Exelon Generation®

Michael P. Gallagher
Exelon Nuclear
Vice President
License Renewal and Decommissioning

200 Exelon Way
Kennett Square, PA 19348

610 765 5958 Office
610 765 5658 Fax
www.exeloncorp.com
michaelp.gallagher@exeloncorp.com

10 CFR 50.90
10 CFR 50.12

RA-19-007

February 13, 2019

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555-0001

Oyster Creek Nuclear Generating Station
Renewed Facility Operating License No. DPR-16
USNRC Docket No. 50-219 and 72-15

Subject: Response to Request for Additional Information (RAI) and Supplemental Information Regarding Request for Changing Emergency Preparedness License Amendment No. 294 Effective Date (Change to Adiabatic Heat-up Calculation) (EPID: L-2018-LLA-0305)

References:

1. Letter from Michael P. Gallagher, Exelon Generation Company, LLC to U.S. Nuclear Regulatory Commission - "License Amendment Request - Proposed Change of Effective and Implementation Dates of License Amendment No. 294, Oyster Creek Emergency Plan for Permanently Defueled Emergency Plan and Emergency Action Level Scheme," dated October 22, 2018 (ADAMS Accession No. ML18295A384)
2. Letter from U.S. Nuclear Regulatory Commission to Bryan C. Hanson (Exelon Generation Company, LLC) - "Oyster Creek Nuclear Generating Station - Issuance of Amendment RE: Changes to the Emergency Plan for Permanently Defueled Emergency Plan and Emergency Action Level Scheme (CAC NO. MG0160; EPID L-2017-LLA-0307)," dated October 17, 2018 (ADAMS Accession No. ML18221A400)
3. Letter from U.S. Nuclear Regulatory Commission to Bryan C. Hanson (Exelon Generation Company, LLC) - "Oyster Creek Nuclear Generating Station - Exemptions from Certain Emergency Planning Requirements and Related Safety Evaluation (CAC NO. MG0153; EPID L-2017-LLE-0020)," dated October 16, 2018 (ADAMS Accession No. ML18220A980)
4. Letter from Michael P. Gallagher, Exelon Generation Company, LLC to U.S. Nuclear Regulatory Commission - "License Amendment Request Supplement – Proposed Change of Effective and Implementation Dates of License Amendment No. 294, Oyster Creek Emergency Plan for Permanently Defueled

Emergency Plan and Emergency Action Level Scheme," dated November 6, 2018 (ADAMS Accession No. ML18310A306)

5. Letter from Michael P. Gallagher, Exelon Generation Company, LLC to U.S. Nuclear Regulatory Commission "Certification of Permanent Removal of Fuel from the Reactor Vessel for Oyster Creek Nuclear Generating Station," dated September 25, 2018 (ADAMS Accession No. ML18268A258)
6. U.S. Nuclear Regulatory Commission Electronic Mail Request to David Helker, et al., (Exelon Generation Company, LLC) – DRAFT - For Your Action - RAI for Oyster Creek EP Exemption (Change to Adiabatic Heat-Up Calculation) (EPID: L-2018-LLA-0305), dated January 22, 2019
7. U.S. Nuclear Regulatory Commission Electronic Mail Request to David Helker (Exelon Generation Company, LLC) – "For Your Action - RAI for Oyster Creek EP Exemption (Change to Adiabatic Heat-Up Calculation) (EPID: L-2018-LLA-0305)," dated January 24, 2018 (ADAMS Accession No. ML19025A117)

By letter dated October 22, 2018 (Reference 1), Exelon Generation Company (Exelon) requested a change in the effective date of License Amendment No. 294, "Oyster Creek Nuclear Generating Station - Issuance of Amendment Re: Changes to The Emergency Plan for Permanently Defueled Emergency Plan and Emergency Action Level Scheme" (Reference 2), from 12 months (365 days) to 9.38 months (285 days) after permanent cessation of power operations. However, the exemptions from emergency planning requirements in 10 CFR 50.47, "Emergency plans," and Appendix E to 10 CFR Part 50, "Emergency Planning and Preparedness for Production and Utilization Facilities" (Reference 3), necessary for implementation of License Amendment No. 294 included the effective date as an integral part of the exemption. Therefore, by letter dated November 6, 2018 (Reference 4), Exelon supplemented the request dated October 22, 2018, with a request to modify the effective date of the exemption to 9.38 months (285 days) after permanent cessation of power operations.

By letter dated September 25, 2018, (Reference 5), Exelon certified the permanent cessation of power operations at OCNGS on September 17, 2018, and permanent removal of all fuel from the reactor vessel as of September 25, 2018. Thus, the effect of the request would be to change the implementation date of the emergency plan changes approved in License Amendment No. 294 from September 17, 2019, to June 29, 2019.

Subsequently, in an electronic mail request dated January 22, 2019 (Reference 6), the U.S. Nuclear Regulatory Commission (NRC) issued a draft Request for Additional Information (RAI) to ensure that the RAI was understandable and the regulatory bases for the question was clear. The draft RAI was further discussed during a teleconference between Exelon and NRC representatives held on January 24, 2019. It was determined that no modification to the draft RAI was needed and the NRC subsequently issued a formal RAI on January 24, 2019 (Reference 7). A response to the RAI was requested by February 25, 2019. Attachment 1 of this letter provides Exelon's response to the NRC's RAI.

Attachment 2 provides a revised adiabatic calculation (Revision 2) in support of the requested effective date change for the previously approved exemption (Reference 3). Revision 2 of the

calculation replaces, in its entirety, the previous revision of the calculation (Revision 1) submitted in Reference 1.

Exelon has reviewed the information supporting a finding of No Significant Hazards Consideration and the Environmental Consideration provided to the NRC in Reference 1. The additional information provided in this submittal does not affect the previously stated bases in Reference 1 for concluding that the proposed exemption does not involve a significant hazards consideration. In addition, the information provided in this submittal does not affect the bases for concluding that neither an environmental impact statement nor an environmental assessment needs to be prepared in connection with the proposed exemption.

There are no regulatory commitments contained in this submittal.

If you should have any questions or require additional information, please contact Mr. Paul Bonnett at 610-765-5264.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 13th day of February 2019.

Respectfully,

Michael P. Gallagher
Vice President, License Renewal & Decommissioning
Exelon Generation Company, LLC

Attachments: 1) Response to NRC's Request for Additional Information
2) Zirconium Fire Analysis for Drained Spent Fuel Pool, C-1302-226-E310-457, Revision 2

cc: USNRC Region I, Regional Administrator
USNRC Project Manager, NRR - Oyster Creek Nuclear Generating Station
USNRC Project Manager, NMSS - Oyster Creek Nuclear Generating Station
Director, Bureau of Nuclear Engineering, New Jersey Dept. of Environmental Protection
Mayor of Lacey Township, Forked River, NJ

bcc:	Sr. Vice President – Mid-Atlantic Operations	w/o attachments
	Sr. Vice President – Engineering and Technical Services	"
	Vice President – L&RA	"
	Plant Manager – OCNGS	"
	Manger, Operations – OCNGS	"
	Director, Licensing – KSA 3E	"
	Manager, Licensing – KSA-3E	w/attachments
	Regulatory Assurance – OCNGS	"
	Sr. Manager, Decommissioning – CAN	"
	Commitment Coordinator – KSA 3E	"
	Licensing Records, – KSA 3-E	"
	F. P. Bonnett – KSA 2-E	"

ATTACHMENT 1

Response to NRC's Request for Additional Information

Oyster Creek Nuclear Generating Station

Renewed Facility Operating License No. DPR-16

SUMMARY DESCRIPTION

By letter dated October 22, 2018 (Reference 1), Exelon Generation Company (Exelon) requested a change in the effective date of License Amendment No. 294, "Oyster Creek Nuclear Generating Station - Issuance of Amendment Re: Changes to The Emergency Plan for Permanently Defueled Emergency Plan and Emergency Action Level Scheme" (Reference 2), from 12 months (365 days) to 9.38 months (285 days) after permanent cessation of power operations. However, the exemptions from emergency planning requirements in 10 CFR 50.47, "Emergency plans," and Appendix E to 10 CFR Part 50, "Emergency Planning and Preparedness for Production and Utilization Facilities" (Reference 3), necessary for implementation of License Amendment No. 294 included the effective date as an integral part of the exemption. Therefore, by letter dated November 6, 2018 (Reference 4), Exelon supplemented the request dated October 22, 2018, with a request to modify the effective date of the exemption to 9.38 months (285 days) after permanent cessation of power operations.

By letter dated September 25, 2018, (Reference 5), Exelon certified the permanent cessation of power operations at OCNGS on September 17, 2018, and permanent removal of all fuel from the reactor vessel as of September 25, 2018. Thus, the effect of the request would be to change the implementation date of the emergency plan changes approved in License Amendment No. 294 from September 17, 2019, to June 29, 2019.

Subsequently, in an electronic mail request dated January 22, 2019 (Reference 6), the U.S. Nuclear Regulatory Commission (NRC) issued a draft Request for Additional Information (RAI) to ensure that the RAI was understandable, the regulatory bases for the question was clear. The draft RAI was further discussed during a teleconference between Exelon and NRC representatives held on January 24, 2019. It was determined that no modification to the draft RAI was needed and the NRC subsequently issued a formal RAI on January 24, 2019 (Reference 7). A response to the RAI was requested by February 25, 2019. Accordingly, Exelon's response to the NRC's RAI is provided below.

Applicable Regulation and Guidance

The current 10 CFR Part 50 regulatory requirements for emergency planning, developed for operating reactors, ensure protection of the health and safety of the public. However, once a nuclear power plant is permanently shutdown and defueled, some of these requirements exceed what is necessary to protect the health and safety of the public. Therefore, pursuant to 10 CFR 50.12 "Specific Exemptions," Exelon requested exemptions from certain emergency planning regulations in 10 CFR 50.47 and 10 CFR Part 50, Appendix E, for the Oyster Creek Nuclear Generation Station (OCNGS).

The NRC staff reviewed this previously granted exemption from certain emergency plan requirements of 10 CFR Part 50 (Reference 3) using the guidance provided in Interim Staff Guidance (ISG) NSIR/DPR-ISG-02, "Emergency Planning Exemption requests for Decommissioning Nuclear Power Plants" (Reference 8). This guidance notes that the provisions of 10 CFR 50.12 permit the NRC to grant exemptions from the requirements of 10 CFR Part 50 regulations in circumstances where the application of the regulation is not necessary to achieve the underlying purpose of the rule. The staff concluded that a minimum of 10 hours would provide adequate time to initiate mitigative actions to cool the fuel or, if needed, for offsite authorities to implement protective actions using a comprehensive emergency management plan (CEMP) approach. Thus, a formal offsite radiological emergency plan would not be necessary for permanently shutdown and defueled nuclear power reactor licensees when at least 10 hours would be necessary for the fuel to heat-up to the cladding ignition temperature following a complete loss of coolant. The decay heat rate is an important

parameter in determining the time available to initiate mitigative actions or offsite protective actions, and the limiting decay heat rate is determined by the fuel power history and the time after permanent cessation of power operations.

Issue

Attachment 2 to Exelon's submittal dated October 22, 2018 (Reference 1), contained Revision 1 to the Oyster Creek Nuclear Generating Station Zirconium Fire Analysis for Drained Spent Fuel Pool, C-1302-226-E310-457. The revision changed the decay heat rate used in the analysis to one specifically based on the final operating cycle power history rather than a projected bounding decay heat rate and increased the assumed heat sinks by including additional hardware masses (such as channel box and upper and lower tie plates). The analysis credited this additional heat sink capacity and revised decay heat rate to show that a 10-hour heat-up time to the ignition temperature (900°C) would be available within 9.38 months of decay time.

The NRC staff found that the document does not adequately justify an assumption used in the analysis that all fuel components heat up at a uniform rate (Assumption 3.6). This assumption is present in the analysis because the heat-up time was calculated by dividing the product of the temperature change and the fuel assembly heat capacity (including the heat capacity of the added fuel assembly components) by the decay heat rate. However, the temperature of the upper and lower tie plates may differ significantly from other fuel assembly components because distance and complex design slow heat transfer via conduction; these components have a poor view factor for radiative heat transfer and significant convective heat transfer is inconsistent with the adiabatic heat-up assumption. While it is common to assume components within an adiabatic envelope are at the same temperature, this assumption must be justified or the envelope boundary should be moved to ensure the assumption is valid.

RAI-OC-1

Provide justification that all components within the assumed adiabatic envelope that have not been previously accepted (specifically, the channel box and upper and lower tie plates) heat-up uniformly with the fuel pellets and cladding in the active fuel region. The justification should consider the complex design of the fuel assembly, the heat transfer mode, and the maximum rate of heat transfer supported by the fuel assembly design in that heat transfer mode relative to the heat capacity of the component.

Exelon's Response to RAI-OC-1:

Calculation C-1302-226-E310-457, Zirconium Fire Analysis for Drained Spent Fuel Pool, has been revised taking into consideration non-uniform heat-up of components in the fuel bundle assembly. Revision 2 of the calculation is included in Attachment 2 to this submittal. Revision 2 of this calculation replaces, in its entirety, Revision 1 of the calculation submitted in Reference 1.

The following changes were made to the calculation:

1. The adiabatic heat-up boundary was re-drawn around components adjacent to active fuel only. This removed the upper tie plate, lower tie plate, and end sections of the fuel assembly. All fuel assembly masses around the active fuel were left in the adiabatic boundary as they would readily receive conductive and radiative heat as the cladding heats up. The masses in the adiabatic boundary include the uranium dioxide (UO_2) fuel, cladding, water rods, pin spacers, and the channel box (excluding the corner thickness) in the horizontal area of active

fuel.

In the revised calculation, only the masses within the active fuel region (fuel pellets, cladding, water rods, and pin spacers) are initially credited. When the bulk temperature reaches 580°F, the channel mass in the active fuel region is added to the adiabatic envelope. Radiative heat transfer between the fuel rods (fuel and cladding) and the channel is a function of the surface area of the fuel rods that is viewed by the channel, the emissivity of the fuel rods, and the difference in temperatures to the fourth power between the fuel rods and the channel ($T^4_{rods} - T^4_{channel}$). With multiple rods in the 10x10 fuel array providing an adequate viewing factor of the channel, and emissivity values typical for Zircaloy-2, the entire bundle decay heat can be transferred to the channel at temperatures significantly less than 580°F. As such, the assumption that the channel box is thermally connected to the active fuel region and can be included in the adiabatic envelope at temperatures exceeding 580°F is justifiable. Heat transfer can occur to all components within the proposed adiabatic envelope, considering the complex design of the fuel assembly components, without significant delay in reaching 900°C within 10 hours.

2. Fuel and cladding specific heat values were adjusted to account for changes that occur as temperature increases.

The results of the revised calculation (Revision 2) as provided in Attachment 2, and taking into consideration the above discussed changes, continue to show that 9.38 months after cessation of power operations the fuel cladding will remain less than 900°C with 10 hours of adiabatic heat-up after loss of all spent fuel pool cooling. The changes made between Revision 2 and Revision 1 of the calculation offset each other and the results continue to support the 9.38-month decay time, while addressing the concerns indicated in the RAI. Revision 2 of the calculation continues to remain conservative due to not crediting actual fuel power history prior to shut down and heat losses that would occur due to radiative, conductive, and convective heat transfer means to other masses present outside of the revised adiabatic boundary. Exelon has always assumed a power history of 100% in all versions of this calculation.

REFERENCES

1. Letter from Michael P. Gallagher, Exelon Generation Company, LLC to U.S. Nuclear Regulatory Commission - "License Amendment Request - Proposed Change of Effective and Implementation Dates of License Amendment No. 294, Oyster Creek Emergency Plan for Permanently Defueled Emergency Plan and Emergency Action Level Scheme," dated October 22, 2018 (ADAMS Accession No. ML18295A384)
2. Letter from U.S. Nuclear Regulatory Commission to Bryan C. Hanson (Exelon Generation Company, LLC) - "Oyster Creek Nuclear Generating Station - Issuance of Amendment RE: Changes to the Emergency Plan for Permanently Defueled Emergency Plan and Emergency Action Level Scheme (CAC NO. MG0160; EPID L-2017-LLA-0307)," dated October 17, 2018 (ADAMS Accession No. ML18221A400)
3. Letter from U.S. Nuclear Regulatory Commission to Bryan C. Hanson (Exelon Generation Company, LLC) - "Oyster Creek Nuclear Generating Station - Exemptions from Certain Emergency Planning Requirements and Related Safety Evaluation (CAC NO. MG0153; EPID L-2017-LLE-0020)," dated October 16, 2018 (ADAMS Accession No. ML18220A980)

4. Letter from Michael P. Gallagher, Exelon Generation Company, LLC to U.S. Nuclear Regulatory Commission - "License Amendment Request Supplement – Proposed Change of Effective and Implementation Dates of License Amendment No. 294, Oyster Creek Emergency Plan for Permanently Defueled Emergency Plan and Emergency Action Level Scheme," dated November 6, 2018 (ADAMS Accession No. ML18310A306)
5. Exelon Letter to NRC, "Certification of Permanent Removal of Fuel from the Reactor Vessel for Oyster Creek Nuclear Generating Station," dated September 25, 2018 (ADAMS Accession No. ML18268A258)
6. U.S. Nuclear Regulatory Commission Electronic Mail Request to David Helker, et al., (Exelon Generation Company, LLC) – DRAFT - For Your Action - RAI for Oyster Creek EP Exemption (Change to Adiabatic Heat-Up Calculation) (EPID: L-2018-LLA-0305), dated January 22, 2019
7. U.S. Nuclear Regulatory Commission Electronic Mail Request to David Helker (Exelon Generation Company, LLC) – "For Your Action - RAI for Oyster Creek EP Exemption (Change to Adiabatic Heat-Up Calculation) (EPID: L-2018-LLA-0305)," dated January 24, 2018 (ADAMS Accession No. ML19025A117)
8. Interim Staff Guidance (ISG) NSIR/DPR-ISG-02, "Emergency Planning Exemption requests for Decommissioning Nuclear Power Plants," (ADAMS Accession No. ML14106A057)

ATTACHMENT 2

Oyster Creek Nuclear Generating Station

Zirconium Fire Analysis for Drained Spent Fuel Pool, C-1302-226-E310-457, Revision 2

Design Analysis		**Last Page No.** [6] 66	
Analysis No.: [1] C-1302-226-E310-457		**Revision:** [2] 2 Major ☒ Minor ☐	
Title: [3] Oyster Creek Nuclear Generating Station Zirconium Fire Analysis for Drained Spent Fuel Pool			
EC/ECR No.: [4] 626993		**Revision:** [5] 0	
Station(s): [7]	OCNGS	**Component(s):** [14]	
Unit No.: [8]	1	N/A	
Discipline: [9]	MECH		
Descrip. Code/Keyword: [10]	N/A		
Safety/QA Class: [11]	NSR		
System Code: [12]	N/A		
Structure: [13]	SFP		

CONTROLLED DOCUMENT REFERENCES [15]

Document No.:	From/To	Document No.:	From/To
C-1302-226-E310-458, R0	From		
GEH-0000-0118-3544, R1	From		
DB-0011.03, R1	From		
26A7584, R0	From		

Is this Design Analysis Safeguards Information? [16] Yes ☐ No ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? [17] Yes ☐ No ☒ If yes, ATI/AR#:

This Design Analysis SUPERCEDES: [18] N/A **in its entirety.**

Description of Revision (list changed pages when all pages of original analysis were not changed): [19]

Revision 2 removes the credit of the upper and lower tie plate as well as other masses away from the active fuel region from the analysis in response to a RAI. Additionally, the calculation is updated to determine the temperature of the limiting OCNGS spent fuel bundle with 9.38 months of decay at a time of 10 hours after becoming uncovered with a starting temperature of 125°F. Material specific heat properties are updated from References 18 and 19. Due to the substantial changes in the calculation rev bars are not included.

