Description	Material	Initial T_{ave}	c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, Ui, BTU
Primary metal												
1001001	3x hot leg noz	steel	615.48	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	925378
1051001	3x hot leg	steel	615.47	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	1069135
1051002	3x hot leg	steel	615.47	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	1643047
1051003	3x hot leg	steel	615.47	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	1336471
1201001	3x rsg in	steel	615.51	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	6666907
1202001	3x rsg div plate	steel	583.53	64.80	66.75	65.71	66.75	30.96	64.11	45.66	66.75	838096
1211001	3x rsg in ts	steel	615.48	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	9912182
1251001	3x rsg tubes	inc	566.34	64.66	66.23	65.32	66.23	30.88	63.81	45.49	63.81	1461228
1251002	3x rsg tubes	inc	563.45	64.64	66.14	65.25	66.14	30.87	63.76	45.46	63.76	1452620
1251003	3x rsg tubes	inc	560.89	64.62	66.06	65.19	66.06	30.85	63.72	45.44	63.72	1445004
1251004	3x rsg tubes	inc	558.48	64.60	65.99	65.14	65.99	30.84	63.67	45.42	63.67	1437842
1251005	3x rsg tubes	inc	556.6	64.58	65.93	65.09	65.93	30.83	63.64	45.40	63.64	1432262
1251006	3x rsg tubes	inc	554.73	64.57	65.87	65.05	65.87	30.83	63.61	45.38	63.61	1426716
1251007	3x rsg tubes	inc	553.67	64.56	65.84	65.03	65.84	30.82	63.59	45.37	63.59	808957
1251008	3x rsg tubes	inc	552.6	64.55	65.81	65.00	65.81	30.82	63.57	45.36	63.57	807156
1251009	3x rsg tubes	inc	551.63	64.54	65.78	64.98	65.78	30.81	63.55	45.35	63.55	805524
1251010	3x rsg tubes	inc	550.68	64.54	65.75	64.96	65.75	30.81	63.54	45.34	63.54	803926
1251011	3x rsg tubes	inc	549.07	64.52	65.70	64.92	65.70	30.80	63.51	45.32	63.51	1409960
1251012	3x rsg tubes	inc	547.62	64.51	65.66	64.89	65.66	30.79	63.48	45.31	63.48	1405675
1251013	3x rsg tubes	inc	546.29	64.50	65.62	64.86	65.62	30.79	63.46	45.30	63.46	1401746
1251014	3x rsg tubes	inc	545.29	64.49	65.59	64.84	65.59	30.78	63.44	45.29	63.44	1398795
1251015	3x rsg tubes	inc	544.3	64.48	65.56	64.82	65.56	30.78	63.43	45.28	63.43	1395874
1251016	3x rsg tubes	inc	543.12	64.47	65.52	64.79	65.52	30.77	63.40	45.27	63.40	1392394
1291001	3x rsg out ts	steel	551.23	64.54	65.77	64.97	65.77	30.81	63.55	45.34	65.77	8628900
1301001	3x rsg out	steel	551.24	64.54	65.77	64.97	65.77	30.81	63.55	45.34	65.77	5803556
1351001	3x cold leg ps	steel	551.21	64.54	65.77	64.97	65.77	30.81	63.55	45.34	65.77	1011789
1351002	3x cold leg ps	steel	551.21	64.54	65.77	64.97	65.77	30.81	63.55	45.34	65.77	939385
1351003	3x cold leg ps	steel	551.22	64.54	65.77	64.97	65.77	30.81	63.55	45.34	65.77	1466578
1351004	3x cold leg ps	steel	551.22	64.54	65.77	64.97	65.77	30.81	63.55	45.34	65.77	730281
1351005	3x cold leg ps	steel	551.21	64.54	65.77	64.97	65.77	30.81	63.55	45.34	65.77	1466545
1601001	3x pump metal	steel	551.54	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	383282060
1651001	3x cold leg	steel	551.65	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	642498
1651002	3x cold leg	steel	551.67	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	2506614
1701001	3x cold leg noz	steel	551.67	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	1422208

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Table 5
Initial Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<---Volumetric Heat Capacity, BTU/ft³---> c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, UI, BTU
2001001	1x hot leg	steel	615.44	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	308434
2051001	1x hot leg	steel	615.44	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	356357
2051002	1x hot leg	steel	615.44	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	547649
2051003	1x hot leg	steel	615.44	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	445463
2201001	1x rsg in	steel	615.47	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	2222123
2202001	1x rsg div plate	steel	583.7	64.81	66.75	65.71	66.75	30.96	64.11	45.66	66.75	279473
2211001	1x rsg in ts	steel	615.45	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	3303732
2251001	1x rsg tubes	inc	566.53	64.67	66.23	65.32	66.23	30.88	63.81	45.49	63.81	487265
2251002	1x rsg tubes	inc	563.67	64.64	66.15	65.26	66.15	30.87	63.76	45.47	63.76	484425
2251003	1x rsg tubes	inc	561.14	64.62	66.07	65.20	66.07	30.86	63.72	45.44	63.72	481916
2251004	1x rsg tubes	inc	558.74	64.60	66.00	65.14	66.00	30.84	63.68	45.42	63.68	479538
2251005	1x rsg tubes	inc	556.88	64.59	65.94	65.10	65.94	30.84	63.65	45.40	63.65	477698
2251006	1x rsg tubes	inc	555.02	64.57	65.88	65.06	65.88	30.83	63.61	45.38	63.61	475859
2251007	1x rsg tubes	inc	553.97	64.56	65.85	65.04	65.85	30.82	63.59	45.37	63.59	269821
2251008	1x rsg tubes	inc	552.9	64.55	65.82	65.01	65.82	30.82	63.58	45.36	63.58	269220
2251009	1x rsg tubes	inc	551.92	64.55	65.79	64.99	65.79	30.81	63.56	45.35	63.56	268671
2251010	1x rsg tubes	inc	550.98	64.54	65.76	64.97	65.76	30.81	63.54	45.34	63.54	268144
2251011	1x rsg tubes	inc	549.36	64.52	65.71	64.93	65.71	30.80	63.51	45.33	63.51	470272
2251012	1x rsg tubes	inc	547.91	64.51	65.67	64.90	65.67	30.79	63.49	45.31	63.49	468844
2251013	1x rsg tubes	inc	546.57	64.50	65.63	64.87	65.63	30.79	63.46	45.30	63.46	467524
2251014	1x rsg tubes	inc	545.56	64.49	65.60	64.84	65.60	30.78	63.45	45.29	63.45	466531
2251015	1x rsg tubes	inc	544.56	64.49	65.56	64.82	65.56	30.78	63.43	45.28	63.43	465547
2251016	1x rsg tubes	inc	543.38	64.48	65.53	64.79	65.53	30.77	63.41	45.27	63.41	464387
2291001	1x rsg out ts	steel	551.61	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	2878676
2301001	1x rsg out	steel	551.62	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	1936192
2351001	1x cold leg ps	steel	551.59	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	337555
2351002	1x cold leg ps	steel	551.59	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	313399
2351003	1x cold leg ps	steel	551.6	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	489282
2351004	1x cold leg ps	steel	551.6	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	243638
2351005	1x cold leg ps	steel	551.59	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	489271
2601001	1x pump metal	steel	551.91	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	127868257
2651001	1x cold leg	steel	552.02	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	214346
2651002	1x cold leg	steel	552.04	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	836241
2701001	1x cold leg noz	steel	552.04	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	474468
3001001	3x dc shell	steel	551.74	64.54	65.78	64.98	65.78	30.81	63.56	45.35	65.78	8014564
3001002	3x dc shell	steel	551.67	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	4484389

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Table 5
Initial Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, Ui, BTU
				<-----Volumetric Heat Capacity, BTU/ft^3----->								
3001003	3x dc shell	steel	551.69	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	7575573
3001004	3x dc shell	steel	551.7	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	7575745
3021001	3x therm sh	steel	551.67	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	870283
3021002	3x therm sh	steel	551.69	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	907813
3021003	3x therm sh	steel	551.7	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	1119394
3021004	3x therm sh	steel	551.71	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	1213150
3081001	3x rv shell	steel	551.71	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	6745520
3101001	rv bottom	steel	585.82	64.82	66.82	65.76	66.82	30.97	64.15	45.68	66.82	3831440
3121001	3x bh internals	steel	585.82	64.82	66.82	65.76	66.82	30.97	64.15	45.68	66.82	1581212
3121002	3x bh internals	steel	551.71	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	1827024
3121003	3x bh internals	steel	551.7	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	2222896
3131001	1x bh internals	steel	552.09	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	609534
3131002	1x bh internals	steel	552.08	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	741657
3401001	3x baf pl	steel	551.69	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	544772
3401002	3x baf pl	steel	551.65	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	544723
3401003	3x baf pl	steel	551.62	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	544685
3411001	1x baf pl	steel	552.07	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	181736
3411002	1x baf pl	steel	552.04	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	181724
3411003	1x baf pl	steel	552	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	181707
3481001	3x n shield	steel	551.7	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	401500
3481002	3x n shield	steel	551.7	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	401500
3481003	3x n shield	steel	551.68	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	401482
3481004	3x n shield	steel	551.67	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	401473
3481005	3x n shield	steel	551.66	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	401464
3481006	3x n shield	steel	551.66	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	401464
3491001	1x n shield	steel	552.08	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	133949
3491002	1x n shield	steel	552.08	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	133949
3491003	1x n shield	steel	552.06	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	133943
3491004	1x n shield	steel	552.05	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	133940
3491005	1x n shield	steel	552.04	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	133937
3491006	1x n shield	steel	552.04	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	133937
3531001	1x up internals	steel	615.5	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	857285
3551001	core barrel	steel	551.7	64.54	65.78	64.98	65.78	30.81	63.55	45.35	65.78	835656
3551002	core barrel	steel	583.09	64.80	66.74	65.70	66.74	30.96	64.10	45.66	66.74	1108681
3551003	core barrel	steel	581.63	64.79	66.69	65.66	66.69	30.95	64.08	45.64	66.69	876011
3551004	core barrel	steel	551.75	64.54	65.78	64.98	65.78	30.81	63.56	45.35	65.78	921682

SDT. [illegible] 6/7/02

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Table 5
Initial Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<--- Volumetric Heat Capacity, BTU/ft^3 --->							Vol Heat Cap	Internal Energy, Ui, BTU
				c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}		
3551005	core barrel	steel	552.09	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	278888
3551006	core barrel	steel	583.13	64.80	66.74	65.70	66.74	30.96	64.10	45.66	66.74	369688
3551007	core barrel	steel	581.85	64.79	66.70	65.67	66.70	30.95	64.08	45.64	66.70	292239
3551008	core barrel	steel	581.85	64.79	66.70	65.67	66.70	30.95	64.08	45.64	66.70	328590
3601001	3x up internals	steel	615.57	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	2572219
3601002	3x up internals	steel	615.56	65.09	67.66	66.48	67.66	31.11	64.68	45.92	67.66	1848419
3601003	3x up internals	steel	551.77	64.54	65.78	64.99	65.78	30.81	63.56	45.35	65.78	2238527
3601004	3x up internals	steel	551.77	64.54	65.78	64.99	65.78	30.81	63.56	45.35	65.78	1167664
3601005	3x up internals	steel	551.76	64.54	65.78	64.98	65.78	30.81	63.56	45.35	65.78	2754233
3601006	3x up internals	steel	585.86	64.82	66.82	65.76	66.82	30.97	64.15	45.68	66.82	1657366
3641001	rv head	steel	551.76	64.54	65.78	64.98	65.78	30.81	63.56	45.35	65.78	5876271
3641002	rv head	steel	585.86	64.82	66.82	65.76	66.82	30.97	64.15	45.68	66.82	6337761
3661001	1x dc shell	steel	552.19	64.55	65.80	64.99	65.80	30.81	63.56	45.35	65.80	2674256
3661002	1x dc shell	steel	552.06	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	1495613
3661003	1x dc shell	steel	552.07	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	2526865
3661004	1x dc shell	steel	552.08	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	2526922
3681001	1x therm sh	steel	552.06	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	290352
3681002	1x therm sh	steel	552.07	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	302866
3681003	1x therm sh	steel	552.08	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	373454
3681004	1x therm sh	steel	552.09	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	404733
3741001	1x rv shell	steel	552.09	64.55	65.79	64.99	65.79	30.81	63.56	45.35	65.79	2250450
4001001	surge line	steel	616.41	65.10	67.69	66.51	67.69	31.12	64.70	45.93	67.69	952347
4101001	pzr	steel	650.04	65.43	68.58	67.38	68.58	31.28	65.30	46.15	68.58	2054218
4101002	pzr	steel	650.06	65.43	68.58	67.38	68.58	31.28	65.30	46.15	68.58	2054297
4101003	pzr	steel	650.11	65.43	68.58	67.38	68.58	31.28	65.30	46.15	68.58	2054495
4101004	pzr	steel	650.11	65.43	68.58	67.38	68.58	31.28	65.30	46.15	68.58	2054495
4101005	pzr	steel	650.19	65.43	68.59	67.38	68.59	31.28	65.30	46.15	68.59	2054812
4101006	pzr	steel	650.32	65.43	68.59	67.38	68.59	31.28	65.31	46.15	68.59	2055326
4101007	pzr	steel	649.79	65.43	68.57	67.37	68.57	31.28	65.30	46.14	68.57	2053229
4101008	pzr	steel	624.95	65.18	67.91	66.73	67.91	31.16	64.85	45.98	67.91	1955711
									RCS Metal Heat =			7.1606E+08

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Table 5
Initial Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<---Volumetric Heat Capacity, BTU/ft³--->							Vol Heat Cap	Internal Energy, Ui, BTU
				c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}		
Core												
3301001	3x clad	zirc	570.35	64.70	66.35	65.41	66.35	30.90	63.88	45.53	30.90	246840
3301002	3x clad	zirc	607.11	65.01	67.44	66.26	67.44	31.07	64.53	45.87	31.07	264232
3301003	3x clad	zirc	637.32	65.31	68.24	67.05	68.24	31.22	65.07	46.06	31.22	278659
3301004	3x clad	zirc	652.96	65.46	68.66	67.45	68.66	31.29	65.35	46.16	31.29	286176
3301005	3x clad	zirc	650.77	65.44	68.60	67.39	68.60	31.28	65.31	46.15	31.28	285121
3301006	3x clad	zirc	632.59	65.26	68.12	66.92	68.12	31.20	64.99	46.03	31.20	276392
3301001	3x fuel	uo2	868.19	67.57	76.05	73.72	76.05	32.31	69.23	47.45	47.45	1753115
3301002	3x fuel	uo2	1475.44	73.52	98.21	91.93	98.21	35.43	80.66	49.60	49.60	3113803
3301003	3x fuel	uo2	1867.33	77.36	112.52	103.69	112.52	35.43	87.58	50.22	50.22	3990486
3301004	3x fuel	uo2	1882.28	77.51	113.06	104.14	113.06	35.43	87.84	50.24	50.24	4023782
3301005	3x fuel	uo2	1517.49	73.93	99.75	93.19	99.75	52.06	81.41	49.71	49.71	3209606
3301006	3x fuel	uo2	927.94	68.15	78.23	75.51	78.23	32.60	70.30	47.75	47.75	1885327
3311001	1x clad	zirc	570.47	64.70	66.35	65.41	66.35	30.90	63.88	45.53	30.90	82299
3311002	1x clad	zirc	607.07	65.01	67.44	66.26	67.44	31.07	64.53	45.87	31.07	88071
3311003	1x clad	zirc	637.05	65.30	68.24	67.04	68.24	31.22	65.07	46.06	31.22	92843
3311004	1x clad	zirc	652.58	65.46	68.65	67.44	68.65	31.29	65.35	46.16	31.29	95331
3311005	1x clad	zirc	650.44	65.43	68.59	67.39	68.59	31.28	65.31	46.15	31.28	94988
3311006	1x clad	zirc	632.29	65.26	68.11	66.92	68.11	31.19	64.98	46.03	31.19	92083
3311001	1x fuel	uo2	867.67	67.56	76.03	73.70	76.03	32.31	69.22	47.45	47.45	583990
3311002	1x fuel	uo2	1476.12	73.53	98.24	91.95	98.24	35.43	80.67	49.60	49.60	1038450
3311003	1x fuel	uo2	1867.07	77.36	112.51	103.68	112.51	35.43	87.57	50.22	50.22	1329969
3311004	1x fuel	uo2	1881.92	77.50	113.05	104.13	113.05	35.43	87.83	50.24	50.24	1340993
3311005	1x fuel	uo2	1517.88	73.94	99.76	93.21	99.76	52.20	81.42	49.71	49.71	1070165
3311006	1x fuel	uo2	927.03	68.14	78.20	75.48	78.20	32.59	70.29	47.74	47.74	627767
										Clad Heat =		2.1830E+06
										Fuel Heat =		2.3967E+07

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Table 5
Initial Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<----Volumetric Heat Capacity, BTU/ft^3----> c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, Ui, BTU
Single SG Secondary												
6001001	1x feedring	steel	516.21	64.25	64.70	64.18	64.70	30.64	62.93	45.00	64.70	164659
6201001	1x lo shell	steel	516.27	64.25	64.70	64.18	64.70	30.64	62.93	45.00	64.70	3124462
6201002	1x lo shell	steel	516.32	64.25	64.71	64.18	64.71	30.64	62.94	45.00	64.71	2218184
6201003	1x lo shell	steel	516.38	64.25	64.71	64.18	64.71	30.64	62.94	45.00	64.71	2218504
6201004	1x lo shell	steel	516.42	64.25	64.71	64.18	64.71	30.64	62.94	45.01	64.71	2218718
6202001	1x lo shell	steel	516.21	64.25	64.70	64.18	64.70	30.64	62.93	45.00	64.70	462164
6301001	1x shroud	steel	523.06	64.31	64.91	64.33	64.91	30.68	63.05	45.07	64.91	365684
6301002	1x shroud	steel	524.9	64.32	64.97	64.38	64.97	30.68	63.09	45.09	64.97	367286
6301003	1x shroud	steel	525.27	64.33	64.98	64.38	64.98	30.69	63.09	45.09	64.98	367609
6301004	1x shroud	steel	525.36	64.33	64.98	64.39	64.98	30.69	63.09	45.09	64.98	367687
6301005	1x shroud	steel	525.44	64.33	64.98	64.39	64.98	30.69	63.10	45.09	64.98	367757
6301006	1x shroud	steel	525.5	64.33	64.99	64.39	64.99	30.69	63.10	45.09	64.99	367809
6301007	1x shroud	steel	525.91	64.33	65.00	64.40	65.00	30.69	63.10	45.10	65.00	694540
6301008	1x shroud	steel	526.41	64.34	65.01	64.41	65.01	30.69	63.11	45.10	65.01	302528
6302001	1x tube supp	steel	531.53	64.38	65.17	64.53	65.17	30.72	63.20	45.15	65.17	77800
6302002	1x tube supp	steel	535.38	64.41	65.29	64.61	65.29	30.73	63.27	45.19	65.29	78504
6302003	1x tube supp	steel	535.7	64.41	65.30	64.62	65.30	30.74	63.27	45.19	65.30	78563
6302004	1x tube supp	steel	535.62	64.41	65.29	64.62	65.29	30.74	63.27	45.19	65.29	78548
6302005	1x tube supp	steel	535.53	64.41	65.29	64.62	65.29	30.73	63.27	45.19	65.29	78531
6302006	1x tube supp	steel	535.4	64.41	65.29	64.61	65.29	30.73	63.27	45.19	65.29	78508
6303001	1x u support	steel	527.69	64.35	65.05	64.44	65.05	30.70	63.13	45.11	65.05	690442
6361001	1x up shell	steel	534.63	64.40	65.26	64.60	65.26	30.73	63.26	45.18	65.26	1063132
6361002	1x up shell	steel	534.54	64.40	65.26	64.59	65.26	30.73	63.25	45.18	65.26	3744557
6361003	1x up shell	steel	534.43	64.40	65.26	64.59	65.26	30.73	63.25	45.18	65.26	2617592
6361004	1x up shell	steel	534.42	64.40	65.26	64.59	65.26	30.73	63.25	45.18	65.26	1462308
6451001	1x sep	steel	531.19	64.38	65.16	64.52	65.16	30.71	63.20	45.15	65.16	85903
6451002	1x sep	steel	535	64.41	65.27	64.60	65.27	30.73	63.26	45.19	65.27	190855
6451003	1x sep	steel	534.85	64.41	65.27	64.60	65.27	30.73	63.26	45.18	65.27	672134
6601001	1x sec sep	steel	534.42	64.40	65.26	64.59	65.26	30.73	63.25	45.18	65.26	930932
6701001	1x st dome	steel	534.31	64.40	65.25	64.59	65.25	30.73	63.25	45.18	65.25	3003904
									1x SG Metal Heat =			2.8540E+07