Preparer: [20]	Dwayne Blaylock (Print Name)	(Sign Name)	2/7/19 (Date)
Method of Review: [21]	**Detailed Review** ☒ **Alternate Calculations (attached)** ☐ **Testing** ☐		
Reviewer: [22]	John Wright (Print Name)	(Sign Name)	2/7/19 (Date)

Review Notes: [23] Independent review ☒ Peer review ☐

This calculation has been independently reviewed per CC-AA-309 and CC-AA-309-1001. All comments have been satisfactorily incorporated.

(For External Analyses Only)

External Approver: [24]	Guy Spikes (Print Name)	(Sign Name)	2/7/19 (Date)
Exelon Reviewer: [25]	Robert Csillag (Print Name)	(Sign Name)	2/8/19 (Date)
Independent 3rd Party Review Reqd? [26]	Yes ☐ No ☒		
Exelon Approver: [27]	William Saracino (Print Name)	(Sign Name)	2/8/19 (Date)

Owner's Acceptance Review checklist for External Design Analysis

Page 1 of 3

Design Analysis No.: C-1302-226-E310-457 **Rev:** 2
Contract #: 597114 **Release #:** 167

No	Question	Instructions and Guidance	Yes / No / N/A
1	Do assumptions have sufficient documented rationale?	All Assumptions should be stated in clear terms with enough justification to confirm that the assumption is conservative. For example, 1) the exact value of a particular parameter may not be known or that parameter may be known to vary over the range of conditions covered by the Calculation. It is appropriate to represent or bound the parameter with an assumed value. 2) The predicted performance of a specific piece of equipment in lieu of actual test data. It is appropriate to use the documented opinion/position of a recognized expert on that equipment to represent predicted equipment performance. Consideration should also be given as to any qualification testing that may be needed to validate the Assumptions. Ask yourself, would you provide more justification if you were performing this analysis? If yes, the rationale is likely incomplete.	☒ ☐ ☐
2	Are assumptions compatible with the way the plant is operated and with the licensing basis?	Ensure the documentation for source and rationale for the assumption supports the way the plant is currently or will be operated post change and they are not in conflict with any design parameters. If the Analysis purpose is to establish a new licensing basis, this question can be answered yes, if the assumption supports that new basis.	☒ ☐ ☐
3	Do all unverified assumptions have a tracking and closure mechanism in place?	If there are unverified assumptions without a tracking mechanism indicated, then create the tracking item either through an ATI or a work order attached to the implementing WO. Due dates for these actions need to support verification prior to the analysis becoming operational or the resultant plant change being op authorized.	☐ ☐ ☒
4	Do the design inputs have sufficient rationale?	The origin of the input, or the source should be identified and be readily retrievable within Exelon's documentation system. If not, then the source should be attached to the analysis. Ask yourself, would you provide more justification if you were performing this analysis? If yes, the rationale is likely incomplete.	☒ ☐ ☐
5	Are design inputs correct and reasonable with critical parameters identified, if appropriate?	The expectation is that an Exelon Engineer should be able to clearly understand which input parameters are critical to the outcome of the analysis. That is, what is the impact of a change in the parameter to the results of the analysis? If the impact is large, then that parameter is critical.	☒ ☐ ☐
6	Are design inputs compatible with the way the plant is operated and with the licensing basis?	Ensure the documentation for source and rationale for the inputs supports the way the plant is currently or will be operated post change and they are not in conflict with any design parameters.	☒ ☐ ☐

Attachment 2

Owner's Acceptance Review checklist for External Design Analysis

Page 2 of 3

Design Analysis No.: C-1302-226-E310-457 Rev: 2

No	Question	Instructions and Guidance	Yes / No / N/A
7	Are Engineering Judgments clearly documented and justified?	See Section 2.13 in CC-AA-309 for the attributes that are sufficient to justify Engineering Judgment. Ask yourself, would you provide more justification if you were performing this analysis? If yes, the rationale is likely incomplete.	☐ ☐ ☒
8	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	Ensure the justification for the engineering judgment supports the way the plant is currently or will be operated post change and is not in conflict with any design parameters. If the Analysis purpose is to establish a new licensing basis, **then** this question can be answered yes, if the judgment supports that new basis.	☐ ☐ ☒
9	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	Why was the analysis being performed? Does the stated purpose match the expectation from Exelon on the proposed application of the results? If yes, **then** the analysis meets the needs of the contract.	☒ ☐ ☐
10	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	Make sure that the results support the UFSAR defined system design and operating conditions, or they support a proposed change to those conditions. If the analysis supports a change, are all of the other changing documents included on the cover sheet as impacted documents?	☒ ☐ ☐
11	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	Does the analysis support a temporary condition or procedure change? Make sure that any other documents needing to be updated are included and clearly delineated in the design analysis. Make sure that the cover sheet includes the other documents where the results of this analysis provide the input.	☐ ☐ ☒
12	Have margin impacts been identified and documented appropriately for any negative impacts (Reference ER-AA-2007)?	Make sure that the impacts to margin are clearly shown within the body of the analysis. If the analysis results in reduced margins ensure that this has been appropriately dispositioned in the EC being used to issue the analysis.	☐ ☐ ☒
13	Does the Design Analysis include the applicable design basis documentation?	Are there sufficient documents included to support the sources of input, and other reference material that is not readily retrievable in Exelon controlled Documents?	☒ ☐ ☐
14	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	Determine if sufficient searches have been performed to identify any related analyses that need to be revised along with the base analysis. It may be necessary to perform some basic searches to validate this.	☒ ☐ ☐
15	Do the sources of inputs **and** analysis methodology used meet committed technical and regulatory requirements?	Compare any referenced codes and standards to the current design basis and ensure that any differences are reconciled. If the input sources **or** analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code	☒ ☐ ☐

Attachment 2
Owner's Acceptance Review checklist for External Design Analysis
Page 3 of 3

Design Analysis No.: C-1302-226-E310-457 **Rev:** 2

No	Question	Instructions and Guidance	Yes / No / N/A
16	Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary?	Based on the risk assessment performed during the pre-job brief for the analysis (per HU-AA-1212), ensure that sufficient reviews of any supporting documents not provided with the final analysis are performed.	☐ ☐ ☒
17	Do operational limits support assumptions and inputs?	Ensure the Tech Specs, Operating Procedures, etc. contain operational limits that support the analysis assumptions and inputs.	☐ ☐ ☒
18	List the critical characteristics of the product, and validate those critical characteristics.		

Create an SFMS entry as required by CC-AA-4008. SFMS Number: 64588

Completed by R. Csillag on 2/7/19.
Cross functional review by Jim Frank on 2/7/19
All comments incorporated.

R A Csillag 2/7/19

Table of Contents

Attachments

1.0 Purpose and Scope

The purpose of this calculation is to conservatively evaluate the length of time required for a bounding uncovered spent fuel bundle in the spent fuel pool with 9.38 months of decay to reach the temperature where the zirconium cladding would fail. This analysis conservatively assumes that there is no air cooling of the assemblies nor heat transfer by conduction, convection, and radiation from the assembly to other structures in the spent fuel pool and/or environments and supports decommissioning of Oyster Creek Nuclear Generating Station (OCNGS). Specifically, this analysis will be used to reduce the emergency planning staff once the hottest fuel assembly decay time is sufficient and is demonstrated to reach 900°C in 10 hours which supports the requirements of ISG-02, Section 5, Item 2 (Ref. 9).

The temperature over time is determined from a starting temperature of 125°F with the heat load from a the limiting GNF2 assembly as determined in Attachment 2. Note, the heat load was previously taken from Attachment 8 of Reference 1 in Revision 0 of this calculation.

2.0 Acceptance Criteria

There are no specific acceptance criteria for this analysis; however, SECY-99-168 (Ref. 8) suggests that "10 hours (is) sufficient time to take mitigative action" and that for BWRs, 2 years is expected to be the decay time needed to reach a 10 hour heat-up time from 30 °C to 900 °C. NUREG-1738 shows that a 10 hour heat up time for a BWR requires less than 2 years of cooling time (Ref. 7, Fig. 2-1).

NUREG/CR-6451 (Ref. 6) presents several studies discussing the maximum allowable temperature of zirconium cladding that will ensure that failure of the zirconium cladding will not occur. NUREG/CR-6451 states 565 °C (1049 °F) is the lowest temperature where incipient cladding failure might occur. Per NUREG-1738 (Ref. 7, pg. 3-7), 900°C (1652 °F) is the temperature where "runaway oxidation" (zirconium fire) is expected to occur. Therefore, the decay period to reach a 10 hour heat-up time from 30 °C (86 °F) to 900 °C is used as the acceptance criteria in this calculation. The decay period to reach a 10 hour heat-up time from 30 °C to 565 °C is also presented to show when cladding failure may occur.

NRC-2015-0070, Appendix A, Section 4.2.6 (Ref. 17) states that for BWRs a 10 month period for Level 1 (post-shutdown emergency planning) shall be used unless a site-specific analysis demonstrates a shorter time period is acceptable for reaching a cladding temperature of 900 °C within 10 hours.

3.0 Assumptions

3.1 The heat-up time is conservatively assumed to start when the spent fuel pool has been completely drained. This is conservative as the drain down time would increase the time to cladding failure.

3.2 The fuel rod spacers, located in the active fuel region are made of Inconel X-750 but are assumed to be zircaloy-2. This assumption is conservative since the specific heat capacity of

zircaloy-2 is less than that of Inconel X-750. For instance, at 300K (~70°F) the specific heat of zircaloy-2 is 0.281×10^3 J/kg·K (Reference 18) and Inconel X-750 is 0.43×10^3 J/kg·K (0.103 Btu/lb·°F) (Reference 14). A lower specific heat capacity is conservative because it results in a shorter heat-up time.

3.3 OCNGS final cycle 26 will contain a full core of GNF2 fuel (Ref. 12); therefore, the analysis herein will only evaluate the heat up of GNF2 fuel assemblies and not any other assembly type in the spent fuel pool because the offloaded fuel directly after a cycle contains the assemblies with the highest decay heat (referred to as the hottest fuel assembly here-in).

3.4 The specific heat capacity for uranium dioxide and the zircaloy-2 cladding are determined at the initial temperature of each time step. Both the empirical formula and the specific heat capacity values in Table 1 are increasing with temperature from the range of 300K (80°F) to 1,173K (900°C). With an increasing temperature in each time step it is conservative to use the initial temperature resulting in a lower specific heat capacity than the average value for the time step.

3.5 This analysis conservatively assumes that there is no air cooling of the assemblies (i.e., adiabatic conditions): the flow paths that would provide natural circulation cooling are assumed to be blocked.

3.6 The fuel assembly materials in the active fuel region (fuel rods, spacers and water rods) are assumed to start at a uniform temperature and heat up at uniform rate. While there are temperature gradients throughout the assemblies, these are small relative to the total heat up from 125 °F (Input 5.5) to 900 °C for zirconium fire. Furthermore, this simplified approach is still conservative overall since convective heat transfer is not considered, nor is conduction to the upper and lower tie plates or other structural materials such as the SFP racks.

3.7 Gadolinium, which is a burnable poison and can be used in some fuel rods (Reference 2), is conservatively not included in this evaluation.

3.8 Radiative heat transfer to the active fuel length of the channel box is credited after the bulk temperature exceeds 580°F. This assumption is conservative as radiative heat transfer between the fuel rods and the channel is a function of the temperature difference $(T_{rods}^4 - T_{channel}^4)$. With an adequate view factor between the fuel rods and the channel, and emissivity values typical of zircaloy-2, the entire decay heat in the bundle can be transferred to the channel when the bulk temperature of the fuel region is less than 580°F. Additionally, some conductive heat transfer occurs to the channel box via the connection to the upper and lower tie plate which in turn are connected to the fuel rods. Therefore, the assumption that the channel and the active fuel region are thermally connected at temperatures greater than 580°F is conservative.

3.9 The oxygen to metal ratio in the equation to determine the specific heat capacity of Uranium Oxide (UO_2) is assumed to be 2.00. This assumption is conservative since in fresh fuel there exists a 2 to 1 ratio of oxygen to uranium atoms in the fuel. As the fuel is burnt some uranium atoms fission and this ratio increases slightly. As demonstrated by Figure 2-1 of Reference 18, the specific heat capacity of UO_2 increases with an increasing oxygen to metal ratio.

4.0 References

1. C-1302-226-E310-458, Rev. 0, "Dose at Exclusion Area Boundary and Control Room Due to Shine from Drained Spent Fuel Pool During SAFSTOR".
2. TODI NF172795, Rev.0, "Transmit GNF2 Dimensional Data for Oyster Creek".
3. OCNGS Technical Specification 5.3.1, Amendment No. 223.
4. Deleted
5. GEH-0000-0118-3544, Rev. 1, "GNF2 Fuel Design Cycle-Independent Analyses for Exelon Oyster Creek Generating Station".
6. NUREG/CR-6451, "A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants", August 1997 (ML082260098).
7. NUREG-1738, "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants", February 2001 (ML010430066).
8. SECY-99-168, "Improving Decommissioning Regulations for Nuclear Power Plants", June 30, 1999 (ML992800087).
9. NSIR/DPR-ISG-02, "Emergency Planning Exemption Requests for Decommissioning Nuclear Power Plants", May 11, 2015.
10. ORNL/TM-2005/39, SCALE 6.1, User's Manual, June 2011.
11. Incropera & DeWitt, "Fundamentals of Heat and Mass Transfer", Third Edition, John Wiley & Sons, Inc., 1990
12. NF183597, Rev. 0, Oyster Creek Unit 1 Cycle 26 EOC Zirc Fire Calculation Inputs. (Attachment 3)
13. 26A7584, Rev. 0, GNF2 BWR/2-3 Fuel Bundle Weights (proprietary).
14. Inconel X-750 Technical Bulletin, Special Metals, <http://www.specialmetals.com/assets/smc/documents/alloys/inconel/inconel-alloy-x-750.pdf> (accessed 2/19/2018). (Attachment 4)
15. GNF2 Product Sheet, General Electrical, <https://nuclear.gepower.com/fuel-a-plant/products/gnf2-advantage> (accessed 2/20/2018). (Attachment 5)
16. DB-0011.03, Rev. 1, GNF2 Design Basis (proprietary).
17. NRC-2015-0070, Regulatory Improvements for Power Reactors Transitioning to Decommissioning, RIN Number 3150-AJ59, November 20, 2017.
18. NUREG/CR-6150, Vol.4, Rev 2, "SCDAP/RELAP/MOD3.3 Code Manual: MATPRO – A Library of Materials Properties for Light-Water-Reactor Accident Analysis", January 2001 (ML010330363, ML010330400 and ML010330422).
19. NUREG/CR-7024, "Material Property Correlations: Comparisons between FRAPCON-3.4, FRAPTRAN 1.4 and MATPRO" March 2011 (ML11101A012).

5.0 Input Data

5.1 Zircaloy-2 Properties

The cladding for the GNF2 fuel is zircaloy-2 (Ref. 5). The density of zircaloy-2 is 6.56 g/cm^3 (409.53 lbm/ft^3) (Ref. 10). The GNF2 channel is also zirconium alloy (Ref. 15).

The specific heat capacity at various temperatures of zircaloy-2 is from Table 4.2 of Reference 18 and Table 3.1-1 of Reference 19 Table 1 contains the specific heat capacity of zircaloy-2 in both J/kg-K and BTU/lbm-°F. The specific heat capacity unit conversion is a 1 joule/kilogram/K (J/kg·K) = 0.238845896627E-03 Btu/pound/°F (Btu/lbm·°F).

Table 1: Zircaloy-2 Specific Heat Capacity

Temperature		Specific Heat Capacity	
(K)	(°F)	J/kg-K	BTU/lb$_m$-°F
300	80.33	281	0.0671
400	260.33	302	0.0721
640	692.33	331	0.0791
1090	1502.33	375	0.0896
1093	1507.73	502	0.1199
1113	1543.73	590	0.1409
1133	1579.73	615	0.1469
1153	1615.73	719	0.1717
1173	1651.73	816	0.1949
1193	1687.73	770	0.1839
1213	1723.73	619	0.1478
1233	1759.73	469	0.1120
1248	1786.73	356	0.0850

5.2 Uranium Properties

The density of uranium dioxide is 10.6 g/cm^3 (661.74 lb/ ft^3) (Ref. 5, p. 19).

The specific heat capacity at various temperatures is calculated by the following empirical formula from Equation 2-5 of Reference 18 and Equation 2.2-1 of Reference 19.

Equation 5-1

$$FCP = \frac{K_1\theta^2\exp(\theta/T)}{T^2[\exp(\theta/T)-1]^2} + K_2T + \frac{YK_3E_D}{2RT^2}\exp\left(-E_D/RT\right)$$

Where:

FCP = Specific heat capacity (J/kg-K)
T = Temperature (K)

Y	=	Oxygen-to-metal ratio = 2 (Assumption 3.9)
R	=	Universal gas constant = 8.3143 (J/mol-K) (Reference 18)
θ	=	the Einstein temperature = 535.285 (K) (Reference 18)
K_1	=	296.7 (J/kg-K) (Reference 18)
K_2	=	2.43×10^{-2} (J/kg-K^2) (Reference 18)
K_3	=	8.745×10^7 (J/kg) (Reference 18)
E_D	=	1.577×10^5 (J/mol) (Reference 18)

5.3 Geometry for Limiting Assemblies

The table below shows the geometry inputs for the fuel assemblies used in this analysis. OCNGS's final cycle before decommissioning will contain a full core of GNF2 fuel (Assumption 3.3); therefore, the analysis herein will only evaluate the heat up of GNF2 fuel assemblies and not any other assembly type in the spent fuel pool because the offloaded fuel directly after a cycle is the hottest fuel assemblies in the pool. Table 2 contains fuel assembly input data for GNF2 fuel.

Table 2: Fuel Assembly Inputs for GNF2 Fuel

Number of Heated Rods	92 rods	Reference 5
Number of Water Rods	2 rods	Reference 5
Number of 2/3 Length Part Length Rod	8 rods	Reference 5
Number of 3/8 Length Part length Rod	6 rods	Reference 5
Length of 2/3 Part Length Rod	102 inches	Reference 2 and 5
Length of 3/8 Part Length Rod	54 inches	Reference 2 and 5
Uranium Pellet Diameter	0.3496 inches	Reference 2
Outer Diameter of Water Rods	0.980 inches	Reference 2
Inner Diameter of Water Rods	0.920 inches	Reference 2
Outer Diameter of Cladding	0.404 inches	Reference 2
Inner Diameter of Cladding	0.3567 inches	Reference 2
Heated Length of Rods	145.24 inches	Reference 2
Channel Width	5.283 inches	Reference 16
Channel Groove Thickness	0.050 inches	Reference 16
Channel Groove Width	0.798 in	Reference 16
Groove Ramp Width	0.027 in	Reference 16
Channel Sidewall Thickness	0.065 in	Reference 16
Number of Spacers in Active Length of Rods	8	Reference 16
Total weight of Spacers	2.13 lbm	Reference 13
Spacer Material Type	Inconel alloy X-750	Reference 13

5.4 Heat Load

Attachment 2 determines the maximum heat load from a single fuel assembly, based on the information provided in Attachment 3. The assembly with the highest heat load will have the shortest heat-up time.

The table showing the maximum fuel assembly heat generation rates for several years is in Attachment 2, Table A2-1.

The worst-case (hottest) bundle is one that was discharged at the end of Cycle 26 and has been cooling for nine months. From Table A2-1, the heat load of this bundle 1.091×10^4 W/MTU. The maximum 0.181368 MTU/assembly value was derived from Cycle 26 data (Reference 12). The decay heat for the worst-case assembly with 9 months of decay is calculated as follows using the maximum assembly weight and a conversion factor of 1 W = 3.4123 BTU/hr from Reference 11.

$$Worst-case\ bundle\ heat\ load = \frac{1.091E+04\ W}{MTU} \times \frac{0.181368\ MTU}{assembly}$$

$$= 1979\ \frac{W}{assembly} \times \frac{3.4123\ \frac{BTU}{hr}}{W} = 6752\ \frac{BTU/hr}{assembly}$$

Similarly, the decay heat of the worst-case assembly at 12 months is calculated to be 5,581 BTU/hr/assembly. From the 9 month and the 12 month decay heat, a 9.38 month decay heat is calculated via linear-logarithmic interpolation due to the exponential decay of the decay heat. The resulting 9.38 month decay heat is calculated to be:

$$Decay\ Heat\ (9.38\ mo) = e^{\left[Ln(6752\ BTU/Hr) - \frac{0.38}{3} \times (Ln(6752\ BTU/hr) - Ln(5581\ BTU/hr)\right]} = 6591\ BTU/hr$$

5.5 Water Temperature

The starting temperature for the heat-up analysis is taken as a uniform 125 °F (51 °C). The temperature of 125 °F (51 °C) is the maximum Technical Specification pool temperature at or near the surface (Ref. 3). Under normal conditions, the pool temperature is procedurally controlled to be significantly less than the Technical Specification limit and would be more consistent with the SECY-99-168 (Ref. 8) and NUREG-1738 (Ref. 7) starting water temperature at 30 °C (86 °F), so setting the initial temperature to the maximum pool temperature is conservative.

6.0 Identification of Computer Codes

The ORIGEN-ARP module of the SCALE 6.1 code package is used to calculate new decay heat values in Attachment 2 of this calculation in revision 1. This revised model is based on the existing ORIGEN-ARP models developed as part of C-1302-226-E310-458 (Reference 1). Further discussion on the use and application of this software is contained within C-1302-226-E310-458.

7.0 Method of Analysis

This analysis determines the heat-up time of the fuel assembly using the thermal capacity of materials.

Equation 7-1 (Ref. 11, Ch. 8):

$$\dot{q} = m \times c_p \times \frac{\Delta T}{\Delta t}$$

$$m = \rho \times V$$

Where:

$\dot{q}$ is the heat generation rate in BTU/hr
m is the mass of material in lb
ρ is the density of the material in lb/ft^3
V is the volume of the material in ft^3
c_p is the specific heat in BTU/lb- °F
ΔT is the temperature increase in °F
Δt is the heat-up time step in hr

For this analysis, there are two materials that are considered: the uranium dioxide fuel pellets and zircaloy-2. Zircaloy-2 comprises the cladding, the water tubes, channel, and the spacers (Assumption 3.2), all of which are also being heated. Under adiabatic conditions, zircaloy-2 and the uranium dioxide are modeled as heating up at the same rate, so the $\frac{\Delta T}{\Delta t}$ will be the same for both materials.

Equation 7-2:

$$\dot{q} = \frac{\Delta T}{\Delta t} \times \left(m_u \times c_{p,u} + m_z \times c_{p,z}\right)$$

Where:

X_u signifies the property is for uranium dioxide
X_z signifies the property is for zircaloy-2
m_u signifies the mass of uranium dioxide
m_z signifies the mass of zircaloy-2

This calculation seeks to determine the increase in temperature over sequential time steps of 0.025 hours (Δt), so Equation 7-2 is solved for ΔT.

Equation 7-3:

$$\Delta T = \frac{\dot{q} \times \Delta t}{\left(m_u \times c_{p,u} + m_z \times c_{p,z}\right)}$$

The volume of uranium is given below.

Equation 7-4:

$$V_u = \left(\left(\pi \times \frac{{D_p}^2}{4}\right) N_{FL} \times L_{FL}\right) + \left(\left(\pi \times \frac{{D_p}^2}{4}\right) N_{\left(\frac{2}{3}\right)} \times L_{\left(\frac{2}{3}\right)}\right) + \left(\left(\pi \times \frac{{D_p}^2}{4}\right) N_{\left(\frac{3}{8}\right)} \times L_{\left(\frac{3}{8}\right)}\right)$$

Where:

D_p is the diameter of the uranium pellet in ft
N_{FL} is the number of full length heated rods
L_{FL} is the heated length of the full length rods in ft
$N_{\left(\frac{2}{3}\right)}$ is the number of 2/3 length heated rods
$L_{\left(\frac{2}{3}\right)}$ is the heated length of 2/3 length rods in ft
$N_{\left(\frac{3}{8}\right)}$ is the number of 3/8 length heated rods
$L_{\left(\frac{3}{8}\right)}$ is the heated length of 3/8 length rods in ft

The mass of uranium is calculated as follows

Equation 7-5:

$$M_U = V_U \times \rho_U$$

Where:

M_U is the mass of the uranium fuel in lb_m
ρ_U is the density of uranium in lb_m/ft^3

The volume of zircaloy-2 in the active fuel region the volume of the heated rods and water rods is summed as determined below. The length of the cladding is the active length of the rods. Water rods are credited for the length of the active fuel region of a full-length fuel rod.

Equation 7-6:

$$V_{z,cl} = \left(\left(\pi \times \frac{{D_{c,o}}^2 - {D_{c,i}}^2}{4}\right) N_{FL} \times L_{FL}\right) + \left(\left(\pi \times \frac{{D_{c,o}}^2 - {D_{c,i}}^2}{4}\right) N_{\left(\frac{2}{3}\right)} \times L_{\left(\frac{2}{3}\right)}\right) + \left(\left(\pi \times \frac{{D_{c,o}}^2 - {D_{c,i}}^2}{4}\right) N_{\left(\frac{3}{8}\right)} \times L_{\left(\frac{3}{8}\right)}\right)$$

Where:

$V_{z,cl}$ is the volume of zircaloy-2 in the cladding of heated tubes in ft^3
$D_{c,o}$ is the outer diameter of the cladding in ft
$D_{c,i}$ is the inner diameter of the cladding in ft

Equation 7-7:

$$V_{z,wr} = \left(\pi \times \frac{{D_{w,o}}^2 - {D_{w,i}}^2}{4}\right) N_{wr} \times L_{FL}$$

Where:

$V_{z,wr}$ is the volume of zircaloy-2 in the water rods in ft^3
$D_{w,o}$ is the outer diameter of the water rods in ft
$D_{w,i}$ is the inner diameter of the water rods in ft
N_{wr} is the number of water rods

The volume of the channel box is determined by the inside width, a weighted average thickness based on the grove and sidewall thickness, and the active length of the rods. In reality, the channel box is slightly thicker due to the thick corners and longer than the active length. As discussed in Assumption 3.8, the mass of the channel box is credited only after the bulk temperature of 580°F.

Equation 7-8

$$V_{z,cb} = 0 \quad : T < 580°\text{F}$$

$$V_{z,cb} = 4 \times L_{TL} \times W_{cb} \times \left[\frac{T_g \times 2 * (W_g + 2W_{gr})}{W_{cb}} + \frac{T_W \times [W_{cb} - 2 * (W_g + 2W_{gr})]}{W_{cb}}\right] : T \geq 580°\text{F}$$

Where:

$V_{z,cb}$ is the volume of zircaloy-2 in the channel box in ft^3
W_{cb} is the inside width of the channel box in ft
W_g is the width of the groove in ft
W_{gr} is the width of the groove ramp in ft
T_g is the groove thickness of the channel box in ft
T_w is the side wall thickness of the channel box in ft

Equation 7-9:

$$V_z = V_{z,cl} + V_{z,wr} + V_{z,cb}$$

Where:

V_z is the total zircaloy-2 volume in ft^3

The mass of the zircaloy-2 is calculated as follows.

Equation 7-10

$$M_Z = (V_Z \times \rho_Z) + M_s$$

Where:

M_Z is the mass of the zircaloy in lb

p_Z is the density of zircaloy in lb/ft^3

M_S is the mass of the spacers in lb

The temperature increase (ΔT) for this analysis is taken to be from the initial temperature of the pool, 125°F (51 °C) (Input 5.5), to the zirconium cladding failure temperatures of interest, 1049°F (565°C) and 1652°F (900°C) (Acceptance Criteria, Section 2).

For each time step Equation 7-3 is solved to determine the change in temperature starting with the initial temperature of 125°F, the specific heat capacity of uranium is determined using equation 5-1 at the initial temperature. The specific heat capacity of zircaloy-2 at the initial temperature is determined by interpolating between the various data points in Table 1. Using the mass of uranium calculated by Equation 7-5 and the mass of zircaloy-2 calculated by Equation 7-10 the change in temperature (ΔT) of the time step is calculated. For the next time step the initial temperature is determined by adding the initial temperature and ΔT from the previous time step.

The hottest assembly source term methodology is described in Attachment 2.

8.0 Numeric Analysis

The volume of Uranium Dioxide in the hottest fuel assembly is determined below using Equation 7-4:

$$V_u = \left(\left(\pi \times \frac{(\frac{0.3496\ in}{12\ in/ft})^2}{4}\right) 78\ rods \times \frac{145.24\ in}{12\ in/ft}\right) + \left(\left(\pi \times \frac{(\frac{0.3496\ in}{12\ in/ft})^2}{4}\right) 8\ rods \times \frac{102\ in}{12\ in/ft}\right)$$
$$+ \left(\left(\pi \times \frac{(\frac{0.3496\ in}{12\ in/ft})^2}{4}\right) 6\ rods \times \frac{54\ in}{12\ in/ft}\right) = 0.693\ ft^3$$

The resulting mass of Uranium Dioxide using Equation 7-5 with the density from Input 5.2 is:

$$m_u = 0.693\ ft^3 \times 661.74 \frac{lbm}{ft^3} = 458.586\ lbm$$

The volume of zircaloy-2 in the cladding is determined below using Equation 7-6:

$$V_{z,cl} = \left(\left(\pi \times \frac{(\frac{0.404\ in}{12\ in/ft})^2 - (\frac{0.3567\ in}{12\ in/ft})^2}{4}\right) 78\ rods \times \frac{145.24\ in}{12\ in/ft}\right) + \left(\left(\pi \times \frac{(\frac{0.404\ in}{12\ in/ft})^2 - (\frac{0.3567\ in}{12\ in/ft})^2}{4}\right) 8\ rods \times \frac{102\ in}{12\ in/ft}\right) + \left(\left(\pi \times \frac{(\frac{0.404\ in}{12\ in/ft})^2 - (\frac{0.3567\ in}{12\ in/ft})^2}{4}\right) 6\ rods \times \frac{54\ in}{12\ in/ft}\right) = 0.204 ft^3$$

The volume of zircaloy-2 in the water rods is determined below using Equation 7-7.

$$V_{z,wr} = \left(\pi \times \frac{(\frac{0.980\ in}{12\ in/ft})^2 - (\frac{0.920\ in}{12\ in/ft})^2}{4}\right) 2\ rods \times \frac{145.24\ in}{12\ in/ft} = 0.0151\ ft^3$$

The volume of zircaloy-2 in the channel is determined below using Equation 7-8.

$$V_{z,cb} = 0 \ : T < 580°\text{F}$$

$$V_{z,cb} = 4 \times \frac{145.24\ in}{12\ in/ft} \times \frac{5.283\ in}{12\ in/ft} \times \left[\frac{0.05\ in \times 2 * (0.798\ in + 2(0.027 in))}{5.283\ in} + \frac{0.065\ in \times [5.283\ in - 2 * (0.798\ in + 2(0.027\ in))]}{5.283\ in}\right] \Big/ _{12\ in/ft} = 0.107\ ft^3 : T \geq 580°\text{F}$$

The total zircaloy-2 volume is then determined below from Equation 7-9:

$$V_z = 0.204\ ft^3 + 0.0151\ ft^3 + 0\ ft^3 = 0.2191\ ft^3 \ : T < 580°\text{F}$$

$$V_z = 0.204\ ft^3 + 0.0151\ ft^3 + 0.107\ ft^3 = 0.3261\ ft^3 \ : T \geq 580°\text{F}$$

The resulting total mass of zircaloy-2 is calculated using Equation 7-10 with the volume above and the density from Input 5.1 along with the mass of the spacers from Input 5.3:

$$m_z = \left(0.2191\ ft^3 \times 409.53 \frac{lbm}{ft^3}\right) + 2.13\ lbm = 91.858\ lbm \ : T < 580°\text{F}$$

$$m_z = \left(0.3261\ ft^3\ \times\ 409.53\frac{lbm}{ft^3}\right) + 2.13\ lbm = 135.678\ lbm\quad : T \geq 580°\text{F}$$

Equation 7-3 is solved in an Excel spreadsheet with an initial temperature of 125°F to determine the change in temperature (ΔT) over the time step. For each time step, the 10-month decay heat from the limiting bundle of 6,591 BTU/hr, the mass of UO_2 of 458.586 lbm and the mass of zircaloy-2 of 91.858 lbm (T< 580°F) or 135.678 lbm (T ≥ 580°F) are used. Specific heat capacity is determined at the initial temperature of the time step by Equation 5-1 for UO_2 and by interpolation of the data in Table 1 for zircaloy-2.

For the subsequent time steps the initial temperature is determined by adding the initial temperature and ΔT from the previous time step. See Attachment 1 for calculation up to 10 hours. At 10 hours (ending temperature of the 9.975 hr time step) the temperature is conservatively calculated to be 896.44°C, below the limit of 900°C.

9.0 Results and Conclusions

With the decay heat from the limiting 9.38-month decay spent fuel bundle, the temperature after 10 hours was calculated to be 896.44°C, which is less than the 900°C requirement in ISG-02 (Reference 9). Therefore, the 10 hour heat-up time from the maximum Technical Specification allowed SFP temperature of 125°F to a "runaway oxidation" (zirconium fire) temperature of 900°C (1652°F) occurs at a decay time less than 9.38 months after shutdown. Based on the results of this analysis, Emergency Planning (EP) staffing could potentially be reduced 9.38 months after shutdown.

The calculated temperature is based off the normal operations maximum SFP temperature of 125°F, the mass of the uranium oxide (UO_2) fuel, the zircaloy-2 mass of the fuel and water rods only in the active fuel region, the mass of the Inconel spacers modeled as zircaloy-2, and the partial mass of the fuel channel in the active fuel region once the bulk temperature exceeded 580 °F.

While the final calculated temperature is close to the 900°C requirement in ISG-02 (Reference 9), the following conservatisms remain. The largest conservatisms are the adiabatic assumption (Assumption 3.5) and the start of the heat up after the bundle has become fully uncovered (Assumption 3.1). Both of the assumptions eliminate other mechanisms in which decay heat would be transferred away from the fuel bundle either by convective heat transfer or by the boiling of spent fuel pool water.

The analysis also does not credit the full mass of material found in the bundle as the thicker corners of the fuel channel are not included in the calculation of the channel mass. Also, the mass of the upper and lower stainless-steel tie plates are not included, but would provide a conductive heat pathway for some of the decay heat.

Parameter	Value	Unit	Reference
Decay Heat	6591	BTU/Hr	Design Input 5.4
Mass UO2	458.586	lbm	Section 8.0
Mass Zirc (Fuel)	91.858	lbm	Section 8.0
Mass Zirc (Fuel+Channel)	135.678	lbm	Section 8.0
Starting Temp	125	°F	Design Input 5.5
Credit Temp	580	°F	Assumption 3.8
10 hour Temp	896.44	°C	Calculated

Elapsed Time	Time Step	Initial Temp	Decay Heat	Mass UO_2	Cp UO_2	Mass Zirc	Cp Zirc	Δ T	Ending Temp	
hr	hr	°F	BTU/hr	lbm	BTU/lbm-°F	lbm	BTU/lbm-°F	°F	°F	°C
0	0.025	125	6.59E+03	458.586	0.0587	91.858	0.0684	4.96	129.96	54.42
0.025	0.025	129.96	6.59E+03	458.586	0.0589	91.858	0.0685	4.95	134.91	57.17
0.05	0.025	134.91	6.59E+03	458.586	0.0591	91.858	0.0686	4.93	139.84	59.91
0.075	0.025	139.84	6.59E+03	458.586	0.0593	91.858	0.0688	4.91	144.76	62.64
0.1	0.025	144.76	6.59E+03	458.586	0.0595	91.858	0.0689	4.90	149.66	65.37
0.125	0.025	149.66	6.59E+03	458.586	0.0597	91.858	0.0690	4.88	154.54	68.08
0.15	0.025	154.54	6.59E+03	458.586	0.0599	91.858	0.0692	4.87	159.41	70.78
0.175	0.025	159.41	6.59E+03	458.586	0.0601	91.858	0.0693	4.85	164.26	73.48
0.2	0.025	164.26	6.59E+03	458.586	0.0603	91.858	0.0695	4.84	169.10	76.17
0.225	0.025	169.10	6.59E+03	458.586	0.0605	91.858	0.0696	4.83	173.93	78.85
0.25	0.025	173.93	6.59E+03	458.586	0.0607	91.858	0.0697	4.81	178.74	81.52
0.275	0.025	178.74	6.59E+03	458.586	0.0609	91.858	0.0699	4.80	183.54	84.19

0.3	0.025	183.54	6.59E+03	458.586	0.0611	91.858	0.0700	4.79	188.33	86.85
0.325	0.025	188.33	6.59E+03	458.586	0.0612	91.858	0.0701	4.77	193.10	89.50
0.35	0.025	193.10	6.59E+03	458.586	0.0614	91.858	0.0703	4.76	197.86	92.15
0.375	0.025	197.86	6.59E+03	458.586	0.0616	91.858	0.0704	4.75	202.61	94.78
0.4	0.025	202.61	6.59E+03	458.586	0.0617	91.858	0.0705	4.74	207.35	97.42
0.425	0.025	207.35	6.59E+03	458.586	0.0619	91.858	0.0707	4.73	212.08	100.04
0.45	0.025	212.08	6.59E+03	458.586	0.0620	91.858	0.0708	4.71	216.79	102.66
0.475	0.025	216.79	6.59E+03	458.586	0.0622	91.858	0.0709	4.70	221.49	105.27
0.5	0.025	221.49	6.59E+03	458.586	0.0623	91.858	0.0710	4.69	226.19	107.88
0.525	0.025	226.19	6.59E+03	458.586	0.0625	91.858	0.0712	4.68	230.87	110.48
0.55	0.025	230.87	6.59E+03	458.586	0.0626	91.858	0.0713	4.67	235.54	113.08
0.575	0.025	235.54	6.59E+03	458.586	0.0628	91.858	0.0714	4.66	240.20	115.67
0.6	0.025	240.20	6.59E+03	458.586	0.0629	91.858	0.0716	4.65	244.85	118.25
0.625	0.025	244.85	6.59E+03	458.586	0.0631	91.858	0.0717	4.64	249.49	120.83
0.65	0.025	249.49	6.59E+03	458.586	0.0632	91.858	0.0718	4.63	254.12	123.40
0.675	0.025	254.12	6.59E+03	458.586	0.0633	91.858	0.0720	4.62	258.75	125.97
0.7	0.025	258.75	6.59E+03	458.586	0.0635	91.858	0.0721	4.61	263.36	128.53
0.725	0.025	263.36	6.59E+03	458.586	0.0636	91.858	0.0722	4.60	267.96	131.09
0.75	0.025	267.96	6.59E+03	458.586	0.0637	91.858	0.0723	4.60	272.56	133.64
0.775	0.025	272.56	6.59E+03	458.586	0.0638	91.858	0.0723	4.59	277.15	136.19
0.8	0.025	277.15	6.59E+03	458.586	0.0640	91.858	0.0724	4.58	281.73	138.74
0.825	0.025	281.73	6.59E+03	458.586	0.0641	91.858	0.0725	4.57	286.30	141.28
0.85	0.025	286.30	6.59E+03	458.586	0.0642	91.858	0.0725	4.56	290.86	143.81
0.875	0.025	290.86	6.59E+03	458.586	0.0643	91.858	0.0726	4.56	295.42	146.34
0.9	0.025	295.42	6.59E+03	458.586	0.0644	91.858	0.0727	4.55	299.97	148.87
0.925	0.025	299.97	6.59E+03	458.586	0.0645	91.858	0.0728	4.54	304.51	151.40
0.95	0.025	304.51	6.59E+03	458.586	0.0646	91.858	0.0728	4.53	309.05	153.92
0.975	0.025	309.05	6.59E+03	458.586	0.0648	91.858	0.0729	4.53	313.57	156.43
1	0.025	313.57	6.59E+03	458.586	0.0649	91.858	0.0730	4.52	318.10	158.94
1.025	0.025	318.10	6.59E+03	458.586	0.0650	91.858	0.0731	4.51	322.61	161.45
1.05	0.025	322.61	6.59E+03	458.586	0.0651	91.858	0.0731	4.51	327.12	163.95
1.075	0.025	327.12	6.59E+03	458.586	0.0652	91.858	0.0732	4.50	331.62	166.45
1.1	0.025	331.62	6.59E+03	458.586	0.0653	91.858	0.0733	4.49	336.11	168.95
1.125	0.025	336.11	6.59E+03	458.586	0.0654	91.858	0.0733	4.49	340.60	171.44
1.15	0.025	340.60	6.59E+03	458.586	0.0655	91.858	0.0734	4.48	345.08	173.93
1.175	0.025	345.08	6.59E+03	458.586	0.0656	91.858	0.0735	4.48	349.56	176.42