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Table 5
Initial Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, Ui, BTU
				<------Volumetric Heat Capacity, BTU/ft³------>								
Triple SG Secondary												
7001001	3x feedring	steel	516.26	64.25	64.70	64.18	64.70	30.64	62.93	45.00	64.70	494036
7201001	3x lo shell	steel	516.32	64.25	64.71	64.18	64.71	30.64	62.94	45.00	64.71	9374514
7201002	3x lo shell	steel	516.37	64.25	64.71	64.18	64.71	30.64	62.94	45.00	64.71	6655347
7201003	3x lo shell	steel	516.43	64.25	64.71	64.18	64.71	30.64	62.94	45.01	64.71	6656308
7201004	3x lo shell	steel	516.47	64.26	64.71	64.18	64.71	30.64	62.94	45.01	64.71	6656949
7202001	3x lo shell	steel	516.26	64.25	64.70	64.18	64.70	30.64	62.93	45.00	64.70	1386660
7301001	3x shroud	steel	523.06	64.31	64.91	64.33	64.91	30.68	63.05	45.07	64.91	1097498
7301002	3x shroud	steel	524.88	64.32	64.97	64.37	64.97	30.68	63.09	45.09	64.97	1102255
7301003	3x shroud	steel	525.25	64.33	64.98	64.38	64.98	30.69	63.09	45.09	64.98	1103223
7301004	3x shroud	steel	525.34	64.33	64.98	64.39	64.98	30.69	63.09	45.09	64.98	1103459
7301005	3x shroud	steel	525.42	64.33	64.98	64.39	64.98	30.69	63.09	45.09	64.98	1103668
7301006	3x shroud	steel	525.47	64.33	64.98	64.39	64.98	30.69	63.10	45.09	64.98	1103799
7301007	3x shroud	steel	525.88	64.33	65.00	64.40	65.00	30.69	63.10	45.10	65.00	2083473
7301008	3x shroud	steel	526.37	64.34	65.01	64.41	65.01	30.69	63.11	45.10	65.01	907499
7302001	3x tube supp	steel	531.46	64.38	65.17	64.52	65.17	30.72	63.20	45.15	65.17	233361
7302002	3x tube supp	steel	535.26	64.41	65.28	64.61	65.28	30.73	63.27	45.19	65.28	235446
7302003	3x tube supp	steel	535.58	64.41	65.29	64.62	65.29	30.73	63.27	45.19	65.29	235622
7302004	3x tube supp	steel	535.5	64.41	65.29	64.62	65.29	30.73	63.27	45.19	65.29	235578
7302005	3x tube supp	steel	535.41	64.41	65.29	64.61	65.29	30.73	63.27	45.19	65.29	235528
7302006	3x tube supp	steel	535.28	64.41	65.28	64.61	65.28	30.73	63.27	45.19	65.28	235457
7303001	3x u support	steel	527.64	64.35	65.05	64.44	65.05	30.70	63.13	45.11	65.05	2071057
7361001	3x up shell	steel	534.51	64.40	65.26	64.59	65.26	30.73	63.25	45.18	65.26	3188501
7361002	3x up shell	steel	534.42	64.40	65.26	64.59	65.26	30.73	63.25	45.18	65.26	11230523
7361003	3x up shell	steel	534.31	64.40	65.25	64.59	65.25	30.73	63.25	45.18	65.25	7850573
7361004	3x up shell	steel	534.3	64.40	65.25	64.59	65.25	30.73	63.25	45.18	65.25	4385693
7451001	3x sep	steel	531.12	64.38	65.16	64.52	65.16	30.71	63.19	45.15	65.16	257666
7451002	3x sep	steel	534.88	64.41	65.27	64.60	65.27	30.73	63.26	45.19	65.27	572404
7451003	3x sep	steel	534.72	64.40	65.27	64.60	65.27	30.73	63.26	45.18	65.27	2015790
7601001	3x sec sep	steel	534.3	64.40	65.25	64.59	65.25	30.73	63.25	45.18	65.25	2792014
7701001	3x st dome	steel	534.27	64.40	65.25	64.59	65.25	30.73	63.25	45.18	65.25	8994137
									3x SG Metal Volume=			8.5598E+07

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Table 5
Initial Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<-----Volumetric Heat Capacity, BTU/ft^3----- c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2} ----->	Vol Heat Cap	Internal Energy, Ui, BTU
Steam Lines												
675010000	st line 1	steel	533.16	64.39	65.22	64.56	65.22	30.72	63.23	45.17	65.22	363165
675020000	st line 2	steel	533.06	64.39	65.22	64.56	65.22	30.72	63.23	45.17	65.22	204091
675030000	st line 3	steel	532.99	64.39	65.21	64.56	65.21	30.72	63.23	45.17	65.21	1125809
675040000	st line 4	steel	532.98	64.39	65.21	64.56	65.21	30.72	63.23	45.17	65.21	906886
676010000	st line 5	steel	532.88	64.39	65.21	64.56	65.21	30.72	63.23	45.17	65.21	642334
677010000	st line 6	steel	542.01	64.46	65.49	64.76	65.49	30.77	63.39	45.25	65.49	1156552
680010000	st line 7	steel	532.49	64.39	65.20	64.55	65.20	30.72	63.22	45.16	65.20	484858
680020000	st line 8	steel	532.54	64.39	65.20	64.55	65.20	30.72	63.22	45.16	65.20	1476630
680030000	st line 9	steel	532.51	64.39	65.20	64.55	65.20	30.72	63.22	45.16	65.20	1476526
680040000	st line 10	steel	532.46	64.39	65.20	64.55	65.20	30.72	63.22	45.16	65.20	1476353
680050000	st line 11	steel	532.42	64.39	65.20	64.55	65.20	30.72	63.22	45.16	65.20	1476215
680060000	st line 12	steel	532.39	64.39	65.19	64.55	65.19	30.72	63.22	45.16	65.19	1476111
680070000	st line 13	steel	532.33	64.39	65.19	64.54	65.19	30.72	63.22	45.16	65.19	1475903
680080000	st line 14	steel	532.3	64.38	65.19	64.54	65.19	30.72	63.22	45.16	65.19	1475799
680090000	st line 15	steel	532.26	64.38	65.19	64.54	65.19	30.72	63.21	45.16	65.19	1475661
680100000	st line 16	steel	532.1	64.38	65.19	64.54	65.19	30.72	63.21	45.16	65.19	1475107
680110000	st line 17	steel	532.02	64.38	65.18	64.54	65.18	30.72	63.21	45.16	65.18	1474830
681010000	st line 18	steel	528.13	64.35	65.07	64.45	65.07	30.70	63.14	45.12	65.07	1254400
683010000	st line 19	steel	533.42	64.39	65.23	64.57	65.23	30.72	63.23	45.17	65.23	2116114
683020000	st line 20	steel	533.32	64.39	65.22	64.57	65.22	30.72	63.23	45.17	65.22	1870207
683030000	st line 21	steel	533.1	64.39	65.22	64.56	65.22	30.72	63.23	45.17	65.22	1986909
683040000	st line 22	steel	532.22	64.38	65.19	64.54	65.19	30.72	63.21	45.16	65.19	1001404
692010000	st line 23	steel	536.91	64.42	65.33	64.65	65.33	30.74	63.30	45.20	65.33	1734847
692020000	st line 24	steel	540.06	64.45	65.43	64.72	65.43	30.76	63.35	45.24	65.43	2258816
692030000	st line 25	steel	542.86	64.47	65.51	64.78	65.51	30.77	63.40	45.26	65.51	2273481
775010000	st line 26	steel	533.06	64.39	65.22	64.56	65.22	30.72	63.23	45.17	65.22	1089240
775020000	st line 27	steel	532.96	64.39	65.21	64.56	65.21	30.72	63.23	45.17	65.21	612129
775030000	st line 28	steel	532.88	64.39	65.21	64.56	65.21	30.72	63.23	45.17	65.21	3376557
775040000	st line 29	steel	532.9	64.39	65.21	64.56	65.21	30.72	63.23	45.17	65.21	2429656
776010000	st line 30	steel	532.79	64.39	65.21	64.55	65.21	30.72	63.22	45.16	65.21	1152868
777010000	st line 31	steel	541.39	64.46	65.47	64.75	65.47	30.76	63.37	45.25	65.47	3464690
780010000	st line 32	steel	532.45	64.39	65.20	64.55	65.20	30.72	63.22	45.16	65.20	1933239
780020000	st line 33	steel	532.45	64.39	65.20	64.55	65.20	30.72	63.22	45.16	65.20	5256774
780030000	st line 34	steel	532.43	64.39	65.20	64.55	65.20	30.72	63.22	45.16	65.20	4428748

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Table 5
Initial Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, Ui, BTU
				<---Volumetric Heat Capacity, BTU/ft^3--->								
780040000	st line 35	steel	532.41	64.39	65.20	64.55	65.20	30.72	63.22	45.16	65.20	4428540
780050000	st line 36	steel	532.38	64.39	65.19	64.55	65.19	30.72	63.22	45.16	65.19	4428228
780060000	st line 37	steel	532.34	64.39	65.19	64.54	65.19	30.72	63.22	45.16	65.19	4427813
780070000	st line 38	steel	532.18	64.38	65.19	64.54	65.19	30.72	63.21	45.16	65.19	4426152
780080000	st line 39	steel	532.1	64.38	65.19	64.54	65.19	30.72	63.21	45.16	65.19	4425322
									Steam Line Metal Heat =			7.2182E+07
Main Feedwater Lines												
	MFW Pipe	steel	435	63.41	62.24	62.18	63.41	30.26	61.51	44.21	63.41	1773517
									MFW Line Metal Heat =			1.7735E+06

Initial Condition Summary for Metals

	Volume	Heat
RCS Metal	19517.08	7.1606E+08
Clad	112.05	2.1830E+06
Fuel	340.42	2.3967E+07
1x SG Metal	833.71	2.8540E+07
3x SG Metal	2500.72	8.5598E+07
Steam Lines	2299.12	7.2182E+07
MFW Lines	64.30	1.7735E+06
Total	25667.39	9.3030E+08

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2.6 Structure Energy Content, Mode 2

Table 6 shows the calculation of the "Mode 2" internal energy for each, of many, model heat structures and summarizes the total energy associated with the plant metal mass at the hot shutdown mode of operation. Table 6 is a duplicate of the initial energy table, Table 5, with the following exceptions.

The average temperature of each heat structure is based on the conditions presumed to exist during Mode 2 operation. The no-load average RCS temperature at Sequoyah is 547 F (see Reference 5, Figure 5.3.4-1). Reference 6, Figures 5-9 and 5-10 illustrate the RCS temperature response to a loss of offsite power event. The event is characterized by, for one, a loss of power to the RCS pumps and an immediate reactor trip. Examining these figures at about 2-hours, the time frame for cooling from full power to the Mode 2 state assumed in this work, the RCS ΔT is about 30 F. The following coolant temperatures for Mode 2 are, therefore:

$$T_{hot,2} = 562 \text{ F}$$
$$T_{ave,2} = 547 \text{ F}$$
$$T_{cold,2} = 532 \text{ F}$$

For those primary RCS structures deemed "cold-side", $T_{cold,2}$ is applied. For the hot side structures, $T_{hot,2}$ is applied. For those structures transferring (adding or extracting) heat, $T_{ave,2}$ is applied.

The metal temperature in the pressurizer components are left at their initial, full power, values. This reflects the fact that the RCS pressure is unchanged from full power operation to Mode 2 operation and the fluid in the pressurizer is saturated.

Secondary, or steam-side, structures should be nearly at $T_{cold,2}$, reflective of the temperature of the fluid exiting the primary side of the steam generator. This includes the steam lines. The feedwater lines are assumed to be full of auxiliary feedwater within two hours so the piping structures are set to the auxiliary feedwater temperature of 120 F.

Given the material and the structure temperature volumetric heat capacity is determined, by interpolation, from Table 4. Note that, as mentioned above, if the material is steel the Mode 2 volumetric heat capacity is the minimum value of all the steels. In this way, the ΔU and the heat structure contribution to the condensate storage tank requirement is maximized.

The initial internal energy is then estimated for each heat structure in the following manner:

$$U_2 \approx c_2 V T_2$$

where,

c_2 = volumetric heat capacity, BTU/ft^3-F, based on structure material and temperature, Table 4
V = structure volume in ft^3, taken from Table 1 for model heat structures, Table 2 for steam line piping, and Table 3 for main feedwater piping.
T = structure temperature, F.

A summary of the structure internal energies is included at the bottom of Table 6. The summary indicates structure volume and internal energy for the RCS metal, clad and fuel, steam generator secondary metal, steam line piping, and main feedwater piping. The sum of all the internal energies of all the plant structures considered:

$$\sum_{metal} U_2 \approx 8.7267E8 \text{ BTU}$$

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Table 6
Mode 2 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<------Volumetric Heat Capacity, BTU/ft^3------> c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_2, BTU
Primary metal												
1001001	3x hot leg noz	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	807089.038
1051001	3x hot leg	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	932489.026
1051002	3x hot leg	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	1433049.87
1051003	3x hot leg	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	1165657.04
1201001	3x rsg in	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	5814341.78
1202001	3x rsg div plate	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	759219.015
1211001	3x rsg in ts	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	8645133.11
1251001	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1251002	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1251003	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1251004	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1251005	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1251006	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1251007	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	797744.595
1251008	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	797744.595
1251009	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	797744.595
1251010	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	797744.595
1251011	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	797744.595
1251012	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1251013	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1251014	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1251015	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1251016	3x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	1403843.08
1291001	3x rsg out ts	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	8152499.09
1301001	3x rsg out	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	5483017.5
1351001	3x cold leg ps	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	955972.102
1351002	3x cold leg ps	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	887562.37
1351003	3x cold leg ps	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1385640.11
1351004	3x cold leg ps	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	689977.814
1351005	3x cold leg ps	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1385640.11
1601001	3x pump metal	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	361865703
1651001	3x cold leg	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	606445.607
1651002	3x cold leg	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2365853.89
1701001	3x cold leg noz	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1342343.55

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Table 6
Mode 2 Metal Internal Energy

				<---Volumetric Heat Capacity, BTU/ft^3--->								
Identification Number	Description	Material	Initial T_{ave}	c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_2, BTU
2001001	1x hot leg	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	269029.679
2051001	1x hot leg	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	310829.675
2051002	1x hot leg	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	477683.289
2051003	1x hot leg	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	388552.346
2201001	1x rsg in	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	1938113.93
2202001	1x rsg div plate	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	253076.926
2211001	1x rsg in ts	steel	562	64.63	66.09	65.22	64.63	30.86	63.74	45.45	64.63	2881598.95
2251001	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251002	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251003	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251004	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251005	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251006	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251007	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	265914.865
2251008	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	265914.865
2251009	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	265914.865
2251010	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	265914.865
2251011	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251012	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251013	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251014	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251015	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2251016	1x rsg tubes	inc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	63.47	467947.693
2291001	1x rsg out ts	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2717394
2301001	1x rsg out	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1827672.5
2351001	1x cold leg ps	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	318657.367
2351002	1x cold leg ps	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	295854.123
2351003	1x cold leg ps	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	461880.035
2351004	1x cold leg ps	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	229992.605
2351005	1x cold leg ps	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	461880.035
2601001	1x pump metal	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	120621901
2651001	1x cold leg	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	202148.536
2651002	1x cold leg	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	788617.965
2701001	1x cold leg noz	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	447447.851
3001001	3x dc shell	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	7791406.35
3001002	3x dc shell	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	4360219.4

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Table 6
Mode 2 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<---Volumetric Heat Capacity, BTU/ft^3--- C_{ss}	C_{sa533}	C_{sa508}	C_{steel}	C_{zirc}	C_{inc}	C_{uo2} --->	Vol Heat Cap	Internal Energy, U_2, BTU
3001003	3x dc shell	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	7365476.13
3001004	3x dc shell	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	7365476.13
3021001	3x therm sh	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	846185.147
3021002	3x therm sh	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	882636.2
3021003	3x therm sh	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	1088324.28
3021004	3x therm sh	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	1179451.91
3081001	3x rv shell	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	6558144.74
3101001	rv bottom	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	3453676.79
3121001	3x bh internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	1425311.91
3121002	3x bh internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	1776273.28
3121003	3x bh internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	2161198.66
3131001	1x bh internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	592091.095
3131002	1x bh internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	720448.563
3401001	3x baf pl	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	529663.757
3401002	3x baf pl	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	529663.757
3401003	3x baf pl	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	529663.757
3411001	1x baf pl	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	176543.559
3411002	1x baf pl	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	176543.559
3411003	1x baf pl	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	176543.559
3481001	3x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	390356.441
3481002	3x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	390356.441
3481003	3x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	390356.441
3481004	3x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	390356.441
3481005	3x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	390356.441
3481006	3x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	390356.441
3491001	1x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	130118.814
3491002	1x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	130118.814
3491003	1x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	130118.814
3491004	1x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	130118.814
3491005	1x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	130118.814
3491006	1x n shield	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	130118.814
3531001	1x up internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	130118.814
3551001	core barrel	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	726329.776
3551002	core barrel	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	812461.873
3551003	core barrel	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	1005297.95
3551004	core barrel	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	895998.151