1.2	0.025	349.56	6.59E+03	458.586	0.0657	91.858	0.0736	4.47	354.02	178.90
1.225	0.025	354.02	6.59E+03	458.586	0.0658	91.858	0.0736	4.46	358.49	181.38
1.25	0.025	358.49	6.59E+03	458.586	0.0659	91.858	0.0737	4.46	362.95	183.86
1.275	0.025	362.95	6.59E+03	458.586	0.0659	91.858	0.0738	4.45	367.40	186.33
1.3	0.025	367.40	6.59E+03	458.586	0.0660	91.858	0.0738	4.45	371.84	188.80
1.325	0.025	371.84	6.59E+03	458.586	0.0661	91.858	0.0739	4.44	376.28	191.27
1.35	0.025	376.28	6.59E+03	458.586	0.0662	91.858	0.0740	4.43	380.72	193.73
1.375	0.025	380.72	6.59E+03	458.586	0.0663	91.858	0.0741	4.43	385.14	196.19
1.4	0.025	385.14	6.59E+03	458.586	0.0664	91.858	0.0741	4.42	389.57	198.65
1.425	0.025	389.57	6.59E+03	458.586	0.0665	91.858	0.0742	4.42	393.99	201.10
1.45	0.025	393.99	6.59E+03	458.586	0.0666	91.858	0.0743	4.41	398.40	203.55
1.475	0.025	398.40	6.59E+03	458.586	0.0666	91.858	0.0743	4.41	402.81	206.00
1.5	0.025	402.81	6.59E+03	458.586	0.0667	91.858	0.0744	4.40	407.21	208.45
1.525	0.025	407.21	6.59E+03	458.586	0.0668	91.858	0.0745	4.40	411.61	210.89
1.55	0.025	411.61	6.59E+03	458.586	0.0669	91.858	0.0746	4.39	416.00	213.33
1.575	0.025	416.00	6.59E+03	458.586	0.0670	91.858	0.0746	4.39	420.38	215.77
1.6	0.025	420.38	6.59E+03	458.586	0.0670	91.858	0.0747	4.38	424.77	218.20
1.625	0.025	424.77	6.59E+03	458.586	0.0671	91.858	0.0748	4.38	429.14	220.64
1.65	0.025	429.14	6.59E+03	458.586	0.0672	91.858	0.0748	4.37	433.52	223.06
1.675	0.025	433.52	6.59E+03	458.586	0.0673	91.858	0.0749	4.37	437.88	225.49
1.7	0.025	437.88	6.59E+03	458.586	0.0673	91.858	0.0750	4.36	442.25	227.92
1.725	0.025	442.25	6.59E+03	458.586	0.0674	91.858	0.0750	4.36	446.61	230.34
1.75	0.025	446.61	6.59E+03	458.586	0.0675	91.858	0.0751	4.35	450.96	232.76
1.775	0.025	450.96	6.59E+03	458.586	0.0675	91.858	0.0752	4.35	455.31	235.17
1.8	0.025	455.31	6.59E+03	458.586	0.0676	91.858	0.0753	4.35	459.66	237.59
1.825	0.025	459.66	6.59E+03	458.586	0.0677	91.858	0.0753	4.34	464.00	240.00
1.85	0.025	464.00	6.59E+03	458.586	0.0678	91.858	0.0754	4.34	468.33	242.41
1.875	0.025	468.33	6.59E+03	458.586	0.0678	91.858	0.0755	4.33	472.67	244.81
1.9	0.025	472.67	6.59E+03	458.586	0.0679	91.858	0.0755	4.33	476.99	247.22
1.925	0.025	476.99	6.59E+03	458.586	0.0680	91.858	0.0756	4.32	481.32	249.62
1.95	0.025	481.32	6.59E+03	458.586	0.0680	91.858	0.0757	4.32	485.64	252.02
1.975	0.025	485.64	6.59E+03	458.586	0.0681	91.858	0.0757	4.32	489.95	254.42
2	0.025	489.95	6.59E+03	458.586	0.0681	91.858	0.0758	4.31	494.26	256.81
2.025	0.025	494.26	6.59E+03	458.586	0.0682	91.858	0.0759	4.31	498.57	259.21
2.05	0.025	498.57	6.59E+03	458.586	0.0683	91.858	0.0760	4.30	502.88	261.60
2.075	0.025	502.88	6.59E+03	458.586	0.0683	91.858	0.0760	4.30	507.18	263.99

2.1	0.025	507.18	6.59E+03	458.586	0.0684	91.858	0.0761	4.30	511.47	266.37
2.125	0.025	511.47	6.59E+03	458.586	0.0685	91.858	0.0762	4.29	515.76	268.76
2.15	0.025	515.76	6.59E+03	458.586	0.0685	91.858	0.0762	4.29	520.05	271.14
2.175	0.025	520.05	6.59E+03	458.586	0.0686	91.858	0.0763	4.28	524.34	273.52
2.2	0.025	524.34	6.59E+03	458.586	0.0686	91.858	0.0764	4.28	528.62	275.90
2.225	0.025	528.62	6.59E+03	458.586	0.0687	91.858	0.0764	4.28	532.90	278.28
2.25	0.025	532.90	6.59E+03	458.586	0.0688	91.858	0.0765	4.27	537.17	280.65
2.275	0.025	537.17	6.59E+03	458.586	0.0688	91.858	0.0766	4.27	541.44	283.02
2.3	0.025	541.44	6.59E+03	458.586	0.0689	91.858	0.0766	4.27	545.71	285.39
2.325	0.025	545.71	6.59E+03	458.586	0.0689	91.858	0.0767	4.26	549.97	287.76
2.35	0.025	549.97	6.59E+03	458.586	0.0690	91.858	0.0768	4.26	554.23	290.13
2.375	0.025	554.23	6.59E+03	458.586	0.0690	91.858	0.0768	4.26	558.48	292.49
2.4	0.025	558.48	6.59E+03	458.586	0.0691	91.858	0.0769	4.25	562.74	294.85
2.425	0.025	562.74	6.59E+03	458.586	0.0691	91.858	0.0770	4.25	566.98	297.21
2.45	0.025	566.98	6.59E+03	458.586	0.0692	91.858	0.0770	4.25	571.23	299.57
2.475	0.025	571.23	6.59E+03	458.586	0.0692	91.858	0.0771	4.24	575.47	301.93
2.5	0.025	575.47	6.59E+03	458.586	0.0693	91.858	0.0772	4.24	579.71	304.28
2.525	0.025	579.71	6.59E+03	458.586	0.0694	91.858	0.0773	4.24	583.95	306.64
2.55	0.025	583.95	6.59E+03	458.586	0.0694	135.678	0.0773	3.89	587.84	308.80
2.575	0.025	587.84	6.59E+03	458.586	0.0695	135.678	0.0774	3.89	591.73	310.96
2.6	0.025	591.73	6.59E+03	458.586	0.0695	135.678	0.0774	3.89	595.62	313.12
2.625	0.025	595.62	6.59E+03	458.586	0.0695	135.678	0.0775	3.89	599.51	315.28
2.65	0.025	599.51	6.59E+03	458.586	0.0696	135.678	0.0776	3.88	603.39	317.44
2.675	0.025	603.39	6.59E+03	458.586	0.0696	135.678	0.0776	3.88	607.27	319.59
2.7	0.025	607.27	6.59E+03	458.586	0.0697	135.678	0.0777	3.88	611.15	321.75
2.725	0.025	611.15	6.59E+03	458.586	0.0697	135.678	0.0778	3.87	615.02	323.90
2.75	0.025	615.02	6.59E+03	458.586	0.0698	135.678	0.0778	3.87	618.89	326.05
2.775	0.025	618.89	6.59E+03	458.586	0.0698	135.678	0.0779	3.87	622.76	328.20
2.8	0.025	622.76	6.59E+03	458.586	0.0699	135.678	0.0779	3.87	626.63	330.35
2.825	0.025	626.63	6.59E+03	458.586	0.0699	135.678	0.0780	3.86	630.49	332.50
2.85	0.025	630.49	6.59E+03	458.586	0.0699	135.678	0.0781	3.86	634.36	334.64
2.875	0.025	634.36	6.59E+03	458.586	0.0700	135.678	0.0781	3.86	638.22	336.79
2.9	0.025	638.22	6.59E+03	458.586	0.0700	135.678	0.0782	3.86	642.07	338.93
2.925	0.025	642.07	6.59E+03	458.586	0.0701	135.678	0.0783	3.85	645.93	341.07
2.95	0.025	645.93	6.59E+03	458.586	0.0701	135.678	0.0783	3.85	649.78	343.21
2.975	0.025	649.78	6.59E+03	458.586	0.0702	135.678	0.0784	3.85	653.63	345.35

3	0.025	653.63	6.59E+03	458.586	0.0702	135.678	0.0784	3.85	657.48	347.49
3.025	0.025	657.48	6.59E+03	458.586	0.0702	135.678	0.0785	3.84	661.32	349.62
3.05	0.025	661.32	6.59E+03	458.586	0.0703	135.678	0.0786	3.84	665.16	351.76
3.075	0.025	665.16	6.59E+03	458.586	0.0703	135.678	0.0786	3.84	669.00	353.89
3.1	0.025	669.00	6.59E+03	458.586	0.0704	135.678	0.0787	3.84	672.84	356.02
3.125	0.025	672.84	6.59E+03	458.586	0.0704	135.678	0.0787	3.84	676.67	358.15
3.15	0.025	676.67	6.59E+03	458.586	0.0704	135.678	0.0788	3.83	680.51	360.28
3.175	0.025	680.51	6.59E+03	458.586	0.0705	135.678	0.0789	3.83	684.34	362.41
3.2	0.025	684.34	6.59E+03	458.586	0.0705	135.678	0.0789	3.83	688.17	364.54
3.225	0.025	688.17	6.59E+03	458.586	0.0705	135.678	0.0790	3.83	691.99	366.66
3.25	0.025	691.99	6.59E+03	458.586	0.0706	135.678	0.0791	3.82	695.82	368.79
3.275	0.025	695.82	6.59E+03	458.586	0.0706	135.678	0.0791	3.82	699.64	370.91
3.3	0.025	699.64	6.59E+03	458.586	0.0707	135.678	0.0792	3.82	703.46	373.03
3.325	0.025	703.46	6.59E+03	458.586	0.0707	135.678	0.0792	3.82	707.27	375.15
3.35	0.025	707.27	6.59E+03	458.586	0.0707	135.678	0.0793	3.82	711.09	377.27
3.375	0.025	711.09	6.59E+03	458.586	0.0708	135.678	0.0793	3.81	714.90	379.39
3.4	0.025	714.90	6.59E+03	458.586	0.0708	135.678	0.0794	3.81	718.71	381.51
3.425	0.025	718.71	6.59E+03	458.586	0.0708	135.678	0.0794	3.81	722.52	383.62
3.45	0.025	722.52	6.59E+03	458.586	0.0709	135.678	0.0794	3.81	726.33	385.74
3.475	0.025	726.33	6.59E+03	458.586	0.0709	135.678	0.0795	3.80	730.13	387.85
3.5	0.025	730.13	6.59E+03	458.586	0.0710	135.678	0.0795	3.80	733.93	389.96
3.525	0.025	733.93	6.59E+03	458.586	0.0710	135.678	0.0796	3.80	737.74	392.08
3.55	0.025	737.74	6.59E+03	458.586	0.0710	135.678	0.0796	3.80	741.53	394.19
3.575	0.025	741.53	6.59E+03	458.586	0.0711	135.678	0.0797	3.80	745.33	396.29
3.6	0.025	745.33	6.59E+03	458.586	0.0711	135.678	0.0797	3.79	749.13	398.40
3.625	0.025	749.13	6.59E+03	458.586	0.0711	135.678	0.0798	3.79	752.92	400.51
3.65	0.025	752.92	6.59E+03	458.586	0.0712	135.678	0.0798	3.79	756.71	402.62
3.675	0.025	756.71	6.59E+03	458.586	0.0712	135.678	0.0799	3.79	760.50	404.72
3.7	0.025	760.50	6.59E+03	458.586	0.0712	135.678	0.0799	3.79	764.28	406.82
3.725	0.025	764.28	6.59E+03	458.586	0.0713	135.678	0.0800	3.79	768.07	408.93
3.75	0.025	768.07	6.59E+03	458.586	0.0713	135.678	0.0800	3.78	771.85	411.03
3.775	0.025	771.85	6.59E+03	458.586	0.0713	135.678	0.0801	3.78	775.63	413.13
3.8	0.025	775.63	6.59E+03	458.586	0.0714	135.678	0.0801	3.78	779.41	415.23
3.825	0.025	779.41	6.59E+03	458.586	0.0714	135.678	0.0802	3.78	783.19	417.33
3.85	0.025	783.19	6.59E+03	458.586	0.0714	135.678	0.0802	3.78	786.97	419.43
3.875	0.025	786.97	6.59E+03	458.586	0.0715	135.678	0.0803	3.77	790.74	421.52

3.9	0.025	790.74	6.59E+03	458.586	0.0715	135.678	0.0803	3.77	794.51	423.62
3.925	0.025	794.51	6.59E+03	458.586	0.0715	135.678	0.0804	3.77	798.28	425.71
3.95	0.025	798.28	6.59E+03	458.586	0.0716	135.678	0.0804	3.77	802.05	427.81
3.975	0.025	802.05	6.59E+03	458.586	0.0716	135.678	0.0805	3.77	805.82	429.90
4	0.025	805.82	6.59E+03	458.586	0.0716	135.678	0.0805	3.76	809.58	431.99
4.025	0.025	809.58	6.59E+03	458.586	0.0717	135.678	0.0806	3.76	813.34	434.08
4.05	0.025	813.34	6.59E+03	458.586	0.0717	135.678	0.0806	3.76	817.11	436.17
4.075	0.025	817.11	6.59E+03	458.586	0.0717	135.678	0.0807	3.76	820.86	438.26
4.1	0.025	820.86	6.59E+03	458.586	0.0717	135.678	0.0807	3.76	824.62	440.35
4.125	0.025	824.62	6.59E+03	458.586	0.0718	135.678	0.0808	3.76	828.38	442.43
4.15	0.025	828.38	6.59E+03	458.586	0.0718	135.678	0.0808	3.75	832.13	444.52
4.175	0.025	832.13	6.59E+03	458.586	0.0718	135.678	0.0809	3.75	835.88	446.60
4.2	0.025	835.88	6.59E+03	458.586	0.0719	135.678	0.0809	3.75	839.63	448.69
4.225	0.025	839.63	6.59E+03	458.586	0.0719	135.678	0.0810	3.75	843.38	450.77
4.25	0.025	843.38	6.59E+03	458.586	0.0719	135.678	0.0810	3.75	847.13	452.85
4.275	0.025	847.13	6.59E+03	458.586	0.0720	135.678	0.0811	3.75	850.87	454.93
4.3	0.025	850.87	6.59E+03	458.586	0.0720	135.678	0.0811	3.74	854.62	457.01
4.325	0.025	854.62	6.59E+03	458.586	0.0720	135.678	0.0812	3.74	858.36	459.09
4.35	0.025	858.36	6.59E+03	458.586	0.0720	135.678	0.0812	3.74	862.10	461.17
4.375	0.025	862.10	6.59E+03	458.586	0.0721	135.678	0.0813	3.74	865.84	463.24
4.4	0.025	865.84	6.59E+03	458.586	0.0721	135.678	0.0813	3.74	869.58	465.32
4.425	0.025	869.58	6.59E+03	458.586	0.0721	135.678	0.0814	3.74	873.31	467.39
4.45	0.025	873.31	6.59E+03	458.586	0.0722	135.678	0.0814	3.73	877.04	469.47
4.475	0.025	877.04	6.59E+03	458.586	0.0722	135.678	0.0815	3.73	880.78	471.54
4.5	0.025	880.78	6.59E+03	458.586	0.0722	135.678	0.0815	3.73	884.51	473.61
4.525	0.025	884.51	6.59E+03	458.586	0.0722	135.678	0.0816	3.73	888.23	475.69
4.55	0.025	888.23	6.59E+03	458.586	0.0723	135.678	0.0816	3.73	891.96	477.76
4.575	0.025	891.96	6.59E+03	458.586	0.0723	135.678	0.0816	3.73	895.69	479.83
4.6	0.025	895.69	6.59E+03	458.586	0.0723	135.678	0.0817	3.72	899.41	481.89
4.625	0.025	899.41	6.59E+03	458.586	0.0724	135.678	0.0817	3.72	903.13	483.96
4.65	0.025	903.13	6.59E+03	458.586	0.0724	135.678	0.0818	3.72	906.85	486.03
4.675	0.025	906.85	6.59E+03	458.586	0.0724	135.678	0.0818	3.72	910.57	488.09
4.7	0.025	910.57	6.59E+03	458.586	0.0724	135.678	0.0819	3.72	914.29	490.16
4.725	0.025	914.29	6.59E+03	458.586	0.0725	135.678	0.0819	3.72	918.00	492.22
4.75	0.025	918.00	6.59E+03	458.586	0.0725	135.678	0.0820	3.71	921.72	494.29
4.775	0.025	921.72	6.59E+03	458.586	0.0725	135.678	0.0820	3.71	925.43	496.35

4.8	0.025	925.43	6.59E+03	458.586	0.0725	135.678	0.0821	3.71	929.14	498.41
4.825	0.025	929.14	6.59E+03	458.586	0.0726	135.678	0.0821	3.71	932.85	500.47
4.85	0.025	932.85	6.59E+03	458.586	0.0726	135.678	0.0822	3.71	936.56	502.53
4.875	0.025	936.56	6.59E+03	458.586	0.0726	135.678	0.0822	3.71	940.26	504.59
4.9	0.025	940.26	6.59E+03	458.586	0.0726	135.678	0.0823	3.70	943.97	506.65
4.925	0.025	943.97	6.59E+03	458.586	0.0727	135.678	0.0823	3.70	947.67	508.71
4.95	0.025	947.67	6.59E+03	458.586	0.0727	135.678	0.0824	3.70	951.37	510.76
4.975	0.025	951.37	6.59E+03	458.586	0.0727	135.678	0.0824	3.70	955.07	512.82
5	0.025	955.07	6.59E+03	458.586	0.0728	135.678	0.0825	3.70	958.77	514.87
5.025	0.025	958.77	6.59E+03	458.586	0.0728	135.678	0.0825	3.70	962.47	516.93
5.05	0.025	962.47	6.59E+03	458.586	0.0728	135.678	0.0826	3.70	966.16	518.98
5.075	0.025	966.16	6.59E+03	458.586	0.0728	135.678	0.0826	3.69	969.86	521.03
5.1	0.025	969.86	6.59E+03	458.586	0.0729	135.678	0.0827	3.69	973.55	523.08
5.125	0.025	973.55	6.59E+03	458.586	0.0729	135.678	0.0827	3.69	977.24	525.13
5.15	0.025	977.24	6.59E+03	458.586	0.0729	135.678	0.0828	3.69	980.93	527.18
5.175	0.025	980.93	6.59E+03	458.586	0.0729	135.678	0.0828	3.69	984.62	529.23
5.2	0.025	984.62	6.59E+03	458.586	0.0730	135.678	0.0829	3.69	988.31	531.28
5.225	0.025	988.31	6.59E+03	458.586	0.0730	135.678	0.0829	3.69	991.99	533.33
5.25	0.025	991.99	6.59E+03	458.586	0.0730	135.678	0.0829	3.68	995.67	535.37
5.275	0.025	995.67	6.59E+03	458.586	0.0730	135.678	0.0830	3.68	999.36	537.42
5.3	0.025	999.36	6.59E+03	458.586	0.0730	135.678	0.0830	3.68	1003.04	539.47
5.325	0.025	1003.04	6.59E+03	458.586	0.0731	135.678	0.0831	3.68	1006.72	541.51
5.35	0.025	1006.72	6.59E+03	458.586	0.0731	135.678	0.0831	3.68	1010.40	543.55
5.375	0.025	1010.40	6.59E+03	458.586	0.0731	135.678	0.0832	3.68	1014.07	545.60
5.4	0.025	1014.07	6.59E+03	458.586	0.0731	135.678	0.0832	3.68	1017.75	547.64
5.425	0.025	1017.75	6.59E+03	458.586	0.0732	135.678	0.0833	3.67	1021.42	549.68
5.45	0.025	1021.42	6.59E+03	458.586	0.0732	135.678	0.0833	3.67	1025.09	551.72
5.475	0.025	1025.09	6.59E+03	458.586	0.0732	135.678	0.0834	3.67	1028.76	553.76
5.5	0.025	1028.76	6.59E+03	458.586	0.0732	135.678	0.0834	3.67	1032.43	555.80
5.525	0.025	1032.43	6.59E+03	458.586	0.0733	135.678	0.0835	3.67	1036.10	557.83
5.55	0.025	1036.10	6.59E+03	458.586	0.0733	135.678	0.0835	3.67	1039.77	559.87
5.575	0.025	1039.77	6.59E+03	458.586	0.0733	135.678	0.0836	3.67	1043.43	561.91
5.6	0.025	1043.43	6.59E+03	458.586	0.0733	135.678	0.0836	3.66	1047.10	563.94
5.625	0.025	1047.10	6.59E+03	458.586	0.0734	135.678	0.0837	3.66	1050.76	565.98
5.65	0.025	1050.76	6.59E+03	458.586	0.0734	135.678	0.0837	3.66	1054.42	568.01
5.675	0.025	1054.42	6.59E+03	458.586	0.0734	135.678	0.0838	3.66	1058.08	570.04