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Table 6
Mode 2 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<------Volumetric Heat Capacity, BTU/ft³------> c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_2, BTU
3551005	core barrel	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	270907.37
3551006	core barrel	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	335186.064
3551007	core barrel	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	265702.618
3551008	core barrel	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	298752.796
3601001	3x up internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	2178989.33
3601002	3x up internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	1565872.9
3601003	3x up internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	2176048.72
3601004	3x up internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	1135074.06
3601005	3x up internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	2677422.11
3601006	3x up internals	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	1493828.04
3641001	rv head	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	5712392.38
3641002	rv head	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	5712392.38
3661001	1x dc shell	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	2597135.45
3661002	1x dc shell	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	1452911.77
3661003	1x dc shell	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	2454664.02
3661004	1x dc shell	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	2454664.02
3681001	1x therm sh	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	282061.716
3681002	1x therm sh	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	294212.067
3681003	1x therm sh	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	362774.761
3681004	1x therm sh	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	393150.638
3741001	1x rv shell	steel	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	64.51	2186048.25
4001001	surge line	steel	616.41	65.10	67.69	66.51	67.69	31.12	64.70	45.93	67.69	952347.416
4101001	pzr	steel	650.04	65.43	68.58	67.38	68.58	31.28	65.30	46.15	68.58	2054218.09
4101002	pzr	steel	650.06	65.43	68.58	67.38	68.58	31.28	65.30	46.15	68.58	2054297.23
4101003	pzr	steel	650.11	65.43	68.58	67.38	68.58	31.28	65.30	46.15	68.58	2054495.08
4101004	pzr	steel	650.11	65.43	68.58	67.38	68.58	31.28	65.30	46.15	68.58	2054495.08
4101005	pzr	steel	650.19	65.43	68.59	67.38	68.59	31.28	65.30	46.15	68.59	2054811.65
4101006	pzr	steel	650.32	65.43	68.59	67.38	68.59	31.28	65.31	46.15	68.59	2055326.12
4101007	pzr	steel	649.79	65.43	68.57	67.37	68.57	31.28	65.30	46.14	68.57	2053228.94
4101008	pzr	steel	624.95	65.18	67.91	66.73	67.91	31.16	64.85	45.98	67.91	1955711.19
									RCS Metal Heat =			6.7692E+08

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Table 6
Mode 2 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<---Volumetric Heat Capacity, BTU/ft³---> c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_2, BTU
Core												
3301001	3x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	235885.41
3301002	3x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	235885.41
3301003	3x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	235885.41
3301004	3x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	235885.41
3301005	3x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	235885.41
3301006	3x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	235885.41
3301001	3x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	1054479.87
3301002	3x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	1054479.87
3301003	3x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	1054479.87
3301004	3x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	1054479.87
3301005	3x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	1054479.87
3301006	3x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	1054479.87
3311001	1x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	78628.4699
3311002	1x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	78628.4699
3311003	1x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	78628.4699
3311004	1x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	78628.4699
3311005	1x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	78628.4699
3311006	1x clad	zirc	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	30.79	78628.4699
3311001	1x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	351493.291
3311002	1x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	351493.291
3311003	1x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	351493.291
3311004	1x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	351493.291
3311005	1x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	351493.291
3311006	1x fuel	uo2	547	64.51	65.64	64.88	64.51	30.79	63.47	45.30	45.30	351493.291
									Clad Heat =			1.8871E+06
									Fuel Heat =			8.4358E+06

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Table 6
Mode 2 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_2, BTU
				<-----Volumetric Heat Capacity, BTU/ft^3----->								
Single SG Secondary												
6001001	1x feedring	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	168855.37
6201001	1x lo shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	3203627.04
6201002	1x lo shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2274112.76
6201003	1x lo shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2274112.76
6201004	1x lo shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2274112.76
6202001	1x lo shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	473942.742
6301001	1x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	368904.749
6301002	1x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	368904.749
6301003	1x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	368904.749
6301004	1x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	368904.749
6301005	1x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	368904.749
6301006	1x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	368904.749
6301007	1x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	368904.749
6301008	1x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	695932.442
6302001	1x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	302775.803
6302002	1x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	76929.1723
6302003	1x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	76929.1723
6302004	1x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	76929.1723
6302005	1x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	76929.1723
6302006	1x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	76929.1723
6303001	1x u support	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	76929.1723
6361001	1x up shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	688918.329
6361002	1x up shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1043631.49
6361003	1x up shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	3676646.73
6361004	1x up shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2570780.33
6451001	1x sep	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1436190.13
6451002	1x sep	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	85009.3612
6451003	1x sep	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	187192.331
6601001	1x sec sep	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	659466.56
6701001	1x st dome	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2951011.74
									1x SG Metal Heat =			2.8556E+07

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Table 6
Mode 2 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<----Volumetric Heat Capacity, BTU/ft^3 c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}---->	Vol Heat Cap	Internal Energy, U_2, BTU
Triple SG Secondary												
7001001	3x feedring	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	506566.109
7201001	3x lo shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	9610881.12
7201002	3x lo shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	6822332.71
7201003	3x lo shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	6822332.71
7201004	3x lo shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	6822332.71
7202001	3x lo shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1421828.23
7301001	3x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1107165.25
7301002	3x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1107165.25
7301003	3x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1107165.25
7301004	3x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1107165.25
7301005	3x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1107165.25
7301006	3x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1107165.25
7301007	3x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2087797.33
7301008	3x shroud	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	908327.408
7302001	3x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	230787.517
7302002	3x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	230787.517
7302003	3x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	230787.517
7302004	3x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	230787.517
7302005	3x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	230787.517
7302006	3x tube supp	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	230787.517
7303001	3x u support	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2066731.7
7361001	3x up shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	3130894.48
7361002	3x up shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	11029940.2
7361003	3x up shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	7712340.98
7361004	3x up shell	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	4308570.38
7451001	3x sep	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	255028.084
7451002	3x sep	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	561576.992
7451003	3x sep	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1978399.68
7601001	3x sec sep	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2742916.6
7701001	3x st dome	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	8836595.05
									3x SG Metal Volume=			8.5653E+07

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Table 6
Mode 2 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<------Volumetric Heat Capacity, BTU/ft³------> c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_2, BTU
Steam Lines												
675010000	st line 1	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	357731.525
675020000	st line 2	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	201084.323
675030000	st line 3	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1109407.35
675040000	st line 4	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	893694.14
676010000	st line 5	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	633139.128
677010000	st line 6	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1116043.13
680010000	st line 7	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	478354.47
680020000	st line 8	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
680030000	st line 9	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
680040000	st line 10	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
680050000	st line 11	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
680060000	st line 12	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
680070000	st line 13	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
680080000	st line 14	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
680090000	st line 15	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
680100000	st line 16	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
680110000	st line 17	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
681010000	st line 18	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1456652.13
683010000	st line 19	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1250332.63
683020000	st line 20	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2083185.73
683030000	st line 21	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1841536.69
683040000	st line 22	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1957457.82
692010000	st line 23	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	988597.395
692020000	st line 24	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1693994.99
692030000	st line 25	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2189551.55
775010000	st line 26	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2189551.55
775020000	st line 27	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1073194.57
775030000	st line 28	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	603252.97
775040000	st line 29	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	3328222.04
776010000	st line 30	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	2394763.48
777010000	st line 31	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1136604
780010000	st line 32	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	3348129.39
780020000	st line 33	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	1907485.89
780030000	st line 34	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	4369956.39

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Table 6
Mode 2 Metal Internal Energy

				<----Volumetric Heat Capacity, BTU/ft³---->								
Identification Number	Description	Material	Initial T_{ave}	c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_2, BTU
780040000	st line 35	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	4369956.39
780050000	st line 36	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	4369956.39
780060000	st line 37	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	4369956.39
780070000	st line 38	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	4369956.39
780080000	st line 39	steel	532	64.38	65.18	64.54	64.38	30.72	63.21	45.16	64.38	4369956.39
									Steam Line Metal Heat =			7.1046E+07
Main Feedwater Lines												
	MFW Pipe	steel	120	57.72	53.49	53.66	57.72	28.76	#N/A	36.18	57.72	170602
									MFW Line Metal Heat =			1.7060E+05

Mode 2 Conditions for Metals

	Volume	Heat
RCS Metal	19517.08	6.7692E+08
Clad	112.05	1.8871E+06
Fuel	340.42	8.4358E+06
1x SG Metal	833.71	2.8556E+07
3x SG Metal	2500.72	8.5653E+07
Steam Lines	2299.12	7.1046E+07
MFW Lines	64.30	1.7060E+05
Total	25667.39	8.7267E+08

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2.7 Structure Energy Content, Mode 3

Table 7 shows the calculation of the "Mode 3" internal energy for each, of many, model heat structures and summarizes the total energy associated with the plant metal mass at the RHR cut-in mode of operation. Table 7 is a duplicate of the initial energy tables, Table 5 and 6, with the following exceptions.

The average temperature of each heat structure is based on the conditions presumed to exist during Mode 3 operation. The RCS temperature and pressure for the RHR cut-in condition is 350 F and 380 psig, respectively (Page 7, Reference 7). The 30 F RCS ΔT from the Mode 2 calculation is conservatively retained for this calculation and 350 F is taken as the maximum RCS liquid temperature. That is,

$$T_{hot,3} = 350\text{ F}$$
$$T_{ave,3} = 335\text{ F}$$
$$T_{cold,3} = 320\text{ F}$$

For those primary RCS structures deemed "cold-side", $T_{cold,3}$ is applied. For the hot side structures, $T_{hot,3}$ is applied. For those structures transferring (adding or extracting) heat, $T_{ave,3}$ is applied.

The metal temperature in the pressurizer components are calculated using the saturated temperature at the RHR cut-in system pressure, about 395 psia.

Secondary, or steam-side, structures should be nearly at $T_{cold,3}$, reflective of the temperature of the fluid exiting the primary side of the steam generator. This includes the steam lines. The feedwater lines are assumed to be full of auxiliary feedwater so the piping structures are set to the auxiliary feedwater temperature of 120 F.

Given the material and the structure temperature volumetric heat capacity is determined, by interpolation, from Table 4. Note that, as mentioned above, if the material is steel the Mode 3 volumetric heat capacity is the minimum value of all the steels. In this way, the ΔU and the heat structure contribution to the condensate storage tank requirement is maximized.

The initial internal energy is then estimated for each heat structure in the following manner:

$$U_3 \approx c_3 V T_3$$

where,

c_3 = volumetric heat capacity, BTU/ft^3-F, based on structure material and temperature, Table 4
V = structure volume in ft^3, taken from Table 1 for model heat structures, Table 2 for steam line piping, and Table 3 for main feedwater piping.
T = structure temperature, F.

A summary of the structure internal energies is included at the bottom of Table 7. The summary indicates structure volume and internal energy for the RCS metal, clad and fuel, steam generator secondary metal, steam line piping, and main feedwater piping. The sum of all the internal energies of all the plant structures considered:

$$\sum_{metal} U_3 \approx 4.8449\text{E}8\text{ BTU}$$

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Table 7
Mode 3 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	Volumetric Heat Capacity, BTU/ft³ c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_3, BTU
Primary metal												
1001001	3x hot leg noz	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	464734
1051001	3x hot leg	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	536941
1051002	3x hot leg	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	825171
1051003	3x hot leg	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	671202
1201001	3x rsg in	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	3347982
1202001	3x rsg div plate	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	427646
1211001	3x rsg in ts	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	4977993
1251001	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251002	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251003	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251004	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251005	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251006	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251007	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251008	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	459757
1251009	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	459757
1251010	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	459757
1251011	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	459757
1251012	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251013	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251014	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251015	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1251016	3x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	809064
1291001	3x rsg out ts	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	4486186
1301001	3x rsg out	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	3017214
1351001	3x cold leg ps	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	526056
1351002	3x cold leg ps	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	488411
1351003	3x cold leg ps	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	762495
1351004	3x cold leg ps	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	379683
1351005	3x cold leg ps	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	762495
1601001	3x pump metal	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	199128720
1651001	3x cold leg	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	333717
1651002	3x cold leg	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1301890
1701001	3x cold leg noz	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	738669

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Table 7
Mode 3 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<------Volumetric Heat Capacity, BTU/ft^3------> c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_3, BTU
2001001	1x hot leg	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	154911
2051001	1x hot leg	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	178980
2051002	1x hot leg	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	275057
2051003	1x hot leg	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	223734
2201001	1x rsg in	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	1115994
2202001	1x rsg div plate	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	142551
2211001	1x rsg in ts	steel	350	62.14	59.76	60.09	59.76	29.85	60.00	43.06	59.76	1659266
2251001	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251002	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251003	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251004	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251005	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251006	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251007	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	153252
2251008	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	153252
2251009	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	153252
2251010	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	153252
2251011	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251012	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251013	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251014	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251015	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2251016	1x rsg tubes	inc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.73	269688
2291001	1x rsg out ts	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1495337
2301001	1x rsg out	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1005738
2351001	1x cold leg ps	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	175352
2351002	1x cold leg ps	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	162804
2351003	1x cold leg ps	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	254165
2351004	1x cold leg ps	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	126561
2351005	1x cold leg ps	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	254165
2601001	1x pump metal	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	66376240
2651001	1x cold leg	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	111239
2651002	1x cold leg	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	433963
2701001	1x cold leg noz	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	246223
3001001	3x dc shell	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	4388674
3001002	3x dc shell	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	2455986

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Table 7
Mode 3 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<------Volumetric Heat Capacity, BTU/ft^3------>							Vol Heat Cap	Internal Energy, U_3, BTU
				c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}		
3001003	3x dc shell	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	4148760
3001004	3x dc shell	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	4148760
3021001	3x therm sh	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	476632
3021002	3x therm sh	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	497163
3021003	3x therm sh	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	613022
3021004	3x therm sh	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	664351
3081001	3x rv shell	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	3694013
3101001	rv bottom	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	1945356
3121001	3x bh internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	802837
3121002	3x bh internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	1000523
3121003	3x bh internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	1217341
3131001	1x bh internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	333508
3131002	1x bh internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	405808
3401001	3x baf pl	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	298344
3401002	3x baf pl	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	298344
3401003	3x baf pl	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	298344
3411001	1x baf pl	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	99442
3411002	1x baf pl	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	99442
3411003	1x baf pl	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	99442
3481001	3x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	219876
3481002	3x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	219876
3481003	3x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	219876
3481004	3x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	219876
3481005	3x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	219876
3481006	3x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	219876
3491001	1x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	73292
3491002	1x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	73292
3491003	1x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	73292
3491004	1x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	73292
3491005	1x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	73292
3491006	1x n shield	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	73292
3531001	1x up internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	409121
3551001	core barrel	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	457636
3551002	core barrel	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	566255
3551003	core barrel	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	448841
3551004	core barrel	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	504690

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Table 7
Mode 3 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_3, BTU
				<------Volumetric Heat Capacity, BTU/ft^3------>								
3551005	core barrel	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	152594
3551006	core barrel	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	188801
3551007	core barrel	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	149663
3551008	core barrel	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	168279
3601001	3x up internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	1227362
3601002	3x up internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	882011
3601003	3x up internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	1225703
3601004	3x up internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	639354
3601005	3x up internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	1508114
3601006	3x up internals	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	841430
3641001	rv head	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	3217625
3641002	rv head	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	3217625
3661001	1x dc shell	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	1462891
3661002	1x dc shell	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	818383
3661003	1x dc shell	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	1382641
3661004	1x dc shell	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	1382641
3681001	1x therm sh	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	158877
3681002	1x therm sh	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	165721
3681003	1x therm sh	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	204341
3681004	1x therm sh	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	221450
3741001	1x rv shell	steel	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	59.33	1231338
4001001	surge line	steel	443.4	63.50	62.50	62.39	62.39	30.30	61.66	44.29	62.39	631437
4101001	pzr	steel	443.4	63.50	62.50	62.39	62.39	30.30	61.66	44.29	62.39	1274701
4101002	pzr	steel	443.4	63.50	62.50	62.39	62.39	30.30	61.66	44.29	62.39	1274701
4101003	pzr	steel	443.4	63.50	62.50	62.39	62.39	30.30	61.66	44.29	62.39	1274701
4101004	pzr	steel	443.4	63.50	62.50	62.39	62.39	30.30	61.66	44.29	62.39	1274701
4101005	pzr	steel	443.4	63.50	62.50	62.39	62.39	30.30	61.66	44.29	62.39	1274701
4101006	pzr	steel	443.4	63.50	62.50	62.39	62.39	30.30	61.66	44.29	62.39	1274701
4101007	pzr	steel	443.4	63.50	62.50	62.39	62.39	30.30	61.66	44.29	62.39	1274701
4101008	pzr	steel	443.4	63.50	62.50	62.39	62.39	30.30	61.66	44.29	62.39	1274701
									RCS Metal Heat =			3.7637E+08

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Table 7
Mode 3 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<----Volumetric Heat Capacity, BTU/ft³----> c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_3, BTU
Core												
3301001	3x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	139745
3301002	3x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	139745
3301003	3x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	139745
3301004	3x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	139745
3301005	3x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	139745
3301006	3x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	139745
3301001	3x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	610309
3301002	3x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	610309
3301003	3x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	610309
3301004	3x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	610309
3301005	3x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	610309
3301006	3x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	610309
3311001	1x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	46582
3311002	1x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	46582
3311003	1x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	46582
3311004	1x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	46582
3311005	1x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	46582
3311006	1x clad	zirc	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	29.78	46582
3311001	1x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	203436
3311002	1x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	203436
3311003	1x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	203436
3311004	1x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	203436
3311005	1x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	203436
3311006	1x fuel	uo2	335	61.87	59.33	59.72	59.33	29.78	59.73	42.81	42.81	203436
									Clad Heat =			1.1180E+06
									Fuel Heat =			4.8825E+06

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Table 7
Mode 3 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<--- Volumetric Heat Capacity, BTU/ft³ ---> c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_3, BTU
Single SG Secondary												
6001001	1x feedring	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	92918
6201001	1x lo shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1762903
6201002	1x lo shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1251407
6201003	1x lo shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1251407
6201004	1x lo shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1251407
6202001	1x lo shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	260803
6301001	1x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	203002
6301002	1x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	203002
6301003	1x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	203002
6301004	1x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	203002
6301005	1x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	203002
6301006	1x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	203002
6301007	1x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	382960
6301008	1x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	166613
6302001	1x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	42333
6302002	1x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	42333
6302003	1x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	42333
6302004	1x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	42333
6302005	1x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	42333
6302006	1x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	42333
6303001	1x u support	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	379100
6361001	1x up shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	574293
6361002	1x up shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	2023198
6361003	1x up shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1414658
6361004	1x up shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	790312
6451001	1x sep	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	46779
6451002	1x sep	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	103009
6451003	1x sep	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	362894
6601001	1x sec sep	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	503127
6701001	1x st dome	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1623893
									1x SG Metal Heat =			1.5714E+07

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Table 7
Mode 3 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	<----Volumetric Heat Capacity, BTU/ft^3---- C_{ss}	C_{sa533}	C_{sa508}	C_{steel}	C_{zirc}	C_{inc}	C_{uo2} ---->	Vol Heat Cap	Internal Energy, U_3, BTU
Triple SG Secondary												
7001001	3x feedring	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	278755
7201001	3x lo shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	5288709
7201002	3x lo shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	3754217
7201003	3x lo shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	3754217
7201004	3x lo shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	3754217
7202001	3x lo shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	782409
7301001	3x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	609255
7301002	3x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	609255
7301003	3x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	609255
7301004	3x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	609255
7301005	3x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	609255
7301006	3x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	609255
7301007	3x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1148880
7301008	3x shroud	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	499838
7302001	3x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	126999
7302002	3x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	126999
7302003	3x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	126999
7302004	3x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	126999
7302005	3x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	126999
7302006	3x tube supp	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	126999
7303001	3x u support	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1137288
7361001	3x up shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1722880
7361002	3x up shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	6069594
7361003	3x up shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	4243974
7361004	3x up shell	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	2370935
7451001	3x sep	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	140338
7451002	3x sep	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	309027
7451003	3x sep	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1088681
7601001	3x sec sep	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1509382
7701001	3x st dome	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	4862632
									3x SG Metal Volume=			4.7133E+07

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Table 7
Mode 3 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_3, BTU
				<----Volumetric Heat Capacity, BTU/ft^3---->								
Steam Lines												
675010000	st line 1	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	196854
675020000	st line 2	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	110653
675030000	st line 3	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	610489
675040000	st line 4	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	491785
676010000	st line 5	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	348406
677010000	st line 6	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	614140
680010000	st line 7	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	263231
680020000	st line 8	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
680030000	st line 9	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
680040000	st line 10	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
680050000	st line 11	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
680060000	st line 12	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
680070000	st line 13	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
680080000	st line 14	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
680090000	st line 15	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
680100000	st line 16	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
680110000	st line 17	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
681010000	st line 18	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	801572
683010000	st line 19	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	688037
683020000	st line 20	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1146343
683030000	st line 21	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1013367
683040000	st line 22	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1077157
692010000	st line 23	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	544009
692020000	st line 24	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	932177
692030000	st line 25	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1204874
775010000	st line 26	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1204874
775020000	st line 27	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	590561
775030000	st line 28	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	331960
775040000	st line 29	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1831466
776010000	st line 30	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1317799
777010000	st line 31	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	625454
780010000	st line 32	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1842420
780020000	st line 33	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	1049658
780030000	st line 34	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	2404715

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Table 7
Mode 3 Metal Internal Energy

Identification Number	Description	Material	Initial T_{ave}	c_{ss}	c_{sa533}	c_{sa508}	c_{steel}	c_{zirc}	c_{inc}	c_{uo2}	Vol Heat Cap	Internal Energy, U_3, BTU
				<------Volumetric Heat Capacity, BTU/ft³------>								
780040000	st line 35	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	2404715
780050000	st line 36	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	2404715
780060000	st line 37	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	2404715
780070000	st line 38	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	2404715
780080000	st line 39	steel	320	61.61	58.90	59.36	58.90	29.71	59.46	42.57	58.90	2404715
									Steam Line Metal Heat =			3.9095E+07
Main Feedwater Lines												
	MFW Pipe	steel	120	57.72	53.49	53.66	57.72	28.76	#N/A	36.18	57.72	170602
									MFW Line Metal Heat =			1.7060E+05

Mode 3 Conditions for Metals	Volume	Heat
RCS Metal	19517.08	3.7637E+08
Clad	112.05	1.1180E+06
Fuel	340.42	4.8825E+06
1x SG Metal	833.71	1.5714E+07
3x SG Metal	2500.72	4.7133E+07
Steam Lines	2299.12	3.9095E+07
MFW Lines	64.30	1.7060E+05
Total	25667.39	4.8449E+08

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3.1 Initial RCS Energy Content

The initial RCS mass is derived from the short RELAP5 run, **sqss/XWEL, dated 2/7/02**. Since the pressurizer is saturated at any given operational state the pressurizer and the remainder of the RCS volume are treated separately in the energy balance. From the short RELAP5 run, the initial RCS mass for System 1 is given in the first (t = 0 seconds) major edit as:

$$m_{sys1} = 5.15113E+05 \text{ lbm}$$

The pressurizer and surge line mass are determined from the short RELAP5 run as well. The process is demonstrated in Table 8. The nodal volume for each node of the pressurizer and surge line is taken from the model input summary. Void fractions (VOIDG), liquid density (RHOF), and vapor density (RHOG) are taken from the first major edit. Nodal density is calculated using the following relation:

$$RHO = (1 - VOIDG) * RHOF + VOIDG * RHOG$$

and the nodal mass is simply determined as the product of the nodal volume and density.

Table 8
RELAP5 Model Pressurizer Initial Mass Calculation

Pressurizer Node		Volume, ft³	VOIDG	RHOF, lbm/ft³	RHOG, lbm/ft³	RHO, lbm/ft³	Mass, lbm
400010000	Surge Line	40.846	0	41.61	6.23	41.61	1699.602
410010000	PZR 1	65.2764	1	37.394	6.1852	6.19	403.7476
410020000	PZR 2	284.879	1	37.392	6.1861	6.19	1762.29
410030000	PZR 3	284.879	1	37.39	6.1859	6.19	1762.233
410040000	PZR 4	284.879	0.703	37.405	6.1893	15.46	4404.688
410050000	PZR 5	284.879	0*	37.375	6.1966	37.38	10647.35
410060000	PZR 6	284.879	0*	37.36	6.2052	37.36	10643.08
410070000	PZR 7	284.879	0	37.453	6.2138	37.45	10669.57
410080000	PZR 8	65.2764	0	40.715	6.2199	40.72	2657.729
* approximate					Total PZR Mass, m_{pzr} =		4.4650E4

The initial model RCS mass is equivalent to the System 1 mass minus the pressurizer mass:

$$m_{RCS,model} = m_{sys1} - m_{pzr} = 4.70463E5 \text{ lbm}$$

The RELAP5 model incorporates an RCS temperature measurement uncertainty, the model average RCS temperature (time = 0 second major edit):

$$T_{ave,model} = \frac{(TEMPF_{100} + TEMPF_{170})}{2} = 583.6 \text{ F}$$

The specific volume at 2250 psia (nominal RCS pressure) and 583.6 F (per ASME steam tables) is:

$$v_{RCS,model} = 0.02247 \text{ ft}^3/\text{lbm.}$$

For nominal RCS pressure and temperature (578.2 F, see Reference 5, Figure 5.3.4-1) the specific volume (per ASME steam tables) is:

$$v_{RCS,i} = 0.02227 \text{ ft}^3/\text{lbm}$$

The initial RCS mass (minus the pressurizer) normalized to nominal conditions, therefore:

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$$m_{RCS,i} = \frac{m_{RCS,model} * v_{RCS,model}}{v_{RCS,i}} = 4.74837E5 \text{ lbm}$$

For nominal full power RCS pressure and temperature (578.2 F, see Reference 5, Figure 5.3.4-1) the specific internal energy (per ASME steam tables) is:

$$u_{RCS,i} = 574.07 \text{ BTU/lbm}$$

The initial internal energy associated with the RCS fluid mass is equivalent to the product of the initial RCS mass and the specific internal energy:

$$U_{RCS,i} = m_{RCS,i} * u_{RCS,i} = 2.72591E8 \text{ BTU}$$

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3.2 Mode 2 RCS Energy Content

The fluid volume of the RCS, exclusive of the pressurizer and surge line is approximately equivalent for all operational states. Therefore, the mass of RCS fluid in Mode 2 of operation can be determined from the initial RCS mass utilizing respective fluid specific volumes. In Mode 2, the average RCS fluid temperature:

$$T_{ave,2} = 547\ F$$

Combined with a nominal RCS pressure of 2250 psia, the specific volume (per ASME steam tables):

$$v_{RCS,2} = 0.02125\ ft^3/lbm$$

and the RCS mass in Mode 2 is determined from the initial mass by a ratio of specific volumes:

$$m_{RCS,2} = \frac{m_{RCS,i} * v_{RCS,i}}{v_{RCS,2}} = 4.97498E5\ lbm$$

For nominal Mode 2 RCS pressure and temperature the specific internal energy (per ASME steam tables) is:

$$u_{RCS,2} = 534.62\ BTU/lbm$$

The Mode 2 internal energy associated with the RCS mass is equivalent to the product of the Mode 2 RCS mass and the specific internal energy:

$$U_{RCS,2} = m_{RCS,2} * u_{RCS,2} = 2.65973E8\ BTU$$

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3.3 Mode 3 RCS Energy Content

The fluid volume of the RCS, exclusive of the pressurizer and surge line is approximately equivalent for all operational states. Therefore, the mass of RCS fluid in Mode 3 of operation can be determined from the initial RCS mass utilizing respective fluid specific volumes. In Mode 3, the average RCS fluid temperature:

$$T_{ave,3} = 335 \text{ F}$$

Combined with a nominal RCS pressure of 395 psia (Page 7, Reference 7), the specific volume (from ASME steam tables):

$$v_{RCS,3} = 0.01780 \text{ ft}^3/\text{lbm}$$

and the RCS mass in Mode 3 is determined from the initial mass by a ratio of specific volumes:

$$m_{RCS,3} = \frac{m_{RCS,i} * v_{RCS,i}}{v_{RCS,3}} = 5.94118\text{E}5 \text{ lbm}$$

For Mode 3 RCS pressure and temperature the specific internal energy (per ASME steam tables) is:

$$u_{RCS,2} = 305.19 \text{ BTU/lbm}$$

The Mode 3 internal energy associated with the RCS mass is equivalent to the product of the Mode 3 RCS mass and the specific internal energy:

$$U_{RCS,3} = m_{RCS,3} * u_{RCS,3} = 1.81321\text{E}8 \text{ BTU}$$

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3.4 Pressurizer Energy Content

Table 9 shows the calculation of pressurizer liquid and vapor mass for the initial full power, Mode 2, and Mode 3 operating points. Pressurizer fluid mass, in this calculation, includes the pressurizer vessel - 8 vertical RELAP5 nodes - and a single-node surge line. The RELAP5 nodes are sequenced such that the first pressurizer node, 410010000, is the top of the pressurizer and the last, 410080000, is the bottom node.

Respective nodal heights are taken from the input echo of the RELAP5 short run, **sqss/XWEL, dated 2/7/02**. The void fraction is 1.0 in the top of the pressurizer and all nodes that are steam filled. The bottom of the pressurizer has a void fraction of 0.0. Summing node heights from the bottom of the pressurizer gives the relative elevation of the top of each node.

The % span is the percent of liquid between the dp taps on the pressurizer and is simulated with CNTRLVAR 861 of the short run, the basic form of the control variable is:

$$\%\text{span} = 2.3099 * (\text{Elevation} - 3.3125)$$

% span is calculated at the top of each pressurizer node. The target span is the nominal % span for each operational point. At full power the target span is taken to be 60% and at no-load conditions, 25% (see inputs for Loss of Electric Load and Main Steam Line Break, respectively, Reference 8). The target span identifies the pressurizer node containing the phasic interface. The void fraction in the target node is arrived at using the respective elevations of the target node and the node beneath it:

$$\text{VOIDG}_n = 1 - \frac{(\text{target span} - \%\text{span}_{n-1})}{(\%\text{span}_n - \%\text{span}_{n-1})}$$

Pressurizer nodal volumes are taken from the input echo of the RELAP5 short run, **sqss/XWEL, dated 2/7/02**. Liquid and vapor densities are saturated values based on nominal RCS pressure (per ASME steam tables). Nominal RCS pressure at the initial and Mode 2 operational points is 2250 psia. For mode 3, the nominal RCS pressure is 395 psia. Liquid mass and vapor mass is calculated for each node based on nodal volume, void fraction, and density:

$$m_l = \text{liquid mass} = \rho_l * V * (1 - \text{VOIDG})$$
$$m_v = \text{vapor mass} = \rho_v * V * \text{VOIDG}$$

where,
ρ_l = liquid density
ρ_v = vapor density
V = nodal volume

Liquid and vapor masses are summed for the pressurizer component at each operational point in Table 9:

$$m_{l,pzr,i} = 4.1832\text{E}4 \text{ lbm}$$
$$m_{v,pzr,i} = 4.7937\text{E}3 \text{ lbm}$$
$$m_{l,pzr,2} = 2.0155\text{E}4 \text{ lbm}$$
$$m_{v,pzr,2} = 8.5199\text{E}3 \text{ lbm}$$
$$m_{l,pzr,3} = 2.8141\text{E}4 \text{ lbm}$$
$$m_{v,pzr,3} = 1.1371\text{E}3 \text{ lbm}$$

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Liquid and vapor specific internal energies are saturated values based on nominal RCS pressures (per ASME steam tables):

$$u_{l,pzr,i} = u_{l,pzr,2} = 690.1\,BTU/lbm$$
$$u_{v,pzr,i} = u_{v,pzr,2} = 1052.5\,BTU/lbm$$
$$u_{l,pzr,3} = 421.4\,BTU/lbm$$
$$u_{v,pzr,3} = 1118.7\,BTU/lbm$$

Finally, the internal energy of the pressurizer fluid is calculated as follows:

$$U_{pzr,i} = m_{l,pzr,i} * u_{l,pzr,i} + m_{v,pzr,i} * u_{v,pzr,i} = 3.39127E7\ BTU$$

$$U_{pzr,2} = m_{l,pzr,2} * u_{l,pzr,2} + m_{v,pzr,2} * u_{v,pzr,2} = 2.28756E7\ BTU$$

$$U_{pzr,3} = m_{l,pzr,3} * u_{l,pzr,3} + m_{v,pzr,3} * u_{v,pzr,3} = 1.31304E7\ BTU$$

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T 9

Pressurizer Mass Calculation

Initial PZR, nominal NRL

Pressurizer Node	Description	Node Height, ft	Elevation, ft	% Span	Target Span, %	Void Fraction	Volume, ft³	Liquid Density, lbm/ft³	Vapor Density, lbm/ft³	Liquid Mass, lbm	Vapor Mass, lbm
400010000	Surge Line			0.00		0	40.846	37.071	6.372	1514.2	0.0
410010000	PZR 1	2.797	49.886	107.58		1	65.2764	37.071	6.372	0.0	416.0
410020000	PZR 2	7.382	47.089	101.12		1	284.879	37.071	6.372	0.0	1815.4
410030000	PZR 3	7.382	39.707	84.07		1	284.879	37.071	6.372	0.0	1815.4
410040000	PZR 4	7.382	32.325	67.02	60	0.411	284.879	37.071	6.372	6215.6	746.9
410050000	PZR 5	7.382	24.943	49.96		0	284.879	37.071	6.372	10560.9	0.0
410060000	PZR 6	7.382	17.561	32.91		0	284.879	37.071	6.372	10560.9	0.0
410070000	PZR 7	7.382	10.179	15.86		0	284.879	37.071	6.372	10560.9	0.0
410080000	PZR 8	2.797	2.797	0.00		0	65.2764	37.071	6.372	2419.9	0.0
										41832.2	4793.7
									Total PZR Mass =		46625.9

Mode 2 Pressurizer

Pressurizer Node	Description	Node Height, ft	Elevation, ft	% Span	Target Span, %	Void Fraction	Volume, ft³	Liquid Density, lbm/ft³	Vapor Density, lbm/ft³	Liquid Mass, lbm	Vapor Mass, lbm
400010000	Surge Line			0.00		0	40.846	37.071	6.372	1514.2	0.0
410010000	PZR 1	2.797	49.886	107.58		1	65.2764	37.071	6.372	0.0	416.0
410020000	PZR 2	7.382	47.089	101.12		1	284.879	37.071	6.372	0.0	1815.4
410030000	PZR 3	7.382	39.707	84.07		1	284.879	37.071	6.372	0.0	1815.4
410040000	PZR 4	7.382	32.325	67.02		1	284.879	37.071	6.372	0.0	1815.4
410050000	PZR 5	7.382	24.943	49.96		1	284.879	37.071	6.372	0.0	1815.4
410060000	PZR 6	7.382	17.561	32.91	25	0.464	284.879	37.071	6.372	5660.2	842.4
410070000	PZR 7	7.382	10.179	15.86		0	284.879	37.071	6.372	10560.9	0.0
410080000	PZR 8	2.797	2.797	0.00		0	65.2764	37.071	6.372	2419.9	0.0
										20155.2	8519.9
									Total PZR Mass =		28675.1

Mode 3 Pressurizer

Pressurizer Node	Description	Node Height, ft	Elevation, ft	% Span	Target Span, %	Void Fraction	Volume, ft³	Liquid Density, lbm/ft³	Vapor Density, lbm/ft³	Liquid Mass, lbm	Vapor Mass, lbm
400010000	Surge Line			0.00		0	40.846	51.7598	0.8505	2114.2	0.0
410010000	PZR 1	2.797	49.886	107.58		1	65.2764	51.7598	0.8505	0.0	55.5
410020000	PZR 2	7.382	47.089	101.12		1	284.879	51.7598	0.8505	0.0	242.3
410030000	PZR 3	7.382	39.707	84.07		1	284.879	51.7598	0.8505	0.0	242.3
410040000	PZR 4	7.382	32.325	67.02		1	284.879	51.7598	0.8505	0.0	242.3
410050000	PZR 5	7.382	24.943	49.96		1	284.879	51.7598	0.8505	0.0	242.3
410060000	PZR 6	7.382	17.561	32.91	25	0.464	284.879	51.7598	0.8505	7902.9	112.4
410070000	PZR 7	7.382	10.179	15.86		0	284.879	51.7598	0.8505	14745.3	0.0
410080000	PZR 8	2.797	2.797	0.00		0	65.2764	51.7598	0.8505	3378.7	0.0
										28141.1	1137.1
									Total PZR Mass =		29278.2

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4.1 Initial SG Secondary Energy Content

The initial liquid mass of the RELAP5 model single and triple steam generators are taken from the short run, **sqss/XWEL, dated 2/7/02,** time = 0 seconds control variables. The total liquid mass is the sum of both control variables:

$$m_{l,SGx3,i} = \text{CNTRLVAR } 458 = 2.93501\text{E}5 \text{ lbm}$$
$$m_{l,SGx1,i} = \text{CNTRLVAR } 358 = 9.75343\text{E}4 \text{ lbm}$$
$$m_{l,SG,i} = m_{l,SGx3,i} + m_{l,SGx1,i} \approx 3.9104\text{E}5 \text{ lbm}$$

The entire secondary mass is given in the major edit as the mass of System 2:

$$m_{sys2} \approx 4.6323\text{E}5 \text{ lbm}$$

The secondary vapor mass is the difference between the System 2 mass and the liquid masses of the two steam generator components:

$$m_{v,SG,i} = m_{sys2} - m_{l,SG,i} = 7.2190\text{E}4 \text{ lbm}$$

The initial steam pressure is taken as 919 psia, see the steam dome volume 670 in the time = 0 major edit of the short RELAP5 run **sqss/XWEL, dated 2/7/02.** The saturated liquid and vapor specific internal energy (per ASME steam tables) at that pressure are:

$$v_{l,SG,i} = 0.0213 \text{ ft}^3/\text{lbm}$$
$$v_{v,SG,i} = 0.4896 \text{ ft}^3/\text{lbm}$$

The total SG secondary volume is approximately:

$$V_{SG} = m_{l,SG,i} * v_{l,SG,i} + m_{v,SG,i} * v_{v,SG,i} \approx 4.3673\text{E}4 \text{ ft}^3$$

The saturated liquid and vapor specific internal energy (per ASME steam tables) at the saturation pressure are:

$$u_{l,SG,i} = 526.2 \text{ BTU/lbm}$$
$$u_{v,SG,i} = 1112.5 \text{ BTU/lbm}$$
$$h_{v,SG,i} = 1195.7 \text{ BTU/lbm}$$

The initial SG secondary internal energy is calculated as follows:

$$U_{SG,i} = m_{l,SG,i} * u_{l,SG,i} + m_{v,SG,i} * u_{v,SG,i} = 2.8608\text{E}8 \text{ BTU}$$

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4.2 Mode 2 SG Energy Content

The SG is nominally controlled to 39% of narrow range span at zero load (Reference 9). The following SG elevations, relative to the base support stool, are taken from Reference 10, pages 21 and 22:

$$\text{Tubesheet upper face elevation} = 66.87 \text{ in}$$
$$\text{Lower NR tap} = 503.62 \text{ in}$$
$$\text{Upper NR tap} = 647.62 \text{ in}$$