5.7	0.025	1058.08	6.59E+03	458.586	0.0734	135.678	0.0838	3.66	1061.74	572.08
5.725	0.025	1061.74	6.59E+03	458.586	0.0734	135.678	0.0839	3.66	1065.39	574.11
5.75	0.025	1065.39	6.59E+03	458.586	0.0735	135.678	0.0839	3.66	1069.05	576.14
5.775	0.025	1069.05	6.59E+03	458.586	0.0735	135.678	0.0839	3.65	1072.70	578.17
5.8	0.025	1072.70	6.59E+03	458.586	0.0735	135.678	0.0840	3.65	1076.36	580.20
5.825	0.025	1076.36	6.59E+03	458.586	0.0735	135.678	0.0840	3.65	1080.01	582.23
5.85	0.025	1080.01	6.59E+03	458.586	0.0736	135.678	0.0841	3.65	1083.66	584.25
5.875	0.025	1083.66	6.59E+03	458.586	0.0736	135.678	0.0841	3.65	1087.31	586.28
5.9	0.025	1087.31	6.59E+03	458.586	0.0736	135.678	0.0842	3.65	1090.95	588.31
5.925	0.025	1090.95	6.59E+03	458.586	0.0736	135.678	0.0842	3.65	1094.60	590.33
5.95	0.025	1094.60	6.59E+03	458.586	0.0737	135.678	0.0843	3.64	1098.24	592.36
5.975	0.025	1098.24	6.59E+03	458.586	0.0737	135.678	0.0843	3.64	1101.89	594.38
6	0.025	1101.89	6.59E+03	458.586	0.0737	135.678	0.0844	3.64	1105.53	596.41
6.025	0.025	1105.53	6.59E+03	458.586	0.0737	135.678	0.0844	3.64	1109.17	598.43
6.05	0.025	1109.17	6.59E+03	458.586	0.0737	135.678	0.0845	3.64	1112.81	600.45
6.075	0.025	1112.81	6.59E+03	458.586	0.0738	135.678	0.0845	3.64	1116.45	602.47
6.1	0.025	1116.45	6.59E+03	458.586	0.0738	135.678	0.0846	3.64	1120.08	604.49
6.125	0.025	1120.08	6.59E+03	458.586	0.0738	135.678	0.0846	3.64	1123.72	606.51
6.15	0.025	1123.72	6.59E+03	458.586	0.0738	135.678	0.0847	3.63	1127.35	608.53
6.175	0.025	1127.35	6.59E+03	458.586	0.0738	135.678	0.0847	3.63	1130.99	610.55
6.2	0.025	1130.99	6.59E+03	458.586	0.0739	135.678	0.0847	3.63	1134.62	612.57
6.225	0.025	1134.62	6.59E+03	458.586	0.0739	135.678	0.0848	3.63	1138.25	614.58
6.25	0.025	1138.25	6.59E+03	458.586	0.0739	135.678	0.0848	3.63	1141.88	616.60
6.275	0.025	1141.88	6.59E+03	458.586	0.0739	135.678	0.0849	3.63	1145.51	618.61
6.3	0.025	1145.51	6.59E+03	458.586	0.0740	135.678	0.0849	3.63	1149.13	620.63
6.325	0.025	1149.13	6.59E+03	458.586	0.0740	135.678	0.0850	3.63	1152.76	622.64
6.35	0.025	1152.76	6.59E+03	458.586	0.0740	135.678	0.0850	3.62	1156.38	624.66
6.375	0.025	1156.38	6.59E+03	458.586	0.0740	135.678	0.0851	3.62	1160.00	626.67
6.4	0.025	1160.00	6.59E+03	458.586	0.0740	135.678	0.0851	3.62	1163.62	628.68
6.425	0.025	1163.62	6.59E+03	458.586	0.0741	135.678	0.0852	3.62	1167.24	630.69
6.45	0.025	1167.24	6.59E+03	458.586	0.0741	135.678	0.0852	3.62	1170.86	632.70
6.475	0.025	1170.86	6.59E+03	458.586	0.0741	135.678	0.0853	3.62	1174.48	634.71
6.5	0.025	1174.48	6.59E+03	458.586	0.0741	135.678	0.0853	3.62	1178.10	636.72
6.525	0.025	1178.10	6.59E+03	458.586	0.0741	135.678	0.0854	3.62	1181.71	638.73
6.55	0.025	1181.71	6.59E+03	458.586	0.0742	135.678	0.0854	3.61	1185.33	640.74
6.575	0.025	1185.33	6.59E+03	458.586	0.0742	135.678	0.0855	3.61	1188.94	642.74

6.6	0.025	1188.94	6.59E+03	458.586	0.0742	135.678	0.0855	3.61	1192.55	644.75
6.625	0.025	1192.55	6.59E+03	458.586	0.0742	135.678	0.0855	3.61	1196.16	646.76
6.65	0.025	1196.16	6.59E+03	458.586	0.0742	135.678	0.0856	3.61	1199.77	648.76
6.675	0.025	1199.77	6.59E+03	458.586	0.0743	135.678	0.0856	3.61	1203.38	650.76
6.7	0.025	1203.38	6.59E+03	458.586	0.0743	135.678	0.0857	3.61	1206.98	652.77
6.725	0.025	1206.98	6.59E+03	458.586	0.0743	135.678	0.0857	3.61	1210.59	654.77
6.75	0.025	1210.59	6.59E+03	458.586	0.0743	135.678	0.0858	3.60	1214.19	656.77
6.775	0.025	1214.19	6.59E+03	458.586	0.0743	135.678	0.0858	3.60	1217.79	658.77
6.8	0.025	1217.79	6.59E+03	458.586	0.0744	135.678	0.0859	3.60	1221.40	660.78
6.825	0.025	1221.40	6.59E+03	458.586	0.0744	135.678	0.0859	3.60	1225.00	662.78
6.85	0.025	1225.00	6.59E+03	458.586	0.0744	135.678	0.0860	3.60	1228.60	664.78
6.875	0.025	1228.60	6.59E+03	458.586	0.0744	135.678	0.0860	3.60	1232.19	666.77
6.9	0.025	1232.19	6.59E+03	458.586	0.0744	135.678	0.0861	3.60	1235.79	668.77
6.925	0.025	1235.79	6.59E+03	458.586	0.0745	135.678	0.0861	3.60	1239.39	670.77
6.95	0.025	1239.39	6.59E+03	458.586	0.0745	135.678	0.0862	3.59	1242.98	672.77
6.975	0.025	1242.98	6.59E+03	458.586	0.0745	135.678	0.0862	3.59	1246.57	674.76
7	0.025	1246.57	6.59E+03	458.586	0.0745	135.678	0.0862	3.59	1250.17	676.76
7.025	0.025	1250.17	6.59E+03	458.586	0.0745	135.678	0.0863	3.59	1253.76	678.75
7.05	0.025	1253.76	6.59E+03	458.586	0.0746	135.678	0.0863	3.59	1257.35	680.75
7.075	0.025	1257.35	6.59E+03	458.586	0.0746	135.678	0.0864	3.59	1260.93	682.74
7.1	0.025	1260.93	6.59E+03	458.586	0.0746	135.678	0.0864	3.59	1264.52	684.73
7.125	0.025	1264.52	6.59E+03	458.586	0.0746	135.678	0.0865	3.59	1268.11	686.73
7.15	0.025	1268.11	6.59E+03	458.586	0.0746	135.678	0.0865	3.58	1271.69	688.72
7.175	0.025	1271.69	6.59E+03	458.586	0.0746	135.678	0.0866	3.58	1275.28	690.71
7.2	0.025	1275.28	6.59E+03	458.586	0.0747	135.678	0.0866	3.58	1278.86	692.70
7.225	0.025	1278.86	6.59E+03	458.586	0.0747	135.678	0.0867	3.58	1282.44	694.69
7.25	0.025	1282.44	6.59E+03	458.586	0.0747	135.678	0.0867	3.58	1286.02	696.68
7.275	0.025	1286.02	6.59E+03	458.586	0.0747	135.678	0.0868	3.58	1289.60	698.67
7.3	0.025	1289.60	6.59E+03	458.586	0.0747	135.678	0.0868	3.58	1293.18	700.65
7.325	0.025	1293.18	6.59E+03	458.586	0.0748	135.678	0.0869	3.58	1296.75	702.64
7.35	0.025	1296.75	6.59E+03	458.586	0.0748	135.678	0.0869	3.58	1300.33	704.63
7.375	0.025	1300.33	6.59E+03	458.586	0.0748	135.678	0.0869	3.57	1303.90	706.61
7.4	0.025	1303.90	6.59E+03	458.586	0.0748	135.678	0.0870	3.57	1307.48	708.60
7.425	0.025	1307.48	6.59E+03	458.586	0.0748	135.678	0.0870	3.57	1311.05	710.58
7.45	0.025	1311.05	6.59E+03	458.586	0.0749	135.678	0.0871	3.57	1314.62	712.57
7.475	0.025	1314.62	6.59E+03	458.586	0.0749	135.678	0.0871	3.57	1318.19	714.55

7.5	0.025	1318.19	6.59E+03	458.586	0.0749	135.678	0.0872	3.57	1321.76	716.53
7.525	0.025	1321.76	6.59E+03	458.586	0.0749	135.678	0.0872	3.57	1325.33	718.51
7.55	0.025	1325.33	6.59E+03	458.586	0.0749	135.678	0.0873	3.57	1328.89	720.50
7.575	0.025	1328.89	6.59E+03	458.586	0.0749	135.678	0.0873	3.57	1332.46	722.48
7.6	0.025	1332.46	6.59E+03	458.586	0.0750	135.678	0.0874	3.56	1336.02	724.46
7.625	0.025	1336.02	6.59E+03	458.586	0.0750	135.678	0.0874	3.56	1339.59	726.44
7.65	0.025	1339.59	6.59E+03	458.586	0.0750	135.678	0.0875	3.56	1343.15	728.42
7.675	0.025	1343.15	6.59E+03	458.586	0.0750	135.678	0.0875	3.56	1346.71	730.39
7.7	0.025	1346.71	6.59E+03	458.586	0.0750	135.678	0.0875	3.56	1350.27	732.37
7.725	0.025	1350.27	6.59E+03	458.586	0.0751	135.678	0.0876	3.56	1353.83	734.35
7.75	0.025	1353.83	6.59E+03	458.586	0.0751	135.678	0.0876	3.56	1357.38	736.32
7.775	0.025	1357.38	6.59E+03	458.586	0.0751	135.678	0.0877	3.56	1360.94	738.30
7.8	0.025	1360.94	6.59E+03	458.586	0.0751	135.678	0.0877	3.56	1364.50	740.28
7.825	0.025	1364.50	6.59E+03	458.586	0.0751	135.678	0.0878	3.55	1368.05	742.25
7.85	0.025	1368.05	6.59E+03	458.586	0.0751	135.678	0.0878	3.55	1371.60	744.22
7.875	0.025	1371.60	6.59E+03	458.586	0.0752	135.678	0.0879	3.55	1375.15	746.20
7.9	0.025	1375.15	6.59E+03	458.586	0.0752	135.678	0.0879	3.55	1378.71	748.17
7.925	0.025	1378.71	6.59E+03	458.586	0.0752	135.678	0.0880	3.55	1382.26	750.14
7.95	0.025	1382.26	6.59E+03	458.586	0.0752	135.678	0.0880	3.55	1385.80	752.11
7.975	0.025	1385.80	6.59E+03	458.586	0.0752	135.678	0.0881	3.55	1389.35	754.08
8	0.025	1389.35	6.59E+03	458.586	0.0752	135.678	0.0881	3.55	1392.90	756.05
8.025	0.025	1392.90	6.59E+03	458.586	0.0753	135.678	0.0881	3.55	1396.44	758.02
8.05	0.025	1396.44	6.59E+03	458.586	0.0753	135.678	0.0882	3.54	1399.99	759.99
8.075	0.025	1399.99	6.59E+03	458.586	0.0753	135.678	0.0882	3.54	1403.53	761.96
8.1	0.025	1403.53	6.59E+03	458.586	0.0753	135.678	0.0883	3.54	1407.07	763.93
8.125	0.025	1407.07	6.59E+03	458.586	0.0753	135.678	0.0883	3.54	1410.61	765.90
8.15	0.025	1410.61	6.59E+03	458.586	0.0754	135.678	0.0884	3.54	1414.15	767.86
8.175	0.025	1414.15	6.59E+03	458.586	0.0754	135.678	0.0884	3.54	1417.69	769.83
8.2	0.025	1417.69	6.59E+03	458.586	0.0754	135.678	0.0885	3.54	1421.23	771.79
8.225	0.025	1421.23	6.59E+03	458.586	0.0754	135.678	0.0885	3.54	1424.77	773.76
8.25	0.025	1424.77	6.59E+03	458.586	0.0754	135.678	0.0886	3.54	1428.30	775.72
8.275	0.025	1428.30	6.59E+03	458.586	0.0754	135.678	0.0886	3.53	1431.84	777.69
8.3	0.025	1431.84	6.59E+03	458.586	0.0755	135.678	0.0887	3.53	1435.37	779.65
8.325	0.025	1435.37	6.59E+03	458.586	0.0755	135.678	0.0887	3.53	1438.90	781.61
8.35	0.025	1438.90	6.59E+03	458.586	0.0755	135.678	0.0887	3.53	1442.44	783.58
8.375	0.025	1442.44	6.59E+03	458.586	0.0755	135.678	0.0888	3.53	1445.97	785.54

8.4	0.025	1445.97	6.59E+03	458.586	0.0755	135.678	0.0888	3.53	1449.50	787.50
8.425	0.025	1449.50	6.59E+03	458.586	0.0755	135.678	0.0889	3.53	1453.02	789.46
8.45	0.025	1453.02	6.59E+03	458.586	0.0756	135.678	0.0889	3.53	1456.55	791.42
8.475	0.025	1456.55	6.59E+03	458.586	0.0756	135.678	0.0890	3.53	1460.08	793.38
8.5	0.025	1460.08	6.59E+03	458.586	0.0756	135.678	0.0890	3.53	1463.60	795.33
8.525	0.025	1463.60	6.59E+03	458.586	0.0756	135.678	0.0891	3.52	1467.13	797.29
8.55	0.025	1467.13	6.59E+03	458.586	0.0756	135.678	0.0891	3.52	1470.65	799.25
8.575	0.025	1470.65	6.59E+03	458.586	0.0756	135.678	0.0892	3.52	1474.17	801.21
8.6	0.025	1474.17	6.59E+03	458.586	0.0757	135.678	0.0892	3.52	1477.69	803.16
8.625	0.025	1477.69	6.59E+03	458.586	0.0757	135.678	0.0892	3.52	1481.21	805.12
8.65	0.025	1481.21	6.59E+03	458.586	0.0757	135.678	0.0893	3.52	1484.73	807.07
8.675	0.025	1484.73	6.59E+03	458.586	0.0757	135.678	0.0893	3.52	1488.25	809.03
8.7	0.025	1488.25	6.59E+03	458.586	0.0757	135.678	0.0894	3.52	1491.76	810.98
8.725	0.025	1491.76	6.59E+03	458.586	0.0757	135.678	0.0894	3.52	1495.28	812.93
8.75	0.025	1495.28	6.59E+03	458.586	0.0758	135.678	0.0895	3.51	1498.79	814.89
8.775	0.025	1498.79	6.59E+03	458.586	0.0758	135.678	0.0895	3.51	1502.31	816.84
8.8	0.025	1502.31	6.59E+03	458.586	0.0758	135.678	0.0896	3.51	1505.82	818.79
8.825	0.025	1505.82	6.59E+03	458.586	0.0758	135.678	0.1092	3.32	1509.14	820.64
8.85	0.025	1509.14	6.59E+03	458.586	0.0758	135.678	0.1207	3.22	1512.37	822.43
8.875	0.025	1512.37	6.59E+03	458.586	0.0758	135.678	0.1226	3.20	1515.57	824.21
8.9	0.025	1515.57	6.59E+03	458.586	0.0759	135.678	0.1245	3.19	1518.76	825.98
8.925	0.025	1518.76	6.59E+03	458.586	0.0759	135.678	0.1263	3.17	1521.93	827.74
8.95	0.025	1521.93	6.59E+03	458.586	0.0759	135.678	0.1282	3.16	1525.09	829.49
8.975	0.025	1525.09	6.59E+03	458.586	0.0759	135.678	0.1300	3.14	1528.23	831.24
9	0.025	1528.23	6.59E+03	458.586	0.0759	135.678	0.1319	3.13	1531.36	832.98
9.025	0.025	1531.36	6.59E+03	458.586	0.0759	135.678	0.1337	3.11	1534.47	834.70
9.05	0.025	1534.47	6.59E+03	458.586	0.0759	135.678	0.1355	3.10	1537.56	836.42
9.075	0.025	1537.56	6.59E+03	458.586	0.0760	135.678	0.1373	3.08	1540.65	838.14
9.1	0.025	1540.65	6.59E+03	458.586	0.0760	135.678	0.1391	3.07	1543.71	839.84
9.125	0.025	1543.71	6.59E+03	458.586	0.0760	135.678	0.1409	3.05	1546.77	841.54
9.15	0.025	1546.77	6.59E+03	458.586	0.0760	135.678	0.1414	3.05	1549.82	843.23
9.175	0.025	1549.82	6.59E+03	458.586	0.0760	135.678	0.1419	3.04	1552.86	844.92
9.2	0.025	1552.86	6.59E+03	458.586	0.0760	135.678	0.1424	3.04	1555.90	846.61
9.225	0.025	1555.90	6.59E+03	458.586	0.0760	135.678	0.1429	3.04	1558.94	848.30
9.25	0.025	1558.94	6.59E+03	458.586	0.0761	135.678	0.1434	3.03	1561.97	849.98
9.275	0.025	1561.97	6.59E+03	458.586	0.0761	135.678	0.1439	3.03	1565.00	851.67