Therefore, the NR tap elevations, relative to the top of the tubesheet:

$$Z_{0\%} = \text{Lower NR tap} = 36.40 \text{ ft}$$
$$Z_{100\%} = \text{Upper NR tap} = 48.40 \text{ ft}$$

and the elevation associated with 39% of span, relative to the tubesheet:

$$Z_{39\%} = 41.08 \text{ ft}$$

Table 10 gives the SG secondary volume vs. elevation above the tubesheet. From Table 10, operation at 39% of narrow range span translates to a collapsed secondary liquid volume of about 3289 ft^3 per steam generator or, for 4 SGs:

$$V_{l,SG,2} = 1.3157E4 \text{ ft}^3$$

The SG secondary pressure at the Mode 2 operational point is taken to be the saturation pressure associated with the RCS cold leg temperature - with the pumps off, the primary fluid temperature leaving the steam generator is essentially the same temperature as the secondary temperature.

$$T_{cold,2} = 532 \text{ F}, \Rightarrow P_{SG,2} = 900.4 \text{ psia}$$

The saturated liquid and vapor specific internal energy (per ASME steam tables) at that pressure are:

$$v_{l,SG,2} = 0.02123 \text{ ft}^3/\text{lbm}$$
$$v_{v,SG,2} = 0.5007 \text{ ft}^3/\text{lbm}$$

and the mass of secondary liquid:

$$m_{l,SG,2} = \frac{V_{l,SG,2}}{v_{l,SG,2}} = 6.1974E5 \text{ lbm}$$

The mass of secondary vapor is:

$$m_{v,SG,2} = \frac{V_{SG} - V_{l,SG,2}}{v_{v,SG,2}} = 6.0837E4 \text{ lbm}$$

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The saturated liquid and vapor specific internal energy (per ASME steam tables) at the saturation pressure are:

$$u_{l,SG,2} = 523.2\,BTU/lbm$$
$$u_{v,SG,2} = 1113.0\,BTU/lbm$$
$$h_{v,SG,2} = 1196.4\,BTU/lbm$$

The Mode 2 SG secondary internal energy is calculated as follows, assuming a return to the nominal SG level:

$$U_{SG,2} = m_{l,SG,2} * u_{l,SG,i} + m_{v,SG,2} * u_{v,SG,2} = 3.9196E8\,BTU$$

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4.3 Mode 3 SG Energy Content

The SG secondary pressure at the Mode 3 operational point is taken to be the saturation pressure associated with the RCS cold leg temperature - with the pumps off, the primary fluid temperature leaving the steam generator is essentially the same temperature as the secondary temperature.

$$T_{cold,3} = 320\,F, \Rightarrow P_{SG,3} = 89.6\,psia$$

The saturated liquid and vapor specific internal energy (per ASME steam tables) at that pressure are:

$$v_{l,SG,3} = 0.01766\,ft^3/lbm$$
$$v_{v,SG,3} = 4.9137\,ft^3/lbm$$

Secondary energy content is determined for each of 4 secondary inventories. First use (1) the original "initial" secondary liquid mass:

$$m^{(1)}_{l,SG,3} = m_{l,SG,i} = 3.9104E5\ lbm$$
$$\Rightarrow V^{(1)}_{l,SG,3} = m_{l,SG,3} * v_{l,SG,3} = 6.9058E3\ ft^3$$

and a steam mass of:

$$m^{(1)}_{v,SG,3} = \frac{V_{SG} - V^{(1)}_{l,SG,3}}{v_{v,SG,3}} = 7.4826E3\,lbm$$

Secondly use (2) a liquid volume just covering the SG tubes. From Reference 10, page 12, the top of the U-bend is 32.19 ft above the tubesheet. Table 10 translates this elevation into a volume of about 2022 ft3 per SG and:

$$V^{(2)}_{l,SG,3} = 4 * 2022 = 8088\ ft^3$$
$$\text{and, } m^{(2)}_{l,SG,3} = \frac{V^{(2)}_{l,SG,3}}{v_{l,SG,3}} = 4.5798E5\ lbm$$

and a steam mass of:

$$m^{(2)}_{v,SG,3} = \frac{V_{SG} - V^{(2)}_{l,SG,3}}{v_{v,SG,3}} = 7.2420E3\,lbm$$

Next, masses are calculated for a liquid level just up to the bottom narrow range tap. From Table 10, using the tap elevation from above:

$$Z_{0\%} = 36.40\ ft$$
$$\text{and } V^{(3)}_{l,SG,3} = 2577 * 4 = 1.0308E4\,ft^3$$

resulting in a mass:

$$m^{(3)}_{l,SG,3} = \frac{V^{(3)}_{l,SG,3}}{v_{l,SG,3}} = 5.8369E5\ lbm$$

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and a steam mass of:

$$m^{(3)}_{v,SG,3} = \frac{V_{SG} - V^{(3)}_{l,SG,3}}{v_{v,SG,3}} = 6.7902E3\,\text{lbm}$$

Finally, (4) SG level measuring 39% on the narrow range scale is used (see Mode 2 calculation):

$$V^{(4)}_{l,SG,3} = V_{l,SG,2} = 1.3157E4\,\text{ft}^3$$

resulting in a mass:

$$m^{(4)}_{l,SG,3} = \frac{V^{(4)}_{l,SG,3}}{v_{l,SG,3}} = 7.4502E5\ \text{lbm}$$

and a steam mass of:

$$m^{(4)}_{v,SG,3} = \frac{V_{SG} - V^{(4)}_{l,SG,3}}{v_{v,SG,3}} = 6.2104E3\,\text{lbm}$$

The saturated liquid and vapor specific internal energy (per ASME steam tables) at the saturation pressure are:

$$u_{l,SG,3} = 290.1\,\text{BTU/lbm}$$
$$u_{v,SG,3} = 1103.7\,\text{BTU/lbm}$$
$$h_{v,SG,3} = 1185.2\,\text{BTU/lbm}$$

The Mode 3 SG secondary internal energy is calculated as follows:

$$U_{SG,3} = m_{l,SG,3} * u_{l,SG,3} + m_{v,SG,3} * u_{v,SG,3}$$
$$U^{(1)}_{SG,3} = 1.2170E8\,\text{BTU}$$
$$U^{(2)}_{SG,3} = 1.4085E8\,\text{BTU}$$
$$U^{(3)}_{SG,3} = 1.7682E8\,\text{BTU}$$
$$U^{(4)}_{SG,3} = 2.2298E8\,\text{BTU}$$

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Table 10
SG Volume vs Height Above Tubesheet

RSG height, ft	Volume, ft3
0	0
1.67	96.8
5.41	314.48
9.16	532.17
12.91	749.85
16.66	967.53
20.4	1185.21
24.49	1422.36
27.05	1609.23
29.62	1797.2
32.19	2022.11
35.04	2397
35.54	2467.9
35.74	2476.9
38.71	2928.1
41.67	3379.3
46.39	4098.89
54.76	5395.81
58.28	5758.2

Reference 11, Table M1

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4.4 MFW Line Fluid Internal Energy Calculation

The fluid in the main feedwater (MFW) pipe from the auxiliary feedwater entry to the steam generator must also be included in this calculation. From Table 3, the fluid volume in the MFW pipe:

$$V_{MFW} = 257.39 \text{ ft}^3$$

Using an initial MFW temperature of 435 F and a pressure of 919 psia the ASME steam table gives the following value for specific volume and internal energy:

$$v_{MFW,i} = 0.01908 \text{ ft}^3/\text{lbm}$$
$$u_{MFW,i} = 410.6 \text{ BTU}/\text{lbm}$$

The mass of the MFW fluid is, then:

$$m_{MFW,i} = \frac{V_{MFW}}{v_{MFW,i}} = 1.3490\text{E}4 \text{ lbm}$$

Using a Mode 2 initial MFW temperature of 100 F and a pressure of 900.4 psia the ASME steam table gives the following value for specific volume and internal energy:

$$v^{100}_{MFW,2} = 0.01609 \text{ ft}^3/\text{lbm}$$
$$h^{100}_{MFW,2} = h^{100}_{AFW} = 70.37 \text{ BTU}/\text{lbm}$$
$$u^{100}_{MFW,2} = 67.69 \text{ BTU}/\text{lbm}$$

The mass of the MFW fluid is, then:

$$m^{100}_{MFW,2} = \frac{V_{MFW}}{v^{100}_{MFW,2}} = 1.5997\text{E}4 \text{ lbm}$$

Using a Mode 2 initial MFW temperature of 120 F and a pressure of 900.4 psia the ASME steam table gives the following value for specific volume and internal energy:

$$v^{120}_{MFW,2} = 0.01616 \text{ ft}^3/\text{lbm}$$
$$h^{120}_{MFW,2} = h^{120}_{AFW} = 90.26 \text{ BTU}/\text{lbm}$$
$$u^{120}_{MFW,2} = 87.57 \text{ BTU}/\text{lbm}$$

The mass of the MFW fluid is, then:

$$m^{120}_{MFW,2} = \frac{V_{MFW}}{v^{120}_{MFW,2}} = 1.5928\text{E}4 \text{ lbm}$$

Since the mass and energy of the MFW line fluid in Mode 2 is associated with the AFW fluid, it will not change significantly for Mode 3:

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$$m^{100}_{MFW,3} \approx m^{100}_{MFW,2} = 1.5997E4 \text{ lbm}$$
$$u^{100}_{MFW,3} \approx u^{100}_{MFW,2} = 67.69 \text{ BTU/lbm}$$
$$m^{120}_{MFW,3} \approx m^{120}_{MFW,2} = 1.5928E4 \text{ lbm}$$
$$u^{120}_{MFW,3} \approx u^{120}_{MFW,2} = 87.57 \text{ BTU/lbm}$$

and the internal energy of the MFW fluid can be calculated for each operational mode:

$$U_{MFW,i} = m_{MFW,i} * u_{MFW,i} = 5.5390E6 \text{ BTU}$$
$$U^{100}_{MFW,2} = m^{100}_{MFW,2} * u^{100}_{MFW,2} = 1.0828E6 \text{ BTU}$$
$$U^{120}_{MFW,2} = m^{120}_{MFW,2} * u^{120}_{MFW,2} = 1.3948E6 \text{ BTU}$$
$$U^{100}_{MFW,3} \approx U^{100}_{MFW,2} = 1.0828E6 \text{ BTU}$$
$$U^{120}_{MFW,3} \approx U^{120}_{MFW,2} = 1.3948E6 \text{ BTU}$$

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5.1 Calculation of RCS Makeup Addition

The RCS fluid shrinks in plant cool-down process. Shrinkage is offset by the chemical and volume control system. Makeup fluid is added to the RCS from the volume control tank by centrifugal charging pumps. The amount of makeup fluid needed to balance RCS fluid shrinkage is calculated in this section.

The initial RCS mass (minus the pressurizer and surge line) is taken from Section 3.1:

$$m_{RCS,i} = 4.74837E5 \text{ lbm}$$

The initial pressurizer mass was determined in Section 3.4:

$$m_{l,pzr,i} = 4.1832E4 \text{ lbm}$$

$$m_{v,pzr,i} = 4.7937E3 \text{ lbm}$$

$$m_{pzr,i} = m_{l,pzr,i} + m_{v,pzr,i} = 4.6626E4 \text{ lbm}$$

With a combined initial RCS mass of:

$$m_{RCS+pzr,i} = 5.2146E5 \quad \text{lbm}$$

The Mode 2 RCS mass (minus the pressurizer and surge line) is taken from Section 3.2:

$$m_{RCS,2} = 4.97498E5 \text{ lbm}$$

The Mode 2 pressurizer mass was determined in Section 3.4:

$$m_{l,pzr,2} = 2.0155E4 \text{ lbm}$$

$$m_{v,pzr,2} = 8.5199E3 \text{ lbm}$$

$$m_{pzr,2} = m_{l,pzr,2} + m_{v,pzr,2} = 2.8675E4 \text{ lbm}$$

With a combined Mode 2 RCS mass of:

$$m_{RCS+pzr,2} = 5.2617E5 \quad \text{lbm}$$

The Mode 3 RCS mass (minus the pressurizer and surge line) is taken from Section 3.3:

$$m_{RCS,3} = 5.94118E5 \text{ lbm}$$

The Mode 3 pressurizer mass was determined in Section 3.4:

$$m_{l,pzr,3} = 2.8141E4 \text{ lbm}$$

$$m_{v,pzr,3} = 1.1371E3 \text{ lbm}$$

$$m_{pzr,3} = m_{l,pzr,3} + m_{v,pzr,3} = 2.9278E4 \text{ lbm}$$

With a combined Mode 3 RCS mass of:

$$m_{RCS+pzr,3} = 6.23396E5 \text{ lbm}$$

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The mass of makeup required to transition from initial, full power, operation to Mode 2 conditions and the mass of makeup required to go from initial to Mode 3 conditions:

$$m_{makeup,i\rightarrow 2} = m_{RCS+pzr,2} - m_{RCS+pzr,i} = 4.7107E3 \text{ lbm}$$

$$m_{makeup,i\rightarrow 3} = m_{RCS+pzr,3} - m_{RCS+pzr,i} = 1.0193E5 \text{ lbm}$$

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5.2 Calculation of Net Secondary Mass Addition

The Secondary fluid shrinks in plant cool-down process. Respective operational states dictate the net (mass added by auxiliary feedwater minus mass steamed off to the steam dump, atmospheric relief valves, or safeties. Shrinkage is offset by the auxiliary feedwater system. Feedwater is added to the SG secondary from the condensate storage tank by auxiliary feedwater pumps. The net amount of fluid needed to balance SG secondary fluid shrinkage is calculated in this section.

The initial SG mass is taken from Sections 4.1 and 4.4:

$$m_{l,SG,i} = 3.9104E5\,\text{lbm}$$
$$m_{v,SG,i} = 7.2190E4\,\text{lbm}$$
$$m_{MFW,i} = 1.3490E4\,\text{lbm}$$
$$m_{SG,i} = m_{l,SG,i} + m_{v,SG,i} + m_{MFW,i} = 4.7672E5\ \text{lbm}$$

The Mode 2 SG mass is taken from Sections 4.2 and 4.4 (note that the assumption on AFW temperature has an insignificant effect on the SG secondary mass):

$$m_{l,SG,2} = 6.1974E5\,\text{lbm}$$
$$m_{v,SG,2} = 6.0837E4\,\text{lbm}$$
$$m^{100}_{MFW,2} = 1.5997E4\,\text{lbm}$$
$$m_{SG,2} = m_{l,SG,2} + m_{v,SG,2} + m^{100}_{MFW,2} = 6.9657E5\ \text{lbm}$$

The net fluid addition to the secondary is simply the difference between the Mode 2 and the initial secondary mass:

$$\boxed{\Delta m_{SG,i\rightarrow 2} = m_{SG,2} - m_{SG,i} = 2.1985E5\,\text{lbm}}$$

The Mode 3 SG mass is taken from Section 4.3 and 4.4. For the case (1) utilizing equivalent initial liquid mass:

$$m^{(1)}_{l,SG,3} = 3.9104E5\ \text{lbm}$$
$$m^{(1)}_{v,SG,3} = 7.4826E3\,\text{lbm}$$
$$m^{100}_{MFW,3} = 1.5997E4\,\text{lbm}$$
$$m^{(1)}_{SG,3} = m^{(1)}_{l,SG,3} + m^{(1)}_{v,SG,3} + m^{100}_{MFW,3} = 4.1452E5\ \text{lbm}$$

The net fluid addition to the secondary is equivalent to the difference between the Mode 3 and the initial secondary mass. For this case,

$$\boxed{\Delta m^{(1)}_{SG,i\rightarrow 3} = m^{(1)}_{SG,3} - m_{SG,i} = -6.2200E4\,\text{lbm}}$$

The negative sign indicates a net-negative mass, more was steamed in the transition that was added by auxiliary feedwater.

The Mode 3 SG mass is taken from Section 4.3. For the case assuming (2) liquid mass just covering the tube bundle:

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$$m^{(2)}_{l,SG,3} = 4.5798E5 \text{ lbm}$$
$$m^{(2)}_{v,SG,3} = 7.2420E3 \text{ lbm}$$
$$m^{100}_{MFW,3} = 1.5997E4 \text{ lbm}$$
$$m^{(2)}_{SG,3} = m^{(2)}_{l,SG,3} + m^{(2)}_{v,SG,3} + m^{100}_{MFW,3} = 4.8122E5 \text{ lbm}$$

The net fluid addition to the secondary is equivalent to the difference between the Mode 3 and the initial secondary mass. For this case,

$$\Delta m^{(2)}_{SG,i\to 3} = m^{(2)}_{SG,3} - m_{SG,i} = 4.500E3 \text{ lbm}$$

The Mode 3 SG mass is taken from Section 4.3. For the case assuming (3) a secondary liquid level that is just on the narrow range scale, NR level = 0.0%:

$$m^{(3)}_{l,SG,3} = 5.8369E5 \text{ lbm}$$
$$m^{(3)}_{v,SG,3} = 6.7902E3 \text{ lbm}$$
$$m^{100}_{MFW,3} = 1.5997E4 \text{ lbm}$$
$$m^{(3)}_{SG,3} = m^{(3)}_{l,SG,3} + m^{(3)}_{v,SG,3} + m^{100}_{MFW,3} = 6.0648E5 \text{ lbm}$$

The net fluid addition to the secondary is equivalent to the difference between the Mode 3 and the initial secondary mass. For this case,

$$\Delta m^{(3)}_{SG,i\to 3} = m^{(3)}_{SG,3} - m_{SG,i} = 1.2976E5 \text{ lbm}$$

The Mode 3 SG mass is taken from Section 4.3. For the case assuming (3) a secondary liquid level measures 39% on the narrow range scale:

$$m^{(4)}_{l,SG,3} = 7.4502E5 \text{ lbm}$$
$$m^{(4)}_{v,SG,3} = 6.2104E3 \text{ lbm}$$
$$m^{100}_{MFW,3} = 1.5997E4 \text{ lbm}$$
$$m^{(4)}_{SG,3} = m^{(4)}_{l,SG,3} + m^{(4)}_{v,SG,3} + m^{100}_{MFW,3} = 7.6723E5 \text{ lbm}$$

The net fluid addition to the secondary is equivalent to the difference between the Mode 3 and the initial secondary mass. For this case,

$$\Delta m^{(4)}_{SG,i\to 3} = m^{(4)}_{SG,3} - m_{SG,i} = 2.9051E5 \text{ lbm}$$

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6.1 Decay Heat Calculation - 1994 Standard

The first step in calculating decay heat using the 1994 standard is to determine the decay heat power, in (MeV/sec)/(fission/sec), for each of the fissile isotopes. The general formula for determining decay heat power follows, from Reference 12, Tables 9, 10, 11, and 12 for ^{235}U, ^{239}Pu, ^{238}U, ^{241}Pu independently:

(1)
$$F(t,T)=\sum_{i=1}^{23}\frac{\alpha_i}{\lambda_i}\exp(-\lambda_i t)[1-\exp(-\lambda_i T)]$$

where,

- t = time after reactor trip, seconds
- T = operational time, seconds

The coefficients (α's and λ's) are defined in Reference 12, Tables 9, 10, 11, and 12. The footnote to these tables indicate that:

(2)
$$F(t,\infty)=F(t,10^{13})$$

The Simplified Method for Determining Decay Heat Power and Uncertainty, Section 3.6 of Reference 12, is used in this document to estimate decay heat. To calculate the fractional decay heat is generated with the following equation:

(3)
$$\frac{P'_d(t,T)}{P_{max}}=\frac{[F_{max}(t,\infty)-F_{min}(t+T,\infty)]}{Q}$$

where,

- $F_{max}(t,\infty)$ = the largest value of $F(t,\infty)$ for the specific post shutdown time of all of the fissile isotopes.
- $F_{min}(t+T,\infty)$ = the smallest value of $F(t,\infty)$ for the specific time = shutdown time + operational time (t+T) of all of the fissile isotopes.
- Q is the energy of one fission of the ^{235}U isotope = 202.2 +/-0.5 = 201.7 MeV/fission (minimum value yields the highest decay heat).