9.3	0.025	1565.00	6.59E+03	458.586	0.0761	135.678	0.1444	3.02	1568.02	853.35
9.325	0.025	1568.02	6.59E+03	458.586	0.0761	135.678	0.1449	3.02	1571.04	855.02
9.35	0.025	1571.04	6.59E+03	458.586	0.0761	135.678	0.1454	3.02	1574.06	856.70
9.375	0.025	1574.06	6.59E+03	458.586	0.0761	135.678	0.1459	3.01	1577.07	858.37
9.4	0.025	1577.07	6.59E+03	458.586	0.0761	135.678	0.1464	3.01	1580.08	860.04
9.425	0.025	1580.08	6.59E+03	458.586	0.0762	135.678	0.1471	3.00	1583.08	861.71
9.45	0.025	1583.08	6.59E+03	458.586	0.0762	135.678	0.1492	2.99	1586.07	863.37
9.475	0.025	1586.07	6.59E+03	458.586	0.0762	135.678	0.1513	2.97	1589.04	865.02
9.5	0.025	1589.04	6.59E+03	458.586	0.0762	135.678	0.1533	2.96	1591.99	866.66
9.525	0.025	1591.99	6.59E+03	458.586	0.0762	135.678	0.1554	2.94	1594.93	868.30
9.55	0.025	1594.93	6.59E+03	458.586	0.0762	135.678	0.1574	2.93	1597.86	869.92
9.575	0.025	1597.86	6.59E+03	458.586	0.0762	135.678	0.1594	2.91	1600.77	871.54
9.6	0.025	1600.77	6.59E+03	458.586	0.0763	135.678	0.1614	2.90	1603.67	873.15
9.625	0.025	1603.67	6.59E+03	458.586	0.0763	135.678	0.1634	2.88	1606.55	874.75
9.65	0.025	1606.55	6.59E+03	458.586	0.0763	135.678	0.1654	2.87	1609.42	876.35
9.675	0.025	1609.42	6.59E+03	458.586	0.0763	135.678	0.1674	2.86	1612.28	877.93
9.7	0.025	1612.28	6.59E+03	458.586	0.0763	135.678	0.1693	2.84	1615.12	879.51
9.725	0.025	1615.12	6.59E+03	458.586	0.0763	135.678	0.1713	2.83	1617.95	881.08
9.75	0.025	1617.95	6.59E+03	458.586	0.0763	135.678	0.1732	2.82	1620.77	882.65
9.775	0.025	1620.77	6.59E+03	458.586	0.0763	135.678	0.1750	2.80	1623.57	884.21
9.8	0.025	1623.57	6.59E+03	458.586	0.0764	135.678	0.1768	2.79	1626.36	885.76
9.825	0.025	1626.36	6.59E+03	458.586	0.0764	135.678	0.1786	2.78	1629.15	887.30
9.85	0.025	1629.15	6.59E+03	458.586	0.0764	135.678	0.1804	2.77	1631.91	888.84
9.875	0.025	1631.91	6.59E+03	458.586	0.0764	135.678	0.1821	2.76	1634.67	890.37
9.9	0.025	1634.67	6.59E+03	458.586	0.0764	135.678	0.1839	2.75	1637.42	891.90
9.925	0.025	1637.42	6.59E+03	458.586	0.0764	135.678	0.1857	2.74	1640.15	893.42
9.95	0.025	1640.15	6.59E+03	458.586	0.0764	135.678	0.1874	2.72	1642.88	894.93
9.975	0.025	1642.88	6.59E+03	458.586	0.0764	135.678	0.1892	2.71	1645.59	896.44
10	**0.025**	**1645.59**	**6.59E+03**	**458.586**	**0.0765**	**135.678**	**0.1909**	**2.70**	**1648.29**	**897.94**
10.025	0.025	1648.29	6.59E+03	458.586	0.0765	135.678	0.1927	2.69	1650.99	899.44
10.05	0.025	1650.99	6.59E+03	458.586	0.0765	135.678	0.1944	2.68	1653.67	900.93
10.075	0.025	1653.67	6.59E+03	458.586	0.0765	135.678	0.1943	2.68	1656.35	902.42
10.1	0.025	1656.35	6.59E+03	458.586	0.0765	135.678	0.1935	2.69	1659.04	903.91

UO_2 Specific Heat Constants (Design Input 3.2)		
Y	2	
R	8.3143	j/mol-K
θ	535.285	K
K1	296.7	J/kg-K
K2	2.430E-02	$J/kg*K^2$
K3	8.745E+07	J/kg
Ed	1.577E+05	J/mol*-K

Zircaloy Specific Heat Capacity Interpolation (Design Input 3.1)			
Temperature		Specific Heat Capicity	
K	°F	J/kg-K	BTU/lbm-°F
300	80.33	281	0.0671
400	260.33	302	0.0721
640	692.33	331	0.0791
1090	1502.33	375	0.0896
1093	1507.73	502	0.1199
1113	1543.73	590	0.1409
1133	1579.73	615	0.1469
1153	1615.73	719	0.1717
1173	1651.73	816	0.1949
1193	1687.73	770	0.1839
1213	1723.73	619	0.1478
1233	1759.73	469	0.1120
1248	1786.73	356	0.0850

			UO_2 C_P Calculation					Zirc C_P Interpolation	
Elapsed Time	C_P Initial Temp		Part 1	Part 2	Part 3	Cp		Cp	
hr	°F	K	-	-	-	j/kg-K	BTU/lbm-°F	Table Match	BTU/lbm-°F
0	125.00	324.82	2.378E+02	7.893E+00	6.860E-19	245.67	0.0587	1	0.0684
0.025	129.96	327.57	2.386E+02	7.960E+00	1.103E-18	246.60	0.0589	1	0.0685
0.05	134.91	330.32	2.395E+02	8.027E+00	1.756E-18	247.51	0.0591	1	0.0686
0.075	139.84	333.06	2.403E+02	8.093E+00	2.770E-18	248.40	0.0593	1	0.0688
0.1	144.76	335.79	2.411E+02	8.160E+00	4.330E-18	249.27	0.0595	1	0.0689
0.125	149.66	338.52	2.419E+02	8.226E+00	6.710E-18	250.13	0.0597	1	0.0690
0.15	154.54	341.23	2.427E+02	8.292E+00	1.031E-17	250.96	0.0599	1	0.0692
0.175	159.41	343.93	2.434E+02	8.358E+00	1.571E-17	251.78	0.0601	1	0.0693
0.2	164.26	346.63	2.442E+02	8.423E+00	2.376E-17	252.58	0.0603	1	0.0695
0.225	169.10	349.32	2.449E+02	8.488E+00	3.565E-17	253.36	0.0605	1	0.0696
0.25	173.93	352.00	2.456E+02	8.554E+00	5.309E-17	254.13	0.0607	1	0.0697
0.275	178.74	354.67	2.463E+02	8.619E+00	7.849E-17	254.88	0.0609	1	0.0699

0.3	183.54	357.34	2.469E+02	8.683E+00	1.152E-16	255.61	0.0611	1	0.0700
0.325	188.33	360.00	2.476E+02	8.748E+00	1.680E-16	256.33	0.0612	1	0.0701
0.35	193.10	362.65	2.482E+02	8.812E+00	2.434E-16	257.04	0.0614	1	0.0703
0.375	197.86	365.30	2.489E+02	8.877E+00	3.504E-16	257.73	0.0616	1	0.0704
0.4	202.61	367.93	2.495E+02	8.941E+00	5.012E-16	258.41	0.0617	1	0.0705
0.425	207.35	370.57	2.501E+02	9.005E+00	7.125E-16	259.08	0.0619	1	0.0707
0.45	212.08	373.19	2.507E+02	9.069E+00	1.007E-15	259.74	0.0620	1	0.0708
0.475	216.79	375.81	2.512E+02	9.132E+00	1.415E-15	260.38	0.0622	1	0.0709
0.5	221.49	378.42	2.518E+02	9.196E+00	1.978E-15	261.01	0.0623	1	0.0710
0.525	226.19	381.03	2.524E+02	9.259E+00	2.749E-15	261.63	0.0625	1	0.0712
0.55	230.87	383.63	2.529E+02	9.322E+00	3.800E-15	262.23	0.0626	1	0.0713
0.575	235.54	386.23	2.534E+02	9.385E+00	5.226E-15	262.83	0.0628	1	0.0714
0.6	240.20	388.82	2.540E+02	9.448E+00	7.152E-15	263.41	0.0629	1	0.0716
0.625	244.85	391.40	2.545E+02	9.511E+00	9.740E-15	263.99	0.0631	1	0.0717
0.65	249.49	393.98	2.550E+02	9.574E+00	1.320E-14	264.56	0.0632	1	0.0718
0.675	254.12	396.55	2.555E+02	9.636E+00	1.781E-14	265.11	0.0633	1	0.0720
0.7	258.75	399.12	2.560E+02	9.699E+00	2.391E-14	265.66	0.0635	1	0.0721
0.725	263.36	401.68	2.564E+02	9.761E+00	3.197E-14	266.19	0.0636	2	0.0722
0.75	267.96	404.24	2.569E+02	9.823E+00	4.256E-14	266.72	0.0637	2	0.0723
0.775	272.56	406.79	2.574E+02	9.885E+00	5.642E-14	267.24	0.0638	2	0.0723
0.8	277.15	409.34	2.578E+02	9.947E+00	7.449E-14	267.75	0.0640	2	0.0724
0.825	281.73	411.89	2.582E+02	1.001E+01	9.796E-14	268.25	0.0641	2	0.0725
0.85	286.30	414.43	2.587E+02	1.007E+01	1.283E-13	268.75	0.0642	2	0.0725
0.875	290.86	416.96	2.591E+02	1.013E+01	1.674E-13	269.23	0.0643	2	0.0726
0.9	295.42	419.49	2.595E+02	1.019E+01	2.177E-13	269.71	0.0644	2	0.0727
0.925	299.97	422.02	2.599E+02	1.026E+01	2.820E-13	270.18	0.0645	2	0.0728
0.95	304.51	424.55	2.603E+02	1.032E+01	3.640E-13	270.65	0.0646	2	0.0728
0.975	309.05	427.07	2.607E+02	1.038E+01	4.681E-13	271.11	0.0648	2	0.0729
1	313.57	429.58	2.611E+02	1.044E+01	6.001E-13	271.56	0.0649	2	0.0730
1.025	318.10	432.09	2.615E+02	1.050E+01	7.667E-13	272.00	0.0650	2	0.0731
1.05	322.61	434.60	2.619E+02	1.056E+01	9.763E-13	272.43	0.0651	2	0.0731
1.075	327.12	437.10	2.622E+02	1.062E+01	1.239E-12	272.87	0.0652	2	0.0732
1.1	331.62	439.60	2.626E+02	1.068E+01	1.568E-12	273.29	0.0653	2	0.0733
1.125	336.11	442.10	2.630E+02	1.074E+01	1.978E-12	273.71	0.0654	2	0.0733
1.15	340.60	444.59	2.633E+02	1.080E+01	2.488E-12	274.12	0.0655	2	0.0734
1.175	345.08	447.08	2.637E+02	1.086E+01	3.121E-12	274.52	0.0656	2	0.0735

1.2	349.56	449.57	2.640E+02	1.092E+01	3.902E-12	274.92	0.0657	2	0.0736
1.225	354.02	452.05	2.643E+02	1.098E+01	4.866E-12	275.32	0.0658	2	0.0736
1.25	358.49	454.53	2.647E+02	1.105E+01	6.051E-12	275.71	0.0659	2	0.0737
1.275	362.95	457.01	2.650E+02	1.111E+01	7.504E-12	276.09	0.0659	2	0.0738
1.3	367.40	459.48	2.653E+02	1.117E+01	9.281E-12	276.47	0.0660	2	0.0738
1.325	371.84	461.95	2.656E+02	1.123E+01	1.145E-11	276.84	0.0661	2	0.0739
1.35	376.28	464.42	2.659E+02	1.129E+01	1.409E-11	277.21	0.0662	2	0.0740
1.375	380.72	466.88	2.662E+02	1.135E+01	1.729E-11	277.57	0.0663	2	0.0741
1.4	385.14	469.34	2.665E+02	1.140E+01	2.117E-11	277.93	0.0664	2	0.0741
1.425	389.57	471.80	2.668E+02	1.146E+01	2.586E-11	278.29	0.0665	2	0.0742
1.45	393.99	474.25	2.671E+02	1.152E+01	3.152E-11	278.64	0.0666	2	0.0743
1.475	398.40	476.70	2.674E+02	1.158E+01	3.832E-11	278.98	0.0666	2	0.0743
1.5	402.81	479.15	2.677E+02	1.164E+01	4.648E-11	279.32	0.0667	2	0.0744
1.525	407.21	481.60	2.680E+02	1.170E+01	5.625E-11	279.66	0.0668	2	0.0745
1.55	411.61	484.04	2.682E+02	1.176E+01	6.793E-11	279.99	0.0669	2	0.0746
1.575	416.00	486.48	2.685E+02	1.182E+01	8.185E-11	280.32	0.0670	2	0.0746
1.6	420.38	488.92	2.688E+02	1.188E+01	9.842E-11	280.64	0.0670	2	0.0747
1.625	424.77	491.35	2.690E+02	1.194E+01	1.181E-10	280.96	0.0671	2	0.0748
1.65	429.14	493.79	2.693E+02	1.200E+01	1.414E-10	281.27	0.0672	2	0.0748
1.675	433.52	496.21	2.695E+02	1.206E+01	1.690E-10	281.59	0.0673	2	0.0749
1.7	437.88	498.64	2.698E+02	1.212E+01	2.016E-10	281.89	0.0673	2	0.0750
1.725	442.25	501.07	2.700E+02	1.218E+01	2.400E-10	282.20	0.0674	2	0.0750
1.75	446.61	503.49	2.703E+02	1.223E+01	2.852E-10	282.50	0.0675	2	0.0751
1.775	450.96	505.91	2.705E+02	1.229E+01	3.382E-10	282.80	0.0675	2	0.0752
1.8	455.31	508.32	2.707E+02	1.235E+01	4.003E-10	283.09	0.0676	2	0.0753
1.825	459.66	510.74	2.710E+02	1.241E+01	4.730E-10	283.38	0.0677	2	0.0753
1.85	464.00	513.15	2.712E+02	1.247E+01	5.580E-10	283.67	0.0678	2	0.0754
1.875	468.33	515.56	2.714E+02	1.253E+01	6.570E-10	283.95	0.0678	2	0.0755
1.9	472.67	517.96	2.716E+02	1.259E+01	7.722E-10	284.23	0.0679	2	0.0755
1.925	476.99	520.37	2.719E+02	1.264E+01	9.062E-10	284.51	0.0680	2	0.0756
1.95	481.32	522.77	2.721E+02	1.270E+01	1.062E-09	284.78	0.0680	2	0.0757
1.975	485.64	525.17	2.723E+02	1.276E+01	1.242E-09	285.06	0.0681	2	0.0757
2	489.95	527.57	2.725E+02	1.282E+01	1.450E-09	285.32	0.0681	2	0.0758
2.025	494.26	529.96	2.727E+02	1.288E+01	1.690E-09	285.59	0.0682	2	0.0759
2.05	498.57	532.36	2.729E+02	1.294E+01	1.967E-09	285.85	0.0683	2	0.0760
2.075	502.88	534.75	2.731E+02	1.299E+01	2.287E-09	286.11	0.0683	2	0.0760

2.1	507.18	537.14	2.733E+02	1.305E+01	2.654E-09	286.37	0.0684	2	0.0761
2.125	511.47	539.52	2.735E+02	1.311E+01	3.075E-09	286.62	0.0685	2	0.0762
2.15	515.76	541.91	2.737E+02	1.317E+01	3.558E-09	286.88	0.0685	2	0.0762
2.175	520.05	544.29	2.739E+02	1.323E+01	4.111E-09	287.13	0.0686	2	0.0763
2.2	524.34	546.67	2.741E+02	1.328E+01	4.742E-09	287.37	0.0686	2	0.0764
2.225	528.62	549.05	2.743E+02	1.334E+01	5.464E-09	287.62	0.0687	2	0.0764
2.25	532.90	551.43	2.745E+02	1.340E+01	6.286E-09	287.86	0.0688	2	0.0765
2.275	537.17	553.80	2.746E+02	1.346E+01	7.223E-09	288.10	0.0688	2	0.0766
2.3	541.44	556.17	2.748E+02	1.351E+01	8.288E-09	288.34	0.0689	2	0.0766
2.325	545.71	558.54	2.750E+02	1.357E+01	9.497E-09	288.57	0.0689	2	0.0767
2.35	549.97	560.91	2.752E+02	1.363E+01	1.087E-08	288.80	0.0690	2	0.0768
2.375	554.23	563.28	2.753E+02	1.369E+01	1.242E-08	289.03	0.0690	2	0.0768
2.4	558.48	565.64	2.755E+02	1.375E+01	1.418E-08	289.26	0.0691	2	0.0769
2.425	562.74	568.00	2.757E+02	1.380E+01	1.617E-08	289.49	0.0691	2	0.0770
2.45	566.98	570.36	2.758E+02	1.386E+01	1.841E-08	289.71	0.0692	2	0.0770
2.475	571.23	572.72	2.760E+02	1.392E+01	2.094E-08	289.93	0.0692	2	0.0771
2.5	575.47	575.08	2.762E+02	1.397E+01	2.379E-08	290.15	0.0693	2	0.0772
2.525	579.71	577.43	2.763E+02	1.403E+01	2.699E-08	290.37	0.0694	2	0.0773
2.55	583.95	579.79	2.765E+02	1.409E+01	3.059E-08	290.58	0.0694	2	0.0773
2.575	587.84	581.95	2.766E+02	1.414E+01	3.429E-08	290.78	0.0695	2	0.0774
2.6	591.73	584.11	2.768E+02	1.419E+01	3.840E-08	290.97	0.0695	2	0.0774
2.625	595.62	586.27	2.769E+02	1.425E+01	4.296E-08	291.17	0.0695	2	0.0775
2.65	599.51	588.43	2.771E+02	1.430E+01	4.802E-08	291.36	0.0696	2	0.0776
2.675	603.39	590.59	2.772E+02	1.435E+01	5.363E-08	291.55	0.0696	2	0.0776
2.7	607.27	592.74	2.773E+02	1.440E+01	5.984E-08	291.74	0.0697	2	0.0777
2.725	611.15	594.90	2.775E+02	1.446E+01	6.670E-08	291.92	0.0697	2	0.0778
2.75	615.02	597.05	2.776E+02	1.451E+01	7.429E-08	292.11	0.0698	2	0.0778
2.775	618.89	599.20	2.777E+02	1.456E+01	8.267E-08	292.29	0.0698	2	0.0779
2.8	622.76	601.35	2.779E+02	1.461E+01	9.191E-08	292.47	0.0699	2	0.0779
2.825	626.63	603.50	2.780E+02	1.467E+01	1.021E-07	292.66	0.0699	2	0.0780
2.85	630.49	605.65	2.781E+02	1.472E+01	1.133E-07	292.84	0.0699	2	0.0781
2.875	634.36	607.79	2.782E+02	1.477E+01	1.257E-07	293.01	0.0700	2	0.0781
2.9	638.22	609.94	2.784E+02	1.482E+01	1.393E-07	293.19	0.0700	2	0.0782
2.925	642.07	612.08	2.785E+02	1.487E+01	1.542E-07	293.37	0.0701	2	0.0783
2.95	645.93	614.22	2.786E+02	1.493E+01	1.706E-07	293.54	0.0701	2	0.0783
2.975	649.78	616.36	2.787E+02	1.498E+01	1.886E-07	293.71	0.0702	2	0.0784

3	653.63	618.50	2.789E+02	1.503E+01	2.083E-07	293.88	0.0702	2	0.0784
3.025	657.48	620.64	2.790E+02	1.508E+01	2.299E-07	294.05	0.0702	2	0.0785
3.05	661.32	622.77	2.791E+02	1.513E+01	2.536E-07	294.22	0.0703	2	0.0786
3.075	665.16	624.91	2.792E+02	1.519E+01	2.795E-07	294.39	0.0703	2	0.0786
3.1	669.00	627.04	2.793E+02	1.524E+01	3.078E-07	294.56	0.0704	2	0.0787
3.125	672.84	629.17	2.794E+02	1.529E+01	3.387E-07	294.72	0.0704	2	0.0787
3.15	676.67	631.30	2.795E+02	1.534E+01	3.724E-07	294.89	0.0704	2	0.0788
3.175	680.51	633.43	2.797E+02	1.539E+01	4.092E-07	295.05	0.0705	2	0.0789
3.2	684.34	635.56	2.798E+02	1.544E+01	4.494E-07	295.21	0.0705	2	0.0789
3.225	688.17	637.69	2.799E+02	1.550E+01	4.931E-07	295.37	0.0705	2	0.0790
3.25	691.99	639.81	2.800E+02	1.555E+01	5.407E-07	295.53	0.0706	2	0.0791
3.275	695.82	641.94	2.801E+02	1.560E+01	5.925E-07	295.69	0.0706	3	0.0791
3.3	699.64	644.06	2.802E+02	1.565E+01	6.488E-07	295.85	0.0707	3	0.0792
3.325	703.46	646.18	2.803E+02	1.570E+01	7.100E-07	296.00	0.0707	3	0.0792
3.35	707.27	648.30	2.804E+02	1.575E+01	7.764E-07	296.16	0.0707	3	0.0793
3.375	711.09	650.42	2.805E+02	1.581E+01	8.485E-07	296.31	0.0708	3	0.0793
3.4	714.90	652.54	2.806E+02	1.586E+01	9.267E-07	296.46	0.0708	3	0.0794
3.425	718.71	654.66	2.807E+02	1.591E+01	1.011E-06	296.62	0.0708	3	0.0794
3.45	722.52	656.77	2.808E+02	1.596E+01	1.103E-06	296.77	0.0709	3	0.0794
3.475	726.33	658.89	2.809E+02	1.601E+01	1.203E-06	296.92	0.0709	3	0.0795
3.5	730.13	661.00	2.810E+02	1.606E+01	1.310E-06	297.07	0.0710	3	0.0795
3.525	733.93	663.11	2.811E+02	1.611E+01	1.427E-06	297.21	0.0710	3	0.0796
3.55	737.74	665.23	2.812E+02	1.616E+01	1.552E-06	297.36	0.0710	3	0.0796
3.575	741.53	667.34	2.813E+02	1.622E+01	1.688E-06	297.51	0.0711	3	0.0797
3.6	745.33	669.44	2.814E+02	1.627E+01	1.834E-06	297.65	0.0711	3	0.0797
3.625	749.13	671.55	2.815E+02	1.632E+01	1.993E-06	297.80	0.0711	3	0.0798
3.65	752.92	673.66	2.816E+02	1.637E+01	2.163E-06	297.94	0.0712	3	0.0798
3.675	756.71	675.77	2.817E+02	1.642E+01	2.347E-06	298.08	0.0712	3	0.0799
3.7	760.50	677.87	2.818E+02	1.647E+01	2.544E-06	298.22	0.0712	3	0.0799
3.725	764.28	679.97	2.818E+02	1.652E+01	2.757E-06	298.36	0.0713	3	0.0800
3.75	768.07	682.08	2.819E+02	1.657E+01	2.987E-06	298.50	0.0713	3	0.0800
3.775	771.85	684.18	2.820E+02	1.663E+01	3.233E-06	298.64	0.0713	3	0.0801
3.8	775.63	686.28	2.821E+02	1.668E+01	3.498E-06	298.78	0.0714	3	0.0801
3.825	779.41	688.38	2.822E+02	1.673E+01	3.782E-06	298.92	0.0714	3	0.0802
3.85	783.19	690.48	2.823E+02	1.678E+01	4.088E-06	299.06	0.0714	3	0.0802
3.875	786.97	692.58	2.824E+02	1.683E+01	4.415E-06	299.19	0.0715	3	0.0803

3.9	790.74	694.67	2.824E+02	1.688E+01	4.767E-06	299.33	0.0715	3	0.0803
3.925	794.51	696.77	2.825E+02	1.693E+01	5.144E-06	299.46	0.0715	3	0.0804
3.95	798.28	698.86	2.826E+02	1.698E+01	5.548E-06	299.59	0.0716	3	0.0804
3.975	802.05	700.96	2.827E+02	1.703E+01	5.980E-06	299.73	0.0716	3	0.0805
4	805.82	703.05	2.828E+02	1.708E+01	6.443E-06	299.86	0.0716	3	0.0805
4.025	809.58	705.14	2.829E+02	1.713E+01	6.939E-06	299.99	0.0717	3	0.0806
4.05	813.34	707.23	2.829E+02	1.719E+01	7.468E-06	300.12	0.0717	3	0.0806
4.075	817.11	709.32	2.830E+02	1.724E+01	8.035E-06	300.25	0.0717	3	0.0807
4.1	820.86	711.41	2.831E+02	1.729E+01	8.640E-06	300.38	0.0717	3	0.0807
4.125	824.62	713.50	2.832E+02	1.734E+01	9.286E-06	300.50	0.0718	3	0.0808
4.15	828.38	715.58	2.832E+02	1.739E+01	9.976E-06	300.63	0.0718	3	0.0808
4.175	832.13	717.67	2.833E+02	1.744E+01	1.071E-05	300.76	0.0718	3	0.0809
4.2	835.88	719.75	2.834E+02	1.749E+01	1.150E-05	300.88	0.0719	3	0.0809
4.225	839.63	721.84	2.835E+02	1.754E+01	1.234E-05	301.01	0.0719	3	0.0810
4.25	843.38	723.92	2.835E+02	1.759E+01	1.323E-05	301.13	0.0719	3	0.0810
4.275	847.13	726.00	2.836E+02	1.764E+01	1.418E-05	301.26	0.0720	3	0.0811
4.3	850.87	728.08	2.837E+02	1.769E+01	1.519E-05	301.38	0.0720	3	0.0811
4.325	854.62	730.16	2.838E+02	1.774E+01	1.627E-05	301.50	0.0720	3	0.0812
4.35	858.36	732.24	2.838E+02	1.779E+01	1.741E-05	301.63	0.0720	3	0.0812
4.375	862.10	734.32	2.839E+02	1.784E+01	1.863E-05	301.75	0.0721	3	0.0813
4.4	865.84	736.39	2.840E+02	1.789E+01	1.993E-05	301.87	0.0721	3	0.0813
4.425	869.58	738.47	2.840E+02	1.794E+01	2.130E-05	301.99	0.0721	3	0.0814
4.45	873.31	740.54	2.841E+02	1.800E+01	2.276E-05	302.11	0.0722	3	0.0814
4.475	877.04	742.62	2.842E+02	1.805E+01	2.431E-05	302.23	0.0722	3	0.0815
4.5	880.78	744.69	2.842E+02	1.810E+01	2.596E-05	302.34	0.0722	3	0.0815
4.525	884.51	746.76	2.843E+02	1.815E+01	2.771E-05	302.46	0.0722	3	0.0816
4.55	888.23	748.84	2.844E+02	1.820E+01	2.956E-05	302.58	0.0723	3	0.0816
4.575	891.96	750.91	2.844E+02	1.825E+01	3.152E-05	302.70	0.0723	3	0.0816
4.6	895.69	752.98	2.845E+02	1.830E+01	3.360E-05	302.81	0.0723	3	0.0817
4.625	899.41	755.04	2.846E+02	1.835E+01	3.581E-05	302.93	0.0724	3	0.0817
4.65	903.13	757.11	2.846E+02	1.840E+01	3.814E-05	303.04	0.0724	3	0.0818
4.675	906.85	759.18	2.847E+02	1.845E+01	4.061E-05	303.16	0.0724	3	0.0818
4.7	910.57	761.24	2.848E+02	1.850E+01	4.323E-05	303.27	0.0724	3	0.0819
4.725	914.29	763.31	2.848E+02	1.855E+01	4.599E-05	303.38	0.0725	3	0.0819
4.75	918.00	765.37	2.849E+02	1.860E+01	4.891E-05	303.50	0.0725	3	0.0820
4.775	921.72	767.44	2.850E+02	1.865E+01	5.200E-05	303.61	0.0725	3	0.0820

4.8	925.43	769.50	2.850E+02	1.870E+01	5.527E-05	303.72	0.0725	3	0.0821
4.825	929.14	771.56	2.851E+02	1.875E+01	5.871E-05	303.83	0.0726	3	0.0821
4.85	932.85	773.62	2.851E+02	1.880E+01	6.235E-05	303.94	0.0726	3	0.0822
4.875	936.56	775.68	2.852E+02	1.885E+01	6.620E-05	304.05	0.0726	3	0.0822
4.9	940.26	777.74	2.853E+02	1.890E+01	7.025E-05	304.16	0.0726	3	0.0823
4.925	943.97	779.80	2.853E+02	1.895E+01	7.453E-05	304.27	0.0727	3	0.0823
4.95	947.67	781.86	2.854E+02	1.900E+01	7.903E-05	304.38	0.0727	3	0.0824
4.975	951.37	783.91	2.854E+02	1.905E+01	8.379E-05	304.48	0.0727	3	0.0824
5	955.07	785.97	2.855E+02	1.910E+01	8.879E-05	304.59	0.0728	3	0.0825
5.025	958.77	788.02	2.855E+02	1.915E+01	9.407E-05	304.70	0.0728	3	0.0825
5.05	962.47	790.08	2.856E+02	1.920E+01	9.962E-05	304.81	0.0728	3	0.0826
5.075	966.16	792.13	2.857E+02	1.925E+01	1.055E-04	304.91	0.0728	3	0.0826
5.1	969.86	794.18	2.857E+02	1.930E+01	1.116E-04	305.02	0.0729	3	0.0827
5.125	973.55	796.23	2.858E+02	1.935E+01	1.181E-04	305.12	0.0729	3	0.0827
5.15	977.24	798.28	2.858E+02	1.940E+01	1.249E-04	305.23	0.0729	3	0.0828
5.175	980.93	800.33	2.859E+02	1.945E+01	1.321E-04	305.33	0.0729	3	0.0828
5.2	984.62	802.38	2.859E+02	1.950E+01	1.396E-04	305.43	0.0730	3	0.0829
5.225	988.31	804.43	2.860E+02	1.955E+01	1.475E-04	305.54	0.0730	3	0.0829
5.25	991.99	806.48	2.860E+02	1.960E+01	1.558E-04	305.64	0.0730	3	0.0829
5.275	995.67	808.52	2.861E+02	1.965E+01	1.645E-04	305.74	0.0730	3	0.0830
5.3	999.36	810.57	2.861E+02	1.970E+01	1.737E-04	305.85	0.0730	3	0.0830
5.325	1003.04	812.62	2.862E+02	1.975E+01	1.833E-04	305.95	0.0731	3	0.0831
5.35	1006.72	814.66	2.863E+02	1.980E+01	1.934E-04	306.05	0.0731	3	0.0831
5.375	1010.40	816.70	2.863E+02	1.985E+01	2.039E-04	306.15	0.0731	3	0.0832
5.4	1014.07	818.75	2.864E+02	1.990E+01	2.150E-04	306.25	0.0731	3	0.0832
5.425	1017.75	820.79	2.864E+02	1.995E+01	2.266E-04	306.35	0.0732	3	0.0833
5.45	1021.42	822.83	2.865E+02	1.999E+01	2.388E-04	306.45	0.0732	3	0.0833
5.475	1025.09	824.87	2.865E+02	2.004E+01	2.516E-04	306.55	0.0732	3	0.0834
5.5	1028.76	826.91	2.866E+02	2.009E+01	2.649E-04	306.65	0.0732	3	0.0834
5.525	1032.43	828.95	2.866E+02	2.014E+01	2.789E-04	306.75	0.0733	3	0.0835
5.55	1036.10	830.98	2.867E+02	2.019E+01	2.936E-04	306.84	0.0733	3	0.0835
5.575	1039.77	833.02	2.867E+02	2.024E+01	3.089E-04	306.94	0.0733	3	0.0836
5.6	1043.43	835.06	2.867E+02	2.029E+01	3.250E-04	307.04	0.0733	3	0.0836
5.625	1047.10	837.09	2.868E+02	2.034E+01	3.418E-04	307.13	0.0734	3	0.0837
5.65	1050.76	839.13	2.868E+02	2.039E+01	3.593E-04	307.23	0.0734	3	0.0837
5.675	1054.42	841.16	2.869E+02	2.044E+01	3.777E-04	307.33	0.0734	3	0.0838

5.7	1058.08	843.19	2.869E+02	2.049E+01	3.968E-04	307.42	0.0734	3	0.0838
5.725	1061.74	845.23	2.870E+02	2.054E+01	4.169E-04	307.52	0.0734	3	0.0839
5.75	1065.39	847.26	2.870E+02	2.059E+01	4.378E-04	307.61	0.0735	3	0.0839
5.775	1069.05	849.29	2.871E+02	2.064E+01	4.597E-04	307.71	0.0735	3	0.0839
5.8	1072.70	851.32	2.871E+02	2.069E+01	4.825E-04	307.80	0.0735	3	0.0840
5.825	1076.36	853.35	2.872E+02	2.074E+01	5.064E-04	307.90	0.0735	3	0.0840
5.85	1080.01	855.38	2.872E+02	2.079E+01	5.312E-04	307.99	0.0736	3	0.0841
5.875	1083.66	857.40	2.872E+02	2.083E+01	5.572E-04	308.08	0.0736	3	0.0841
5.9	1087.31	859.43	2.873E+02	2.088E+01	5.843E-04	308.18	0.0736	3	0.0842
5.925	1090.95	861.46	2.873E+02	2.093E+01	6.125E-04	308.27	0.0736	3	0.0842
5.95	1094.60	863.48	2.874E+02	2.098E+01	6.420E-04	308.36	0.0737	3	0.0843
5.975	1098.24	865.51	2.874E+02	2.103E+01	6.727E-04	308.45	0.0737	3	0.0843
6	1101.89	867.53	2.875E+02	2.108E+01	7.047E-04	308.55	0.0737	3	0.0844
6.025	1105.53	869.56	2.875E+02	2.113E+01	7.380E-04	308.64	0.0737	3	0.0844
6.05	1109.17	871.58	2.875E+02	2.118E+01	7.727E-04	308.73	0.0737	3	0.0845
6.075	1112.81	873.60	2.876E+02	2.123E+01	8.089E-04	308.82	0.0738	3	0.0845
6.1	1116.45	875.62	2.876E+02	2.128E+01	8.465E-04	308.91	0.0738	3	0.0846
6.125	1120.08	877.64	2.877E+02	2.133E+01	8.857E-04	309.00	0.0738	3	0.0846
6.15	1123.72	879.66	2.877E+02	2.138E+01	9.265E-04	309.09	0.0738	3	0.0847
6.175	1127.35	881.68	2.878E+02	2.142E+01	9.689E-04	309.18	0.0738	3	0.0847
6.2	1130.99	883.70	2.878E+02	2.147E+01	1.013E-03	309.27	0.0739	3	0.0847
6.225	1134.62	885.72	2.878E+02	2.152E+01	1.059E-03	309.36	0.0739	3	0.0848
6.25	1138.25	887.73	2.879E+02	2.157E+01	1.107E-03	309.44	0.0739	3	0.0848
6.275	1141.88	889.75	2.879E+02	2.162E+01	1.156E-03	309.53	0.0739	3	0.0849
6.3	1145.51	891.76	2.879E+02	2.167E+01	1.208E-03	309.62	0.0740	3	0.0849
6.325	1149.13	893.78	2.880E+02	2.172E+01	1.262E-03	309.71	0.0740	3	0.0850
6.35	1152.76	895.79	2.880E+02	2.177E+01	1.317E-03	309.80	0.0740	3	0.0850
6.375	1156.38	897.81	2.881E+02	2.182E+01	1.375E-03	309.88	0.0740	3	0.0851
6.4	1160.00	899.82	2.881E+02	2.187E+01	1.435E-03	309.97	0.0740	3	0.0851
6.425	1163.62	901.83	2.881E+02	2.191E+01	1.498E-03	310.06	0.0741	3	0.0852
6.45	1167.24	903.84	2.882E+02	2.196E+01	1.562E-03	310.14	0.0741	3	0.0852
6.475	1170.86	905.85	2.882E+02	2.201E+01	1.630E-03	310.23	0.0741	3	0.0853
6.5	1174.48	907.86	2.883E+02	2.206E+01	1.699E-03	310.31	0.0741	3	0.0853
6.525	1178.10	909.87	2.883E+02	2.211E+01	1.772E-03	310.40	0.0741	3	0.0854
6.55	1181.71	911.88	2.883E+02	2.216E+01	1.847E-03	310.49	0.0742	3	0.0854
6.575	1185.33	913.89	2.884E+02	2.221E+01	1.925E-03	310.57	0.0742	3	0.0855

6.6	1188.94	915.89	2.884E+02	2.226E+01	2.006E-03	310.66	0.0742	3	0.0855
6.625	1192.55	917.90	2.884E+02	2.230E+01	2.089E-03	310.74	0.0742	3	0.0855
6.65	1196.16	919.91	2.885E+02	2.235E+01	2.176E-03	310.82	0.0742	3	0.0856
6.675	1199.77	921.91	2.885E+02	2.240E+01	2.266E-03	310.91	0.0743	3	0.0856
6.7	1203.38	923.91	2.885E+02	2.245E+01	2.359E-03	310.99	0.0743	3	0.0857
6.725	1206.98	925.92	2.886E+02	2.250E+01	2.456E-03	311.08	0.0743	3	0.0857
6.75	1210.59	927.92	2.886E+02	2.255E+01	2.556E-03	311.16	0.0743	3	0.0858
6.775	1214.19	929.92	2.886E+02	2.260E+01	2.659E-03	311.24	0.0743	3	0.0858
6.8	1217.79	931.92	2.887E+02	2.265E+01	2.766E-03	311.32	0.0744	3	0.0859
6.825	1221.40	933.93	2.887E+02	2.269E+01	2.877E-03	311.41	0.0744	3	0.0859
6.85	1225.00	935.93	2.887E+02	2.274E+01	2.992E-03	311.49	0.0744	3	0.0860
6.875	1228.60	937.93	2.888E+02	2.279E+01	3.111E-03	311.57	0.0744	3	0.0860
6.9	1232.19	939.92	2.888E+02	2.284E+01	3.234E-03	311.65	0.0744	3	0.0861
6.925	1235.79	941.92	2.888E+02	2.289E+01	3.361E-03	311.73	0.0745	3	0.0861
6.95	1239.39	943.92	2.889E+02	2.294E+01	3.492E-03	311.82	0.0745	3	0.0862
6.975	1242.98	945.92	2.889E+02	2.299E+01	3.628E-03	311.90	0.0745	3	0.0862
7	1246.57	947.91	2.889E+02	2.303E+01	3.769E-03	311.98	0.0745	3	0.0862
7.025	1250.17	949.91	2.890E+02	2.308E+01	3.914E-03	312.06	0.0745	3	0.0863
7.05	1253.76	951.90	2.890E+02	2.313E+01	4.064E-03	312.14	0.0746	3	0.0863
7.075	1257.35	953.90	2.890E+02	2.318E+01	4.219E-03	312.22	0.0746	3	0.0864
7.1	1260.93	955.89	2.891E+02	2.323E+01	4.380E-03	312.30	0.0746	3	0.0864
7.125	1264.52	957.88	2.891E+02	2.328E+01	4.545E-03	312.38	0.0746	3	0.0865
7.15	1268.11	959.88	2.891E+02	2.332E+01	4.716E-03	312.46	0.0746	3	0.0865
7.175	1271.69	961.87	2.892E+02	2.337E+01	4.893E-03	312.54	0.0746	3	0.0866
7.2	1275.28	963.86	2.892E+02	2.342E+01	5.075E-03	312.62	0.0747	3	0.0866
7.225	1278.86	965.85	2.892E+02	2.347E+01	5.264E-03	312.70	0.0747	3	0.0867
7.25	1282.44	967.84	2.893E+02	2.352E+01	5.458E-03	312.78	0.0747	3	0.0867
7.275	1286.02	969.83	2.893E+02	2.357E+01	5.659E-03	312.85	0.0747	3	0.0868
7.3	1289.60	971.82	2.893E+02	2.362E+01	5.865E-03	312.93	0.0747	3	0.0868
7.325	1293.18	973.80	2.893E+02	2.366E+01	6.079E-03	313.01	0.0748	3	0.0869
7.35	1296.75	975.79	2.894E+02	2.371E+01	6.299E-03	313.09	0.0748	3	0.0869
7.375	1300.33	977.78	2.894E+02	2.376E+01	6.526E-03	313.17	0.0748	3	0.0869
7.4	1303.90	979.76	2.894E+02	2.381E+01	6.761E-03	313.24	0.0748	3	0.0870
7.425	1307.48	981.75	2.895E+02	2.386E+01	7.002E-03	313.32	0.0748	3	0.0870
7.45	1311.05	983.73	2.895E+02	2.390E+01	7.251E-03	313.40	0.0749	3	0.0871
7.475	1314.62	985.72	2.895E+02	2.395E+01	7.508E-03	313.48	0.0749	3	0.0871