The decay heat power for each fissile isotope is calculated using Equations (1) and (2) and is shown in Table 11 in the columns labeled **F(t,inf)** for a range of post-trip times. Table 11 also contains the decay heat power at post-trip time *plus* operational time (3 - 18 month fuel cycles):

(4)
$$T=3*1.5*365\text{ days}*24\text{ hr/day}*3600\text{ s/hr}=1.42E8\text{ seconds}$$

for each isotope in columns labeled **F(t+T,inf)**.

The data points at 8 hours (2.88E4 sec) and 18 months are boldfaced in Table 11. In addition, Table 11 indicates the F_{max} and F_{min} values needed for Equation (3) with bold borders. Note that the F_{max} term is identified with ^{238}U for the first 300 seconds following reactor trip and U235, thereafter. The F_{min} term is identified with ^{241}Pu.

Fractional decay heat power is calculated using Equation 3 at each time. Maximum and minimum values of isotopic decay heat power are taken from Table 11. Table 12 shows the fractional decay heat power in the column labeled **P'/P_{max}**.

The fractional decay heat power calculated with Equation 3 has not been corrected to account for neutron capture in fission products. The 1994 standard accounts for neutron capture using a tabulated multiplier:

(5)
$$P(t,T)=P'(t,T)G(t)$$

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where,

- P'(t,T) is defined above
- G(t) is taken from Table 13 of Reference 12.

Table 12 shows the neutron capture correction factor in the column labeled **G**. The fractional decay heat, corrected for neutron capture of fission products, is included in Table 12 in the column labeled **P/Pmax**.

Table 13 is the final worksheet for the calculation of decay heat using the 1994 standard. The table begins with time following reactor trip and P/Pmax from Table 12. Next, the uncertainty in the decay heat is calculated.

The uncertainty associated with the 1994 decay heat standard, simplified method, is calculated with the following equation (see Page 5 of Reference 12):

(6)
$$\frac{\Delta P_d}{P_d} = \sqrt{\left(\frac{\Delta P_{max}}{P_{max}}\right)^2 + \frac{(\Delta F_{max})^2 + (\Delta F_{min})^2}{Q^2}}$$

where,

$\Delta P_{max}/P_{max}$ = the uncertainty in P_{max} (calorimetric uncertainty)
ΔF_{max} = the uncertainty in isotopic decay heat power associated with the calculation of $F_{max}(t,\infty)$ above.
ΔF_{min} = the uncertainty in isotopic decay heat power associated with the calculation of $F_{min}(t+T,\infty)$ above.

Note from above that the isotope associated with *maximum* decay heat power from 0 to 300 seconds is ^{238}U and over 300 seconds, the ^{235}U isotope dominates. As a function of time, the *one-sigma* uncertainties for these two isotopes are taken from Reference 12, Tables 7 and 5, respectively. They are listed in Table 13 under the **dFmax** heading.

ΔF_{min} is effectively equivalent to the uncertainty of the *minimum* decay heat power produced (which happens to be by the ^{241}Pu isotope -see Table 2) at time equivalent to T. Since we are examining only the first 8 hours (t < 2.88E4 seconds), any interpolation to account for the t+T term would make no significant difference, given the very coarse time interval in the data tables at T (= 1.42E8 seconds). That is,

ΔF_{min} = 7.882E-3 MeV/fission, *one-sigma*, from Table 8 of Reference 12.

Since the ΔF's are one sigma, they are doubled to cover the 95 percentile in uncertainty. An example of a calculation of uncertainty, using Equation (6) for the 0.1 second data point (see Table 13):

$$\frac{\Delta P_d}{P_d} = \sqrt{\left(\frac{\Delta P_{max}}{P_{max}}\right)^2 + \frac{(\Delta F_{max})^2 + (\Delta F_{min})^2}{Q^2}} = \sqrt{0.007^2 + \frac{(2 * 1.330)^2 + (2 * 7.883E-3)^2}{(201.2)^2}} = 1.496E-2$$

The uncertainties are calculated as a function of time and entered into Table 13 under the heading **uncert**. The decay heat, accounting for uncertainty is simply:

(10)
$$\frac{P}{P_{max}} = \frac{P_d}{P_{max}} * \left(1 + \frac{\Delta P_d}{P_d}\right)$$

and is listed in the column under the **DH w/uncert** header in Table 13.

Decay heat with uncertainty, generated with the 1994 decay heat standard is integrated and presented under the heading **Integral (fraction-second)** in Table 13.

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An applicable two-group model for actinides is found in Reference 13 (see page 13):

(11) $$\frac{P_{act}}{P_{max}} = A_1 e^{-\lambda_1 t} + A_2 e^{-\lambda_2 t}$$

where, the appropriate values for the core are:
$A_1 = 0.001615$
$A_2 = 0.001455$
$\lambda_1 = 0.000491$
$\lambda_2 = 0.00000341$

Table 14 shows the calculation of relative actinide power, using Equation 11. Actinide power, calculated with the above relationship is meant for application in LOCA analysis and bounds measurement with no additional application of uncertainty. Actinide power is, however, adjusted by the calorimetric error, multiplied by 1.007, and integrated. The integral of the error-adjusted actinide power is included in Table 14.

The total decay heat generated in the fuel can now be determined. The up-rated core thermal power, P_{max}, is 3455 MWth or:

$$P_{max} = 3.2769E6 \text{ BTU / s}$$

The combined decay heat and actinide relative power at 2 hours (Mode 2) and 8 hours (Mode 3) is taken from Tables 13 and 14:

At 2 hours:

$$Q_{i \to 2} = (108.55 + 13.7) * 3.2769E6 = 4.0060E8 \text{ BTU}$$

At 8 hours:

$$Q_{i \to 3} = (291.37 + 43.6) * 3.2769E6 = 1.0977E9 \text{ BTU}$$

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Table 11
1994 Decay Heat Standard [12]
Isotopic Decay Heat Power

time	$F(t,inf)_{U235}$	$F(t,inf)_{Pu239}$	$F(t,inf)_{U238}$	$F(t,inf)_{Pu241}$	$F(t+T,inf)_{U235}$	$F(t+T,inf)_{Pu239}$	$F(t+T,inf)_{U238}$	$F(t+T,inf)_{Pu241}$
0.00E+00	1.345E+01	1.093E+01	1.686E+01	1.322E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.00E-01	1.331E+01	1.085E+01	1.657E+01	1.307E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
2.00E-01	1.318E+01	1.077E+01	1.631E+01	1.294E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
3.00E-01	1.306E+01	1.070E+01	1.607E+01	1.282E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
4.00E-01	1.295E+01	1.063E+01	1.585E+01	1.271E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
5.00E-01	1.284E+01	1.057E+01	1.565E+01	1.260E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
6.00E-01	1.274E+01	1.050E+01	1.546E+01	1.250E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
7.00E-01	1.264E+01	1.044E+01	1.529E+01	1.240E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
8.00E-01	1.255E+01	1.038E+01	1.512E+01	1.231E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
9.00E-01	1.246E+01	1.033E+01	1.497E+01	1.222E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.00E+00	1.238E+01	1.027E+01	1.482E+01	1.214E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.20E+00	1.222E+01	1.017E+01	1.455E+01	1.198E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.40E+00	1.208E+01	1.008E+01	1.430E+01	1.183E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.50E+00	1.201E+01	1.003E+01	1.418E+01	1.176E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.60E+00	1.194E+01	9.987E+00	1.407E+01	1.169E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.80E+00	1.182E+01	9.902E+00	1.386E+01	1.156E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
2.00E+00	1.170E+01	9.822E+00	1.367E+01	1.144E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
2.20E+00	1.159E+01	9.747E+00	1.349E+01	1.133E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
2.40E+00	1.149E+01	9.676E+00	1.332E+01	1.122E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
2.60E+00	1.140E+01	9.608E+00	1.316E+01	1.112E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
2.80E+00	1.130E+01	9.543E+00	1.302E+01	1.102E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
3.00E+00	1.122E+01	9.482E+00	1.288E+01	1.093E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
3.20E+00	1.113E+01	9.423E+00	1.275E+01	1.084E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
3.40E+00	1.106E+01	9.367E+00	1.262E+01	1.076E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
3.60E+00	1.098E+01	9.314E+00	1.251E+01	1.068E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
3.80E+00	1.091E+01	9.262E+00	1.240E+01	1.060E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
4.00E+00	1.084E+01	9.213E+00	1.229E+01	1.053E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
4.20E+00	1.077E+01	9.165E+00	1.219E+01	1.046E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
4.40E+00	1.071E+01	9.119E+00	1.209E+01	1.039E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
4.60E+00	1.064E+01	9.075E+00	1.200E+01	1.032E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
4.80E+00	1.058E+01	9.032E+00	1.191E+01	1.026E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
5.00E+00	1.053E+01	8.990E+00	1.182E+01	1.020E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
5.20E+00	1.047E+01	8.950E+00	1.174E+01	1.014E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
5.40E+00	1.042E+01	8.911E+00	1.166E+01	1.008E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
5.60E+00	1.036E+01	8.874E+00	1.159E+01	1.003E+01	1.129E-01	8.587E-02	8.641E-02	7.750E-02
5.80E+00	1.031E+01	8.837E+00	1.151E+01	9.978E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
6.00E+00	1.026E+01	8.802E+00	1.144E+01	9.927E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
6.20E+00	1.021E+01	8.767E+00	1.137E+01	9.877E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
6.40E+00	1.017E+01	8.734E+00	1.131E+01	9.829E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
6.60E+00	1.012E+01	8.701E+00	1.124E+01	9.783E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
6.80E+00	1.008E+01	8.669E+00	1.118E+01	9.738E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
7.00E+00	1.003E+01	8.638E+00	1.112E+01	9.694E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
7.20E+00	9.992E+00	8.608E+00	1.106E+01	9.651E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02

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Table 11
1994 Decay Heat Standard [12]
Isotopic Decay Heat Power

time	$F(t,inf)_{U235}$	$F(t,inf)_{Pu239}$	$F(t,inf)_{U238}$	$F(t,inf)_{Pu241}$	$F(t+T,inf)_{U235}$	$F(t+T,inf)_{Pu239}$	$F(t+T,inf)_{U238}$	$F(t+T,inf)_{Pu241}$
7.40E+00	9.951E+00	8.578E+00	1.101E+01	9.609E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
7.60E+00	9.911E+00	8.550E+00	1.095E+01	9.569E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
7.80E+00	9.872E+00	8.521E+00	1.090E+01	9.529E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
8.00E+00	9.834E+00	8.494E+00	1.085E+01	9.490E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
8.20E+00	9.796E+00	8.467E+00	1.079E+01	9.453E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
8.40E+00	9.760E+00	8.441E+00	1.074E+01	9.416E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
8.60E+00	9.725E+00	8.415E+00	1.070E+01	9.380E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
8.80E+00	9.690E+00	8.390E+00	1.065E+01	9.345E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
9.00E+00	9.656E+00	8.365E+00	1.060E+01	9.311E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
9.20E+00	9.623E+00	8.341E+00	1.056E+01	9.277E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
9.40E+00	9.590E+00	8.318E+00	1.051E+01	9.244E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
9.60E+00	9.558E+00	8.294E+00	1.047E+01	9.212E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
9.80E+00	9.527E+00	8.272E+00	1.043E+01	9.181E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.00E+01	9.497E+00	8.250E+00	1.039E+01	9.150E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.50E+01	8.886E+00	7.801E+00	9.588E+00	8.534E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
2.00E+01	8.460E+00	7.483E+00	9.052E+00	8.102E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
4.00E+01	7.463E+00	6.713E+00	7.853E+00	7.079E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
6.00E+01	6.892E+00	6.257E+00	7.191E+00	6.498E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
8.00E+01	6.497E+00	5.935E+00	6.735E+00	6.097E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.00E+02	6.202E+00	5.691E+00	6.392E+00	5.798E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
[illegible]50E+02	5.700E+00	5.268E+00	5.808E+00	5.297E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
[illegible].00E+02	5.373E+00	4.988E+00	5.433E+00	4.979E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
3.00E+02	4.950E+00	4.618E+00	4.958E+00	4.573E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
4.00E+02	4.671E+00	4.363E+00	4.648E+00	4.302E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
6.00E+02	4.287E+00	3.999E+00	4.232E+00	3.926E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
8.00E+02	4.013E+00	3.733E+00	3.944E+00	3.657E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.00E+03	3.799E+00	3.522E+00	3.719E+00	3.446E+00	1.129E-01	8.587E-02	8.641E-02	7.750E-02
1.50E+03	3.411E+00	3.134E+00	3.306E+00	3.063E+00	1.129E-01	8.587E-02	8.641E-02	7.749E-02
2.00E+03	3.140E+00	2.864E+00	3.020E+00	2.797E+00	1.129E-01	8.587E-02	8.641E-02	7.749E-02
3.60E+03	2.623E+00	2.361E+00	2.495E+00	2.297E+00	1.129E-01	8.587E-02	8.641E-02	7.749E-02
4.00E+03	2.538E+00	2.282E+00	2.411E+00	2.217E+00	1.129E-01	8.587E-02	8.641E-02	7.749E-02
6.00E+03	2.238E+00	2.009E+00	2.118E+00	1.940E+00	1.129E-01	8.587E-02	8.641E-02	7.749E-02
7.20E+03	2.116E+00	1.902E+00	2.001E+00	1.831E+00	1.129E-01	8.587E-02	8.641E-02	7.749E-02
8.00E+03	2.048E+00	1.845E+00	1.937E+00	1.772E+00	1.129E-01	8.587E-02	8.641E-02	7.749E-02
1.00E+04	1.912E+00	1.733E+00	1.809E+00	1.657E+00	1.129E-01	8.587E-02	8.640E-02	7.749E-02
1.50E+04	1.688E+00	1.554E+00	1.602E+00	1.475E+00	1.129E-01	8.587E-02	8.640E-02	7.749E-02
2.00E+04	1.549E+00	1.443E+00	1.473E+00	1.368E+00	1.129E-01	8.587E-02	8.640E-02	7.749E-02
2.88E+04	**1.390E+00**	**1.317E+00**	**1.328E+00**	**1.252E+00**	**1.129E-01**	**8.587E-02**	**8.640E-02**	**7.749E-02**
6.00E+04	1.121E+00	1.087E+00	1.080E+00	1.045E+00	1.129E-01	8.586E-02	8.640E-02	7.748E-02
8.00E+04	1.033E+00	1.006E+00	9.970E-01	9.707E-01	1.129E-01	8.586E-02	8.640E-02	7.748E-02
8.64E+04	1.012E+00	9.856E-01	9.761E-01	9.519E-01	1.129E-01	8.586E-02	8.639E-02	7.748E-02
1.00E+05	9.729E-01	9.482E-01	9.378E-01	9.173E-01	1.129E-01	8.586E-02	8.639E-02	7.748E-02
1.50E+05	8.772E-01	8.541E-01	8.421E-01	8.298E-01	1.129E-01	8.585E-02	8.639E-02	7.748E-02
2.00E+05	8.191E-01	7.951E-01	7.827E-01	7.743E-01	1.129E-01	8.584E-02	8.638E-02	7.746E-02

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Table 11
1994 Decay Heat Standard [12]
Isotopic Decay Heat Power

time	$F(t,inf)_{U235}$	$F(t,inf)_{Pu239}$	$F(t,inf)_{U238}$	$F(t,inf)_{Pu241}$	$F(t+T,inf)_{U235}$	$F(t+T,inf)_{Pu239}$	$F(t+T,inf)_{U238}$	$F(t+T,inf)_{Pu241}$
4.00E+05	7.012E-01	6.695E-01	6.595E-01	6.559E-01	1.129E-01	8.581E-02	8.635E-02	7.742E-02
6.00E+05	6.368E-01	6.005E-01	5.915E-01	5.907E-01	1.129E-01	8.578E-02	8.633E-02	7.739E-02
8.00E+05	5.906E-01	5.523E-01	5.437E-01	5.450E-01	1.128E-01	8.575E-02	8.630E-02	7.735E-02
1.00E+06	5.547E-01	5.157E-01	5.074E-01	5.102E-01	1.128E-01	8.572E-02	8.627E-02	7.732E-02
1.50E+06	4.904E-01	4.525E-01	4.441E-01	4.497E-01	1.128E-01	8.564E-02	8.621E-02	7.723E-02
2.00E+06	4.463E-01	4.107E-01	4.019E-01	4.093E-01	1.127E-01	8.557E-02	8.614E-02	7.714E-02
4.00E+06	3.494E-01	3.223E-01	3.118E-01	3.235E-01	1.124E-01	8.527E-02	8.589E-02	7.680E-02
6.00E+06	3.020E-01	2.802E-01	2.683E-01	2.832E-01	1.122E-01	8.498E-02	8.563E-02	7.647E-02
8.00E+06	2.717E-01	2.537E-01	2.410E-01	2.582E-01	1.119E-01	8.470E-02	8.539E-02	7.615E-02
1.00E+07	2.494E-01	2.342E-01	2.211E-01	2.398E-01	1.117E-01	8.443E-02	8.515E-02	7.584E-02
1.42E+08	**1.129E-01**	**8.587E-02**	**8.641E-02**	**7.750E-02**	**1.002E-01**	**7.435E-02**	**7.539E-02**	**6.527E-02**

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Table 12
1994 Decay Heat Standard [12]
Fractional Decay Heat Power

time	P'/P_{max}	G	P/P_{max}
0.00E+00	8.341E-02	1.020	8.508E-02
1.00E-01	8.196E-02	1.020	8.360E-02
2.00E-01	8.066E-02	1.020	8.228E-02
3.00E-01	7.948E-02	1.020	8.107E-02
4.00E-01	7.840E-02	1.020	7.997E-02
5.00E-01	7.740E-02	1.020	7.895E-02
6.00E-01	7.647E-02	1.020	7.800E-02
7.00E-01	7.559E-02	1.020	7.711E-02
8.00E-01	7.477E-02	1.020	7.627E-02
9.00E-01	7.400E-02	1.020	7.548E-02
1.00E+00	7.327E-02	1.020	7.473E-02
1.20E+00	7.191E-02	1.020	7.335E-02
1.40E+00	7.068E-02	1.020	7.209E-02
1.50E+00	7.010E-02	1.020	7.150E-02
1.60E+00	6.955E-02	1.020	7.094E-02
1.80E+00	6.851E-02	1.020	6.988E-02
2.00E+00	6.755E-02	1.020	6.890E-02
2.20E+00	6.666E-02	1.020	6.800E-02
2.40E+00	6.583E-02	1.020	6.716E-02
2.60E+00	6.505E-02	1.020	6.637E-02
2.80E+00	6.432E-02	1.020	6.563E-02
3.00E+00	6.363E-02	1.021	6.493E-02
3.20E+00	6.298E-02	1.021	6.427E-02
3.40E+00	6.236E-02	1.021	6.365E-02
3.60E+00	6.178E-02	1.021	6.306E-02
3.80E+00	6.122E-02	1.021	6.250E-02
4.00E+00	6.069E-02	1.021	6.197E-02
4.20E+00	6.019E-02	1.021	6.146E-02
4.40E+00	5.971E-02	1.021	6.097E-02
4.60E+00	5.925E-02	1.021	6.051E-02
4.80E+00	5.880E-02	1.021	6.006E-02
5.00E+00	5.838E-02	1.022	5.964E-02
5.20E+00	5.797E-02	1.022	5.923E-02
5.40E+00	5.758E-02	1.022	5.883E-02
5.60E+00	5.720E-02	1.022	5.845E-02
5.80E+00	5.684E-02	1.022	5.808E-02
6.00E+00	5.649E-02	1.022	5.773E-02
6.20E+00	5.615E-02	1.022	5.738E-02
6.40E+00	5.582E-02	1.022	5.705E-02
6.60E+00	5.550E-02	1.022	5.672E-02
6.80E+00	5.519E-02	1.022	5.641E-02
7.00E+00	5.489E-02	1.022	5.610E-02
7.20E+00	5.460E-02	1.022	5.580E-02
7.40E+00	5.432E-02	1.022	5.551E-02

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Table 12
1994 Decay Heat Standard [12]
Fractional Decay Heat Power

time	P'/P_{max}	G	P/P_{max}
7.60E+00	5.404E-02	1.022	5.523E-02
7.80E+00	5.378E-02	1.022	5.496E-02
8.00E+00	5.352E-02	1.022	5.469E-02
8.20E+00	5.326E-02	1.022	5.444E-02
8.40E+00	5.302E-02	1.022	5.418E-02
8.60E+00	5.278E-02	1.022	5.394E-02
8.80E+00	5.254E-02	1.022	5.370E-02
9.00E+00	5.231E-02	1.022	5.347E-02
9.20E+00	5.209E-02	1.022	5.324E-02
9.40E+00	5.187E-02	1.022	5.301E-02
9.60E+00	5.166E-02	1.022	5.280E-02
9.80E+00	5.145E-02	1.022	5.258E-02
1.00E+01	5.125E-02	1.022	5.238E-02
1.50E+01	4.727E-02	1.022	4.831E-02
2.00E+01	4.461E-02	1.022	4.559E-02
4.00E+01	3.865E-02	1.022	3.950E-02
6.00E+01	3.536E-02	1.022	3.613E-02
8.00E+01	3.309E-02	1.022	3.382E-02
1.00E+02	3.139E-02	1.023	3.211E-02
1.50E+02	2.848E-02	1.024	2.916E-02
2.00E+02	2.662E-02	1.025	2.728E-02
3.00E+02	2.426E-02	1.027	2.490E-02
4.00E+02	2.283E-02	1.028	2.347E-02
6.00E+02	2.092E-02	1.030	2.155E-02
8.00E+02	1.956E-02	1.032	2.019E-02
1.00E+03	1.850E-02	1.033	1.911E-02
1.50E+03	1.657E-02	1.037	1.718E-02
2.00E+03	1.522E-02	1.039	1.582E-02
3.60E+03	1.265E-02	1.046	1.324E-02
4.00E+03	1.223E-02	1.048	1.282E-02
6.00E+03	1.074E-02	1.054	1.132E-02
7.20E+03	1.013E-02	1.058	1.071E-02
8.00E+03	9.795E-03	1.060	1.038E-02
1.00E+04	9.118E-03	1.064	9.701E-03
1.50E+04	8.006E-03	1.074	8.598E-03
2.00E+04	7.311E-03	1.081	7.903E-03
2.88E+04	**6.526E-03**	**1.088**	**7.103E-03**
6.00E+04	5.184E-03	1.111	5.760E-03
8.00E+04	4.751E-03	1.119	5.316E-03
8.64E+04	4.644E-03	1.121	5.204E-03
1.00E+05	4.450E-03	1.124	5.002E-03
1.50E+05	3.975E-03	1.130	4.491E-03
2.00E+05	3.686E-03	1.131	4.169E-03
4.00E+05	3.101E-03	1.126	3.491E-03

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Table 12
1994 Decay Heat Standard [12]
Fractional Decay Heat Power

time	P'/P_{max}	G	P/P_{max}
6.00E+05	2.780E-03	1.124	3.125E-03
8.00E+05	2.551E-03	1.123	2.865E-03
1.00E+06	2.372E-03	1.124	2.667E-03
1.50E+06	2.053E-03	1.125	2.310E-03
2.00E+06	1.835E-03	1.127	2.068E-03
4.00E+06	1.355E-03	1.134	1.537E-03
6.00E+06	1.121E-03	1.146	1.285E-03
8.00E+06	9.721E-04	1.162	1.130E-03
1.00E+07	8.625E-04	1.181	1.019E-03
1.42E+08	**2.370E-04**	**1.514**	**3.588E-04**

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Table 13
1994 Decay Heat Standard [12]

time	P/P_{max}	dF_{max}	uncert	DH w/uncert	Integral (fraction-second)
0.00E+00	8.508E-02	1.330E+00	1.496E-02	8.635E-02	0.00
1.00E-01	8.360E-02	1.330E+00	1.496E-02	8.485E-02	0.01
2.00E-01	8.228E-02	1.330E+00	1.496E-02	8.351E-02	0.02
3.00E-01	8.107E-02	1.330E+00	1.496E-02	8.229E-02	0.03
4.00E-01	7.997E-02	1.330E+00	1.496E-02	8.116E-02	0.03
5.00E-01	7.895E-02	1.330E+00	1.496E-02	8.013E-02	0.04
6.00E-01	7.800E-02	1.330E+00	1.496E-02	7.916E-02	0.05
7.00E-01	7.711E-02	1.330E+00	1.496E-02	7.826E-02	0.06
8.00E-01	7.627E-02	1.330E+00	1.496E-02	7.741E-02	0.07
9.00E-01	7.548E-02	1.330E+00	1.496E-02	7.661E-02	0.07
1.00E+00	7.473E-02	1.330E+00	1.496E-02	7.585E-02	0.08
1.20E+00	7.335E-02	1.282E+00	1.454E-02	7.442E-02	0.10
1.40E+00	7.209E-02	1.234E+00	1.412E-02	7.311E-02	0.11
1.50E+00	7.150E-02	1.210E+00	1.392E-02	7.250E-02	0.12
1.60E+00	7.094E-02	1.190E+00	1.375E-02	7.192E-02	0.12
1.80E+00	6.988E-02	1.150E+00	1.340E-02	7.082E-02	0.14
2.00E+00	6.890E-02	1.110E+00	1.307E-02	6.980E-02	0.15
2.20E+00	6.800E-02	1.085E+00	1.286E-02	6.887E-02	0.17
2.40E+00	6.716E-02	1.060E+00	1.265E-02	6.801E-02	0.18
2.60E+00	6.637E-02	1.035E+00	1.244E-02	6.719E-02	0.19
2.80E+00	6.563E-02	1.010E+00	1.224E-02	6.643E-02	0.21
3.00E+00	6.493E-02	9.850E-01	1.204E-02	6.571E-02	0.22
3.20E+00	6.427E-02	9.600E-01	1.184E-02	6.503E-02	0.23
3.40E+00	6.365E-02	9.350E-01	1.164E-02	6.439E-02	0.25
3.60E+00	6.306E-02	9.100E-01	1.144E-02	6.378E-02	0.26
3.80E+00	6.250E-02	8.850E-01	1.124E-02	6.320E-02	0.27
4.00E+00	6.197E-02	8.600E-01	1.105E-02	6.265E-02	0.28
4.20E+00	6.146E-02	8.460E-01	1.094E-02	6.213E-02	0.30
4.40E+00	6.097E-02	8.320E-01	1.084E-02	6.163E-02	0.31
4.60E+00	6.051E-02	8.180E-01	1.073E-02	6.116E-02	0.32
4.80E+00	6.006E-02	8.040E-01	1.062E-02	6.070E-02	0.33
5.00E+00	5.964E-02	7.900E-01	1.052E-02	6.026E-02	0.35
5.20E+00	5.923E-02	7.760E-01	1.042E-02	5.984E-02	0.36
5.40E+00	5.883E-02	7.620E-01	1.031E-02	5.944E-02	0.37
5.60E+00	5.845E-02	7.480E-01	1.021E-02	5.905E-02	0.38
5.80E+00	5.808E-02	7.340E-01	1.011E-02	5.867E-02	0.39
6.00E+00	5.773E-02	7.200E-01	1.001E-02	5.831E-02	0.41
6.20E+00	5.738E-02	7.130E-01	9.962E-03	5.795E-02	0.42
6.40E+00	5.705E-02	7.060E-01	9.912E-03	5.761E-02	0.43
6.60E+00	5.672E-02	6.990E-01	9.863E-03	5.728E-02	0.44
6.80E+00	5.641E-02	6.920E-01	9.814E-03	5.696E-02	0.45
7.00E+00	5.610E-02	6.850E-01	9.766E-03	5.665E-02	0.46

Table 13
1994 Decay Heat Standard [12]

time	P/P_{max}	dF_{max}	uncert	DH w/uncert	Integral (fraction-second)
7.20E+00	5.580E-02	6.780E-01	9.717E-03	5.634E-02	0.47
7.40E+00	5.551E-02	6.710E-01	9.669E-03	5.605E-02	0.49
7.60E+00	5.523E-02	6.640E-01	9.621E-03	5.576E-02	0.50
7.80E+00	5.496E-02	6.570E-01	9.574E-03	5.549E-02	0.51
8.00E+00	5.469E-02	6.500E-01	9.526E-03	5.522E-02	0.52
8.20E+00	5.444E-02	6.440E-01	9.486E-03	5.495E-02	0.53
8.40E+00	5.418E-02	6.380E-01	9.446E-03	5.470E-02	0.54
8.60E+00	5.394E-02	6.320E-01	9.406E-03	5.445E-02	0.55
8.80E+00	5.370E-02	6.260E-01	9.366E-03	5.420E-02	0.56
9.00E+00	5.347E-02	6.200E-01	9.327E-03	5.396E-02	0.57
9.20E+00	5.324E-02	6.140E-01	9.287E-03	5.373E-02	0.58
9.40E+00	5.301E-02	6.080E-01	9.248E-03	5.350E-02	0.59
9.60E+00	5.280E-02	6.020E-01	9.210E-03	5.328E-02	0.61
9.80E+00	5.258E-02	5.960E-01	9.171E-03	5.307E-02	0.62
1.00E+01	5.238E-02	5.900E-01	9.132E-03	5.285E-02	0.63
1.50E+01	4.831E-02	5.270E-01	8.743E-03	4.873E-02	0.88
2.00E+01	4.559E-02	4.890E-01	8.523E-03	4.598E-02	1.12
4.00E+01	3.950E-02	4.160E-01	8.131E-03	3.982E-02	1.98
6.00E+01	3.613E-02	3.810E-01	7.959E-03	3.642E-02	2.74
8.00E+01	3.382E-02	3.500E-01	7.817E-03	3.408E-02	3.44
1.00E+02	3.211E-02	3.320E-01	7.739E-03	3.236E-02	4.11
1.50E+02	2.916E-02	2.960E-01	7.594E-03	2.939E-02	5.65
2.00E+02	2.728E-02	2.770E-01	7.522E-03	2.749E-02	7.07
3.00E+02	2.490E-02	2.545E-01	7.444E-03	2.509E-02	9.70
4.00E+02	2.347E-02	8.400E-02	7.050E-03	2.364E-02	12.14
6.00E+02	2.155E-02	7.700E-02	7.042E-03	2.170E-02	16.67
8.00E+02	2.019E-02	7.200E-02	7.037E-03	2.033E-02	20.87
1.00E+03	1.911E-02	6.800E-02	7.033E-03	1.924E-02	24.83
1.50E+03	1.718E-02	6.100E-02	7.027E-03	1.730E-02	33.97
2.00E+03	1.582E-02	5.700E-02	7.023E-03	1.593E-02	42.28
3.60E+03	1.324E-02	4.820E-02	7.017E-03	1.333E-02	65.68
4.00E+03	1.282E-02	4.600E-02	7.015E-03	1.291E-02	70.93
6.00E+03	1.132E-02	3.800E-02	7.011E-03	1.140E-02	95.23
7.20E+03	**1.071E-02**	**3.620E-02**	**7.010E-03**	**1.079E-02**	**108.55**
8.00E+03	1.038E-02	3.500E-02	7.009E-03	1.046E-02	117.04
1.00E+04	9.701E-03	3.300E-02	7.008E-03	9.769E-03	137.27
1.50E+04	8.598E-03	3.000E-02	7.007E-03	8.659E-03	183.34
2.00E+04	7.903E-03	2.800E-02	7.006E-03	7.959E-03	224.88
2.88E+04	**7.103E-03**	**2.580E-02**	**7.005E-03**	**7.153E-03**	**291.37**

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Table 14
BandW Heavy Actinides [13]

time	Pact/Pmax	Integral (fraction-second)
0.00E+00	3.07E-03	0.00E+00
1.00E-01	3.07E-03	3.09E-04
2.00E-01	3.07E-03	6.18E-04
3.00E-01	3.07E-03	9.27E-04
4.00E-01	3.07E-03	1.24E-03
5.00E-01	3.07E-03	1.55E-03
6.00E-01	3.07E-03	1.85E-03
7.00E-01	3.07E-03	2.16E-03
8.00E-01	3.07E-03	2.47E-03
9.00E-01	3.07E-03	2.78E-03
1.00E+00	3.07E-03	3.09E-03
1.20E+00	3.07E-03	3.71E-03
1.40E+00	3.07E-03	4.33E-03
1.50E+00	3.07E-03	4.64E-03
1.60E+00	3.07E-03	4.95E-03
1.80E+00	3.07E-03	5.56E-03
2.00E+00	3.07E-03	6.18E-03
2.20E+00	3.07E-03	6.80E-03
2.40E+00	3.07E-03	7.42E-03
2.60E+00	3.07E-03	8.04E-03
2.80E+00	3.07E-03	8.65E-03
3.00E+00	3.07E-03	9.27E-03
3.20E+00	3.07E-03	9.89E-03
3.40E+00	3.07E-03	1.05E-02
3.60E+00	3.07E-03	1.11E-02
3.80E+00	3.07E-03	1.17E-02
4.00E+00	3.07E-03	1.24E-02
4.20E+00	3.07E-03	1.30E-02
4.40E+00	3.07E-03	1.36E-02
4.60E+00	3.07E-03	1.42E-02
4.80E+00	3.07E-03	1.48E-02
5.00E+00	3.07E-03	1.54E-02
5.20E+00	3.07E-03	1.61E-02
5.40E+00	3.07E-03	1.67E-02
5.60E+00	3.07E-03	1.73E-02
5.80E+00	3.07E-03	1.79E-02
6.00E+00	3.07E-03	1.85E-02
6.20E+00	3.07E-03	1.92E-02
6.40E+00	3.06E-03	1.98E-02
6.60E+00	3.06E-03	2.04E-02
6.80E+00	3.06E-03	2.10E-02
7.00E+00	3.06E-03	2.16E-02

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Table 14
BandW Heavy Actinides [13]

time	Pact/Pmax	Integral (fraction-second)
7.20E+00	3.06E-03	2.22E-02
7.40E+00	3.06E-03	2.29E-02
7.60E+00	3.06E-03	2.35E-02
7.80E+00	3.06E-03	2.41E-02
8.00E+00	3.06E-03	2.47E-02
8.20E+00	3.06E-03	2.53E-02
8.40E+00	3.06E-03	2.59E-02
8.60E+00	3.06E-03	2.66E-02
8.80E+00	3.06E-03	2.72E-02
9.00E+00	3.06E-03	2.78E-02
9.20E+00	3.06E-03	2.84E-02
9.40E+00	3.06E-03	2.90E-02
9.60E+00	3.06E-03	2.96E-02
9.80E+00	3.06E-03	3.03E-02
1.00E+01	3.06E-03	3.09E-02
1.50E+01	3.06E-03	4.63E-02
2.00E+01	3.05E-03	6.17E-02
4.00E+01	3.04E-03	1.23E-01
6.00E+01	3.02E-03	1.84E-01
8.00E+01	3.01E-03	2.45E-01
1.00E+02	2.99E-03	3.05E-01
1.50E+02	2.95E-03	4.55E-01
2.00E+02	2.92E-03	6.03E-01
3.00E+02	2.85E-03	8.93E-01
4.00E+02	2.78E-03	1.18E+00
6.00E+02	2.65E-03	1.72E+00
8.00E+02	2.54E-03	2.25E+00
1.00E+03	2.44E-03	2.75E+00
1.50E+03	2.22E-03	3.92E+00
2.00E+03	2.05E-03	5.00E+00
3.60E+03	1.71E-03	8.03E+00
4.00E+03	1.66E-03	8.71E+00
6.00E+03	1.51E-03	1.19E+01
7.20E+03	**1.47E-03**	**1.37E+01**
8.00E+03	1.45E-03	1.49E+01
1.00E+04	1.42E-03	1.78E+01
1.50E+04	1.38E-03	2.48E+01
2.00E+04	1.36E-03	3.17E+01
2.88E+04	**1.32E-03**	**4.36E+01**

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7.1 First Law Formulation, Auxiliary Feedwater Requirement

Consider a control volume containing the RCS boundary and the SG secondary boundary (including the portion of main feedwater line back to the auxiliary feedwater entry and the steam line extension to the turbine). The familiar form of the First Law of Thermodynamics is written as:

(12) $$Q = U_f - U_i + \sum m_e h_e - \sum m_i h_i + W$$

where, for the chosen control volume

- Q is the heat added by the core
- U_f is the final internal energy
- U_i is the initial internal energy
- m_e is the mass of fluid exiting
- h_e is the enthalpy of fluid exiting
- m_i is the mass of fluid entering
- h_i is the enthalpy of fluid entering
- W is the work done

The internal energy terms are arrived at by the summation of the individual internal energy components determined earlier in this file:

$$\begin{aligned} U = \sum_{metal} U & \text{ (Section 2.5, 2.6, and 2.7)} + \\ U_{RCS} & \text{ (Sections 3.1, 3.2, and 3.3)} + \\ U_{pzr} & \text{ (Section 3.4)} + \\ U_{SG} & \text{ (Sections 4.1, 4.2, and 4.3)} + \\ U_{MFW} & \text{ (Section 4.4)} \end{aligned}$$

The "i" subscript on internal energy denotes the initial power operation state. Either Mode 2 or Mode 3 are the final "f" operational states.

The RCS is being cooled from full power operation to hot shutdown, then cold shutdown conditions. Since this is a controlled cooldown the RCS does not pressurize and there is no release of steam from the RCS. Therefore, the only energy of the fluid exiting the control volume,

$$\sum m_e h_e = m_{mssv} h_{mssv}$$

where,

- m_{mssv} = mass released from the SG secondary via the safety valves
- h_{mssv} = enthalpy of secondary steam

The mass of steam released through the safety valves can be re-written using the net secondary mass addition, Δm_{SG} calculated in Section 5.2:

$$m_{mssv} = m_{AFW} - \Delta m_{SG}$$

Fluid entering the control volume includes RCS makeup by the Chemical and Volume Control System on the primary and auxiliary feedwater on the secondary:

$$\sum m_i h_i = m_{makeup} h_{makeup} + m_{AFW} h_{AFW}$$

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Work - referring to mechanical or shaft work, for this control volume, is equal to zero:

$$W = 0$$

The "first law" equation then becomes:

$$\begin{aligned} Q &= U_f - U_i + (m_{AFW} - \Delta m_{SG})h_{mssv} - m_{makeup}h_{makeup} - m_{AFW}h_{AFW} \\ &= U_f - U_i - \Delta m_{SG}h_{mssv} - m_{makeup}h_{makeup} + m_{AFW}(h_{mssv} - h_{AFW}) \end{aligned}$$

rearranging and solving for m_{AFW} (condensate storage tank volume requirement):

(13) $$m_{AFW} = \frac{Q + U_i - U_f + \Delta m_{SG}h_{mssv} + m_{makeup}h_{makeup}}{h_{mssv} - h_{AFW}}$$

For the cooldown from the initial, full power operational mode to Mode 2 over a span of 2 hours:

$$\mathbf{Q = Q_{i \to 2} = 4.0060E8\ BTU\ (Section\ 6.1)}$$

$$\sum_{metal} U_i = 9.3030E8 \text{ BTU (Section 2.5)}$$
$$U_{RCS,i} = 2.72591E8 \text{ BTU (Section 3.1)}$$
$$U_{pzr,i} = 3.39127E7 \text{ BTU (Section 3.4)}$$
$$U_{SG,i} = 2.8608E8 \text{ BTU (Section 4.1)}$$
$$U_{MFW,i} = 5.5390E6 \text{ BTU (Section 4.4)}$$
$$\Rightarrow \mathbf{U_i = \sum_{metal} U_i + U_{RCS,i} + U_{pzr,i} + U_{SG,i} + U_{MFW,i} \approx 1.5284E9\ BTU}$$

$$\sum_{metal} U_2 = 8.7267E8 \text{ BTU (Section 2.6)}$$
$$U_{RCS,2} = 2.65973E8 \text{ BTU (Section 3.2)}$$
$$U_{pzr,2} = 2.28756E7 \text{ BTU (Section 3.4)}$$
$$U_{SG,2} = 3.9196E8 \text{ BTU (Section 4.2)}$$
$$U^{100}_{MFW,2} = 1.0828E6 \text{ BTU (Section 4.4, 100 F is used to maximize AFW requirement)}$$
$$\Rightarrow \mathbf{U_f = \sum_{metal} U_2 + U_{RCS,2} + U_{pzr,2} + U_{SG,2} + U^{100}_{MFW,2} \approx 1.5546E9\ BTU}$$

$$\Delta m_{SG} = \Delta m_{SG,i \to 2} = 2.1985E5 \text{ lbm (Section 5.2)}$$
$$\mathbf{h_{mssv} \approx \frac{h_{v,SG,i} + h_{v,SG,2}}{2} = 1196.1\ BTU/lbm}\text{ (Sections 4.1 and 4.2)}$$
$$\Rightarrow \mathbf{\Delta m_{SG}h_{mssv} = 2.6296E8\ BTU}$$
$$m_{makeup} = m_{makeup,i \to 2} = 4.7107E3 \text{ lbm (Section 5.1)}$$
$$h_{makeup} \approx h_{l,sat}(495\,F) = 448.4 \text{ BTU / lbm (See Table 3.0 – 1, Reference 14 and ASME steam tables)}$$
$$\Rightarrow \mathbf{m_{makeup}h_{makeup} = 2.1123E6\ BTU}$$
$$\mathbf{h^{100}_{AFW} = 70.37\ BTU/lbm}\text{ (Section 4.4)}$$
$$\mathbf{h^{120}_{AFW} = 90.26\ BTU/lbm}\text{ (Section 4.4)}$$

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The auxiliary feedwater mass required to cool the plant from full power operation to hot shutdown (Mode 2) conditions in two hours is calculated using Equation (13):

$$m^{100}_{AFW,i\to 2} = 5.6805E5 \text{ lbm}$$
$$m^{120}_{AFW,i\to 2} = 5.7827E5 \text{ lbm}$$

AFW specific volumes are calculated in Section 4.4:

$$v^{100}_{AFW} \approx v^{100}_{MFW,2} = 0.01609 \text{ ft}^3/\text{lbm}$$
$$v^{120}_{AFW} \approx v^{120}_{MFW,2} = 0.01616 \text{ ft}^3/\text{lbm}$$

And the condensate storage tank requirement for cooling the plant to operational Mode 2 in 2 hours:

$$V^{100}_{CST,1\to 2} = m^{100}_{AFW,i\to 2} * v^{100}_{AFW} = 9.1399E3 \text{ ft}^3 = 6.8371E04 \text{ gallons} \approx 68{,}400 \text{ gallons}$$
$$V^{120}_{CST,1\to 2} = m^{120}_{AFW,i\to 2} * v^{120}_{AFW} = 9.3448E3 \text{ ft}^3 = 6.9904E04 \text{ gallons} \approx 70{,}000 \text{ gallons}$$

For the cooldown from the initial, full power operational mode to Mode 3 over a span of 8 hours:

$$\mathbf{Q = Q_{i\to 3} = 1.0977E9 \text{ BTU (Section 6.1)}}$$

From above,

$$\Rightarrow \mathbf{U_i \approx 1.5284E9 \text{ BTU}}$$

$$\sum_{metal} U_3 = 4.8449E8 \text{ BTU (Section 2.7)}$$
$$U_{RCS,3} = 1.81321E8 \text{ BTU (Section 3.3)}$$
$$U_{pzr,3} = 1.31304E7 \text{ BTU (Section 3.4)}$$

The SG secondary internal energy was determined for 4 different liquid masses. The first case assumes (1) that the secondary liquid mass for Mode 3 is identical to the initial, full power, secondary liquid mass.

$$U^{(1)}_{SG,3} = 1.2170E8 \text{ BTU (Section 4.3)}$$

The second case assumes (2) that the secondary liquid just covers the top of the SG tubes:

$$U^{(2)}_{SG,3} = 1.4085E8 \text{ BTU (Section 4.3)}$$

The third case assumes (3) the secondary liquid is just on the narrow range level scale, NRL= 0%:

$$U^{(3)}_{SG,3} = 1.7682E8 \text{ BTU (Section 4.3)}$$

The final case assumes (4) a nominal SG level of 39% on the narrow range scale:

$$U^{(4)}_{SG,3} = 2.2298E8 \text{ BTU (Section 4.3)}$$

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$$U^{100}_{MFW,3} = 1.0828E6 \text{ BTU (Section 4.4, 100 F is used to maximize AFW requirement)}$$

and the final internal energy content for Mode 3:

$$\Rightarrow U_f = \sum_{metal} U_3 + U_{RCS,3} + U_{pzr,3} + U^{(n)}_{SG,3} + U^{100}_{MFW,3}$$

where n represents the Mode 3 secondary mass case:

$$U_f^{(1)} \approx 8.0064E8 \text{ BTU}$$
$$U_f^{(2)} \approx 8.1979E8 \text{ BTU}$$
$$U_f^{(3)} \approx 8.5576E8 \text{ BTU}$$
$$U_f^{(4)} \approx 9.0192E8 \text{ BTU}$$

The net steam generator mass balance is taken from Section 5.2 for each Mode 3 secondary mass case:

$$\Delta m^{(1)}_{SG} = \Delta m^{(1)}_{SG,i\to 3} = -6.2200E4 \text{ lbm}$$
$$\Delta m^{(2)}_{SG} = \Delta m^{(2)}_{SG,i\to 3} = 4.500E3 \text{ lbm}$$
$$\Delta m^{(3)}_{SG} = \Delta m^{(3)}_{SG,i\to 3} = 1.2976E5 \text{ lbm}$$
$$\Delta m^{(4)}_{SG} = \Delta m^{(4)}_{SG,i\to 3} = 2.9051E5 \text{ lbm}$$

$$h_{mssv} \approx \frac{h_{v,SG,i} + h_{v,SG,3}}{2} = 1190.5 \text{ BTU/lbm (Sections 4.1 and 4.3)}$$
$$\Rightarrow \Delta m^{(1)}_{SG} h_{mssv} = -7.4049E7 \text{ BTU}$$
$$\Delta m^{(2)}_{SG} h_{mssv} = 5.3573E6 \text{ BTU}$$
$$\Delta m^{(3)}_{SG} h_{mssv} = 1.5448E8 \text{ BTU}$$
$$\Delta m^{(4)}_{SG} h_{mssv} = 3.4585E8 \text{ BTU}$$

$$m_{makeup} = m_{makeup,i\to 3} = 1.0193E4 \text{ lbm (Section 5.1)}$$
$$h_{makeup} \approx h_{l,sat}(495\text{ F}) = 448.4 \text{ BTU/lbm (See Table 3.0-1, Reference 14 and ASME steam tables)}$$
$$\Rightarrow m_{makeup} h_{makeup} = 4.5705E6 \text{ BTU}$$
$$h^{100}_{AFW} = 70.37 \text{ BTU/lbm (Section 4.4)}$$
$$h^{120}_{AFW} = 90.26 \text{ BTU/lbm (Section 4.4)}$$

The auxiliary feedwater mass required to cool the plant from full power operation to hot shutdown (Mode 3) conditions in eight hours is calculated using the following version of Equation (13):

(13')
$$m_{AFW} = \frac{Q + U_i - U_f^{(n)} + \Delta m^{(n)}_{SG} h_{mssv} + m_{makeup} h_{makeup}}{h_{mssv} - h_{AFW}}$$

where (n) represents the Mode 3 secondary mass case:

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For the case (1) in which the Mode 3 SG secondary liquid mass is equivalent to the initial mass:

$$m^{100}_{AFW,i\to3} = 1.5677E6 \text{ lbm}$$
$$m^{120}_{AFW,i\to3} = 1.5960E6 \text{ lbm}$$

And the condensate storage tank requirement for case (1):

$$V^{100}_{CST,i\to3} = m^{100}_{AFW,i\to3} * v^{100}_{AFW} = 2.5224E4 \text{ ft}^3 = 1.8869E05 \text{ gallons} \approx 188{,}700 \text{ gallons}$$

$$V^{120}_{CST,i\to3} = m^{120}_{AFW,i\to2} * v^{120}_{AFW} = 2.5791E4 \text{ ft}^3 = 1.9293E05 \text{ gallons} \approx 193{,}000 \text{ gallons}$$

For the case (2) in which the Mode 3 SG secondary liquid mass completely covers the SG tubes:

$$m^{100}_{AFW,i\to3} = 1.6215E6 \text{ lbm}$$
$$m^{120}_{AFW,i\to3} = 1.6508E6 \text{ lbm}$$

And the condensate storage tank requirement for case (2):

$$V^{100}_{CST,i\to3} = m^{100}_{AFW,i\to3} * v^{100}_{AFW} = 2.6090E4 \text{ ft}^3 = 1.9517E05 \text{ gallons} \approx 195{,}200 \text{ gallons}$$

$$V^{120}_{CST,i\to3} = m^{120}_{AFW,i\to2} * v^{120}_{AFW} = 2.6677E4 \text{ ft}^3 = 1.9956E05 \text{ gallons} \approx 199{,}600 \text{ gallons}$$

For the case (3) in which the Mode 3 SG secondary liquid level just registers on the narrow range scale, 0% NRL:

$$m^{100}_{AFW,i\to3} = 1.7225E6 \text{ lbm}$$
$$m^{120}_{AFW,i\to3} = 1.7536E6 \text{ lbm}$$

And the condensate storage tank requirement for case (3):

$$V^{100}_{CST,i\to3} = m^{100}_{AFW,i\to3} * v^{100}_{AFW} = 2.7715E4 \text{ ft}^3 = 2.0732E05 \text{ gallons} \approx 207{,}400 \text{ gallons}$$

$$V^{120}_{CST,i\to3} = m^{120}_{AFW,i\to2} * v^{120}_{AFW} = 2.8338E4 \text{ ft}^3 = 2.1198E05 \text{ gallons} \approx 212{,}000 \text{ gallons}$$

For the case (4) in which the Mode 3 SG secondary liquid level registers 39% on the narrow range scale:

$$m^{100}_{AFW,i\to3} = 1.8521E6 \text{ lbm}$$
$$m^{120}_{AFW,i\to3} = 1.8856E6 \text{ lbm}$$

And the condensate storage tank requirement for case (3):

$$V^{100}_{CST,i\to3} = m^{100}_{AFW,i\to3} * v^{100}_{AFW} = 2.9800E4 \text{ ft}^3 = 2.2292E05 \text{ gallons} \approx 223{,}000 \text{ gallons}$$

$$V^{120}_{CST,i\to3} = m^{120}_{AFW,i\to2} * v^{120}_{AFW} = 3.0471E4 \text{ ft}^3 = 2.2794E05 \text{ gallons} \approx 228{,}000 \text{ gallons}$$

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8.1 Results and Conclusions

The condensate storage tank inventory requirement was examined in this calculation. The original basis regarding cooldown is adapted -- the plant is tripped from full power and cooled to hot shutdown conditions over a 2-hour period followed by a cool-down to RHR cut-in conditions in 5 hours; a total of 8 hours. Parametric studies regarding the auxiliary feedwater temperature and SG secondary inventory conditions - at RHR cut-in - were performed. Results of the study are detailed in Table 15.

Table 15
Condensate Storage Tank Inventory Requirement

Cooldown from full-power to hot shutdown conditions:		
100 F AFW temperature	68,400	gal
120 F AFW temperature	70,000	gal
Cooldown from full-power to RHR cut-in conditions:		
No change in SG secondary inventory		
100 F AFW temperature	188,700	gal
120 F AFW temperature	193,000	gal
SG tubes covered by secondary inventory at RHR cut-in		
100 F AFW temperature	195,200	gal
120 F AFW temperature	199,600	gal
0% Narrow Range Level at RHR cut-in		
100 F AFW temperature	207,400	gal
120 F AFW temperature	212,000	gal
39% Narrow Range Level at RHR cut-in		
100 F AFW temperature	223,000	gal
120 F AFW temperature	228,000	gal

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References

1. Framatome Document 32- 5008687-00, "SQN UNIT 1 MSLBOC," RJ Lowe.
2. TVA Document TVA-89-859, SQN-03-D053, "Sequoyah Nuclear Plant Auxiliary Feedwater Volume." *
3. TVA Drawing 47W401-4, "Mechanical Feedwater Piping." *
4. TVA Design Criteria SQN-DC-V-4.2, "Sequoyah Nuclear Plant - Main Feedwater." *
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6. Framatome Document 32-5008852-00, "SQN LOOP to Station Aux. W/RSGs," SL Claunch.
7. TVA Sequoyah Nuclear Plant Design Criteria, "Residual Heat Removal System," SQN-DC-V-27.6, R08.*
8. Framatome Document 38-1288055-00, "Approved Inputs - MSLB, LOEL, LOOP," ML Miller.
9. Framatome Document 38-1288418-00, "Sequoyah-1 FWCS Design Inputs," ES Williams.
10. Framatome Document 32-5008940-00, "OSG-RSG Comparison for Sequoyah Unit 1," J Eapen.
11. Framatome Document 38-1247982-00, "RSG Design Inputs," WL Redd.
12. American Nuclear Society Document ANSI/ANS-5.1-1994, "American National Standard for Decay Heat Power in Light water Reactors," 8/94.**
13. Framatome Document 32-1266117-02, "New Actinides for LOCA Analysis," GJ Wissinger.
14. TVA Design Criteria SQN-DC-V-27.2, "Chemical and Volume Control System" *

* These documents are controlled by TVA and are approved for use in the document.

** Publicly available reference.

WL Redd

WL Redd, Project Mgr.

Computer Run Listing

sqss/XWEL, dated 2/7/02 Short RELAP5 steady state run based on the steady state deck utilized in the analysis of a main steam line break outside containment, Reference 1.

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Appendix A

Customer Information Regarding the Feedwater System Volume

Reference 2, Figure 1

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TVA-89-859

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SEQUOYAH NUCLEAR PLANT — SQN-03-D053

D-HCG-HVS-040786

AUXILIARY FEEDWATER SYSTEM VOLUME — COMPUTED HvS DATE 8/8/86 — CHECKED PBS DATE 9/12/86

(Note: Volumes for Main Feedwater Piping is from AFW tie-in to SG's. Does not include volumes from AFW tie-in back to Main Feedwater Isolation Valves/FCV)

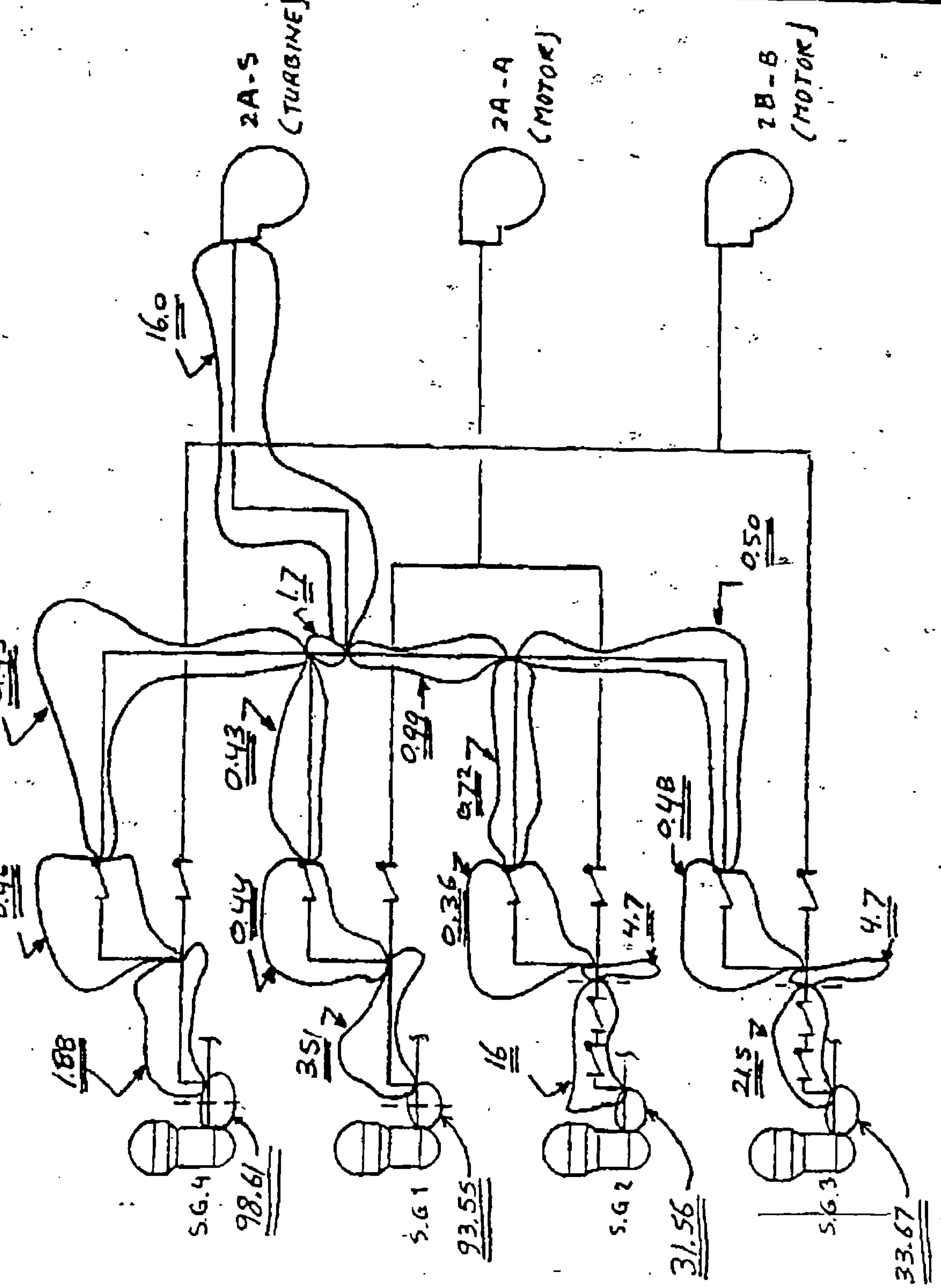

FIG. 1

AUXILIARY FEEDWATER PUMP DIAGRAM (FOR VOLUME INDICATION ONLY) (VOL. IN FT^3)

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