7.5	1318.19	987.70	2.895E+02	2.400E+01	7.772E-03	313.55	0.0749	3	0.0872
7.525	1321.76	989.68	2.896E+02	2.405E+01	8.044E-03	313.63	0.0749	3	0.0872
7.55	1325.33	991.66	2.896E+02	2.410E+01	8.325E-03	313.71	0.0749	3	0.0873
7.575	1328.89	993.65	2.896E+02	2.415E+01	8.614E-03	313.78	0.0749	3	0.0873
7.6	1332.46	995.63	2.897E+02	2.419E+01	8.912E-03	313.86	0.0750	3	0.0874
7.625	1336.02	997.61	2.897E+02	2.424E+01	9.219E-03	313.93	0.0750	3	0.0874
7.65	1339.59	999.59	2.897E+02	2.429E+01	9.535E-03	314.01	0.0750	3	0.0875
7.675	1343.15	1001.57	2.897E+02	2.434E+01	9.860E-03	314.09	0.0750	3	0.0875
7.7	1346.71	1003.54	2.898E+02	2.439E+01	1.019E-02	314.16	0.0750	3	0.0875
7.725	1350.27	1005.52	2.898E+02	2.443E+01	1.054E-02	314.24	0.0751	3	0.0876
7.75	1353.83	1007.50	2.898E+02	2.448E+01	1.089E-02	314.31	0.0751	3	0.0876
7.775	1357.38	1009.47	2.898E+02	2.453E+01	1.126E-02	314.39	0.0751	3	0.0877
7.8	1360.94	1011.45	2.899E+02	2.458E+01	1.163E-02	314.46	0.0751	3	0.0877
7.825	1364.50	1013.43	2.899E+02	2.463E+01	1.202E-02	314.54	0.0751	3	0.0878
7.85	1368.05	1015.40	2.899E+02	2.467E+01	1.242E-02	314.61	0.0751	3	0.0878
7.875	1371.60	1017.37	2.899E+02	2.472E+01	1.283E-02	314.68	0.0752	3	0.0879
7.9	1375.15	1019.35	2.900E+02	2.477E+01	1.325E-02	314.76	0.0752	3	0.0879
7.925	1378.71	1021.32	2.900E+02	2.482E+01	1.368E-02	314.83	0.0752	3	0.0880
7.95	1382.26	1023.29	2.900E+02	2.487E+01	1.412E-02	314.91	0.0752	3	0.0880
7.975	1385.80	1025.26	2.901E+02	2.491E+01	1.458E-02	314.98	0.0752	3	0.0881
8	1389.35	1027.23	2.901E+02	2.496E+01	1.505E-02	315.05	0.0752	3	0.0881
8.025	1392.90	1029.20	2.901E+02	2.501E+01	1.553E-02	315.13	0.0753	3	0.0881
8.05	1396.44	1031.17	2.901E+02	2.506E+01	1.602E-02	315.20	0.0753	3	0.0882
8.075	1399.99	1033.14	2.902E+02	2.511E+01	1.653E-02	315.27	0.0753	3	0.0882
8.1	1403.53	1035.11	2.902E+02	2.515E+01	1.705E-02	315.35	0.0753	3	0.0883
8.125	1407.07	1037.08	2.902E+02	2.520E+01	1.759E-02	315.42	0.0753	3	0.0883
8.15	1410.61	1039.05	2.902E+02	2.525E+01	1.814E-02	315.49	0.0754	3	0.0884
8.175	1414.15	1041.01	2.902E+02	2.530E+01	1.871E-02	315.56	0.0754	3	0.0884
8.2	1417.69	1042.98	2.903E+02	2.534E+01	1.929E-02	315.64	0.0754	3	0.0885
8.225	1421.23	1044.94	2.903E+02	2.539E+01	1.988E-02	315.71	0.0754	3	0.0885
8.25	1424.77	1046.91	2.903E+02	2.544E+01	2.049E-02	315.78	0.0754	3	0.0886
8.275	1428.30	1048.87	2.903E+02	2.549E+01	2.112E-02	315.85	0.0754	3	0.0886
8.3	1431.84	1050.84	2.904E+02	2.554E+01	2.177E-02	315.92	0.0755	3	0.0887
8.325	1435.37	1052.80	2.904E+02	2.558E+01	2.243E-02	316.00	0.0755	3	0.0887
8.35	1438.90	1054.76	2.904E+02	2.563E+01	2.311E-02	316.07	0.0755	3	0.0887
8.375	1442.44	1056.73	2.904E+02	2.568E+01	2.380E-02	316.14	0.0755	3	0.0888

8.4	1445.97	1058.69	2.905E+02	2.573E+01	2.452E-02	316.21	0.0755	3	0.0888
8.425	1449.50	1060.65	2.905E+02	2.577E+01	2.525E-02	316.28	0.0755	3	0.0889
8.45	1453.02	1062.61	2.905E+02	2.582E+01	2.600E-02	316.35	0.0756	3	0.0889
8.475	1456.55	1064.57	2.905E+02	2.587E+01	2.677E-02	316.42	0.0756	3	0.0890
8.5	1460.08	1066.53	2.905E+02	2.592E+01	2.756E-02	316.49	0.0756	3	0.0890
8.525	1463.60	1068.48	2.906E+02	2.596E+01	2.837E-02	316.56	0.0756	3	0.0891
8.55	1467.13	1070.44	2.906E+02	2.601E+01	2.920E-02	316.63	0.0756	3	0.0891
8.575	1470.65	1072.40	2.906E+02	2.606E+01	3.004E-02	316.71	0.0756	3	0.0892
8.6	1474.17	1074.36	2.906E+02	2.611E+01	3.092E-02	316.78	0.0757	3	0.0892
8.625	1477.69	1076.31	2.907E+02	2.615E+01	3.181E-02	316.85	0.0757	3	0.0892
8.65	1481.21	1078.27	2.907E+02	2.620E+01	3.272E-02	316.92	0.0757	3	0.0893
8.675	1484.73	1080.22	2.907E+02	2.625E+01	3.366E-02	316.99	0.0757	3	0.0893
8.7	1488.25	1082.18	2.907E+02	2.630E+01	3.462E-02	317.06	0.0757	3	0.0894
8.725	1491.76	1084.13	2.907E+02	2.634E+01	3.560E-02	317.13	0.0757	3	0.0894
8.75	1495.28	1086.08	2.908E+02	2.639E+01	3.660E-02	317.19	0.0758	3	0.0895
8.775	1498.79	1088.04	2.908E+02	2.644E+01	3.763E-02	317.26	0.0758	3	0.0895
8.8	1502.31	1089.99	2.908E+02	2.649E+01	3.869E-02	317.33	0.0758	3	0.0896
8.825	1505.82	1091.94	2.908E+02	2.653E+01	3.977E-02	317.40	0.0758	4	0.1092
8.85	1509.14	1093.79	2.908E+02	2.658E+01	4.081E-02	317.47	0.0758	5	0.1207
8.875	1512.37	1095.58	2.909E+02	2.662E+01	4.185E-02	317.53	0.0758	5	0.1226
8.9	1515.57	1097.36	2.909E+02	2.667E+01	4.290E-02	317.59	0.0759	5	0.1245
8.925	1518.76	1099.13	2.909E+02	2.671E+01	4.397E-02	317.66	0.0759	5	0.1263
8.95	1521.93	1100.89	2.909E+02	2.675E+01	4.506E-02	317.72	0.0759	5	0.1282
8.975	1525.09	1102.64	2.909E+02	2.679E+01	4.616E-02	317.78	0.0759	5	0.1300
9	1528.23	1104.39	2.910E+02	2.684E+01	4.729E-02	317.84	0.0759	5	0.1319
9.025	1531.36	1106.13	2.910E+02	2.688E+01	4.843E-02	317.90	0.0759	5	0.1337
9.05	1534.47	1107.85	2.910E+02	2.692E+01	4.958E-02	317.97	0.0759	5	0.1355
9.075	1537.56	1109.57	2.910E+02	2.696E+01	5.076E-02	318.03	0.0760	5	0.1373
9.1	1540.65	1111.29	2.910E+02	2.700E+01	5.195E-02	318.09	0.0760	5	0.1391
9.125	1543.71	1112.99	2.910E+02	2.705E+01	5.317E-02	318.15	0.0760	5	0.1409
9.15	1546.77	1114.69	2.911E+02	2.709E+01	5.440E-02	318.20	0.0760	6	0.1414
9.175	1549.82	1116.38	2.911E+02	2.713E+01	5.565E-02	318.26	0.0760	6	0.1419
9.2	1552.86	1118.07	2.911E+02	2.717E+01	5.693E-02	318.32	0.0760	6	0.1424
9.225	1555.90	1119.76	2.911E+02	2.721E+01	5.823E-02	318.38	0.0760	6	0.1429
9.25	1558.94	1121.45	2.911E+02	2.725E+01	5.955E-02	318.44	0.0761	6	0.1434
9.275	1561.97	1123.13	2.911E+02	2.729E+01	6.090E-02	318.50	0.0761	6	0.1439

9.3	1565.00	1124.82	2.912E+02	2.733E+01	6.227E-02	318.56	0.0761	6	0.1444
9.325	1568.02	1126.50	2.912E+02	2.737E+01	6.366E-02	318.62	0.0761	6	0.1449
9.35	1571.04	1128.17	2.912E+02	2.741E+01	6.508E-02	318.68	0.0761	6	0.1454
9.375	1574.06	1129.85	2.912E+02	2.746E+01	6.653E-02	318.73	0.0761	6	0.1459
9.4	1577.07	1131.52	2.912E+02	2.750E+01	6.800E-02	318.79	0.0761	6	0.1464
9.425	1580.08	1133.19	2.912E+02	2.754E+01	6.950E-02	318.85	0.0762	7	0.1471
9.45	1583.08	1134.86	2.913E+02	2.758E+01	7.102E-02	318.91	0.0762	7	0.1492
9.475	1586.07	1136.52	2.913E+02	2.762E+01	7.256E-02	318.97	0.0762	7	0.1513
9.5	1589.04	1138.17	2.913E+02	2.766E+01	7.412E-02	319.02	0.0762	7	0.1533
9.525	1591.99	1139.81	2.913E+02	2.770E+01	7.570E-02	319.08	0.0762	7	0.1554
9.55	1594.93	1141.45	2.913E+02	2.774E+01	7.731E-02	319.14	0.0762	7	0.1574
9.575	1597.86	1143.07	2.913E+02	2.778E+01	7.893E-02	319.19	0.0762	7	0.1594
9.6	1600.77	1144.69	2.914E+02	2.782E+01	8.058E-02	319.25	0.0763	7	0.1614
9.625	1603.67	1146.30	2.914E+02	2.786E+01	8.224E-02	319.30	0.0763	7	0.1634
9.65	1606.55	1147.90	2.914E+02	2.789E+01	8.393E-02	319.36	0.0763	7	0.1654
9.675	1609.42	1149.50	2.914E+02	2.793E+01	8.563E-02	319.41	0.0763	7	0.1674
9.7	1612.28	1151.08	2.914E+02	2.797E+01	8.736E-02	319.47	0.0763	7	0.1693
9.725	1615.12	1152.66	2.914E+02	2.801E+01	8.911E-02	319.52	0.0763	7	0.1713
9.75	1617.95	1154.23	2.914E+02	2.805E+01	9.088E-02	319.58	0.0763	8	0.1732
9.775	1620.77	1155.80	2.915E+02	2.809E+01	9.268E-02	319.63	0.0763	8	0.1750
9.8	1623.57	1157.36	2.915E+02	2.812E+01	9.449E-02	319.69	0.0764	8	0.1768
9.825	1626.36	1158.91	2.915E+02	2.816E+01	9.633E-02	319.74	0.0764	8	0.1786
9.85	1629.15	1160.45	2.915E+02	2.820E+01	9.819E-02	319.79	0.0764	8	0.1804
9.875	1631.91	1161.99	2.915E+02	2.824E+01	1.001E-01	319.84	0.0764	8	0.1821
9.9	1634.67	1163.52	2.915E+02	2.827E+01	1.020E-01	319.90	0.0764	8	0.1839
9.925	1637.42	1165.05	2.915E+02	2.831E+01	1.039E-01	319.95	0.0764	8	0.1857
9.95	1640.15	1166.57	2.915E+02	2.835E+01	1.059E-01	320.00	0.0764	8	0.1874
9.975	1642.88	1168.08	2.916E+02	2.838E+01	1.078E-01	320.05	0.0764	8	0.1892
10	1645.59	1169.59	2.916E+02	2.842E+01	1.098E-01	320.11	0.0765	8	0.1909
10.025	1648.29	1171.09	2.916E+02	2.846E+01	1.118E-01	320.16	0.0765	8	0.1927
10.05	1650.99	1172.59	2.916E+02	2.849E+01	1.139E-01	320.21	0.0765	8	0.1944
10.075	1653.67	1174.08	2.916E+02	2.853E+01	1.160E-01	320.26	0.0765	9	0.1943
10.1	1656.35	1175.57	2.916E+02	2.857E+01	1.181E-01	320.31	0.0765	9	0.1935

Decay Heat Calculation

The revised decay heat run is based on the Cycle 26 maximum burnup (48762.3 MWd/MTU), minimum enrichment (3.43%), and maximum MTU (0.181368 MTU/Assy) from Reference 12. Using the same 560 assemblies in the core, power level of 1930 MWt, and GNF2 fuel from Reference 1, the new bounding bundle power level is calculated below:

$$Bounding\ Avg.\ Power\ Level = 1930\ MWt \times \frac{1\ core}{560\ assemblies} \times \frac{1}{0.181368 \frac{MTU}{assembly}} = 19.0024\ MWt/MTU$$

This results in a total irradiation period calculated as

$$Irradiation\ Period = \frac{48762.3 \frac{MWd}{MTU}}{19.0024 \frac{MWt}{MTU}} = 2566.11\ days$$

These values are used to update the ORIGEN-ARP decay heat model from Reference 1 and the revised input file is included in Attachment 6 of this calculation. Table A8-2 from Attachment 8 of Reference 1 is recreated below using this Cycle 26 fuel information and accounts for the additional assembly hardware mass. This also includes a 9-month (0.75 year) time step due to the increased margin from using this cycle.

Table A2-1: Decay Heat Source Terms from ORIGEN-ARP

Decay Time	0.75 Year Decay (W/MTU)	1 Year Decay (W/MTU)	1.25 Year Decay (W/MTU)	1.5 Year Decay (W/MTU)	2 Year Decay (W/MTU)	3 Year Decay (W/MTU)	5 Year Decay (W/MTU)
Cycle 26, max. burnup, min. enrichment, max. MTU	1.091E+04	9.018E+03	7.707E+03	6.721E+03	5.318E+03	3.720E+03	2.454E+03

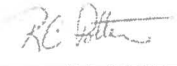
NUCLEAR FUELS
TRANSMITTAL OF DESIGN INFORMATION

☐ SAFETY RELATED ☒ NON-SAFETY RELATED ☐ REGULATORY RELATED	Originating Organization ☒ Nuclear Fuels ☐ Other (specify) _____	NF ID# NF183597 Revision 0 SRRS # 3A.130 Page 1 of 18

Subject: Oyster Creek Unit 1 Cycle 26 EOC Zirc Fire Calculation Inputs

Station: Oyster Creek Unit: 1 Cycle: 26 Generic: N/A

To: Dwayne Blaylock (Enercon) EC/ECR#: N/A

Ferheen Qureshi		2/16/2018
Prepared by	Signature	Date
Robert Potter		2/16/2018
Reviewed by	Signature	Date
Armando Johnson		16FEB18
Approved by	Signature	Date

Status of Information:
☒ Verified
☐ Unverified
☐ Engineering Judgment

Action Tracking # for Method and Schedule of Verification for Unverified DESIGN INFORMATION: N/A

Purpose of Information:

Provides inputs to Enercon calculation for "Oyster Creek Nuclear Generating Station Zirconium Fire Analysis for Drained Spent Fuel Pool" assuming a shutdown date of October 1st, 2018.

Description of Information/Basis:

This package provides information necessary to revise the "Oyster Creek Nuclear Generating Station Zirconium Fire Analysis for Drained Spent Fuel Pool" which was previously based on the final operating cycle 27 fuel data. With Exelon decision to shut down Oyster Creek after cycle 26, the calculation is being revised to determine the potential reduction in acceptable decay time for the limiting bundle for the cycle 26 core. The information generated assumes a shutdown date of October 1st, 2018.

The following information is included as attachments in this TODI:

1. Attachment 1: Oyster Creek Cycle 26 Fuel Bundle Inventory
2. Attachment 2: Oyster Creek Cycle 26 Fuel Bundle Identification Array
3. Attachment 3: Oyster Creek Cycle 26 Fuel IAT Map
4. Attachment 4: Oyster Creek Cycle 26 Fuel Bundle Exposure, Uranium Mass, & Enrichment

Source of Information (References):

1. Oyster Creek Unit 1 Cycle 26 Core Loading Plan Rev. 3
2. Disk6:[Readonly.OC.C26.Project.zircfire]OC1C26D_OC_02-12-18.WRP

Supplemental Distribution:	E - Mail: Robert Csillag Armando Johnson Brian Froese NCS Controlled Documents Distribution	Hard Copy: None.

ATTACHMENT 1: Oyster Creek Cycle 26 Fuel Bundle Inventory

BUNDLE TYPE	NO.	FUEL BUNDLE DESCRIPTION	CHANNEL MATERIAL	CYCLE LOADED	BATCH ID RANGE
6	48	GNF2-P10DG2B370-16GZ-100T2-145-T6-3356	ZR2RX	23	JYN413-JYN460
7	12	GNF2-P10DG2B369-16GZ-100T2-145-T6-3357-LTD	ZR2RX	23	JYN501-JYN516
8	32	GNF2-P10DG2B370-16GZ-100T2-145-T6-4137	ZR2RX	24	JYX370-JYX401
9	16	GNF2-P10DG2B372-14GZ-100T2-145-T6-4138	ZR4RX	24	JYX426-JYX441
10	16	GNF2-P10DG2B370-15GZ-100T2-145-T6-3355	ZR2RX	23	JYN381-JYN404
11	40	GNF2-P10DG2B371-14GZ-100T2-145-T6-4300	ZR2RX	25	YLD792-YLD831
12	24	GNF2-P10DG2B371-16GZ-100T2-145-T6-4301	ZR2RX	25	YLD856-YLD879
13	16	GNF2-P10DG2B370-16GZ-100T2-145-T6-3356	ZR4RX	23	JYN461-JYN476
14	16	GNF2-P10DG2B369-16GZ-100T2-145-T6-3357-LTD	ZR4RX	23	JYN525-JYN540
15	24	GNF2-P10DG2B372-14GZ-100T2-145-T6-4138	ZR2RX	24	JYX402-JYX425
17	48	GNF2-P10DG2B371-14GZ-100T2-145-T6-4136	ZR4RX	24	JYX322-JYX369
20	32	GNF2-P10DG2B371-14GZ-100T2-145-T6-4136	ZR2RX	24	JYX290-JYX321
21	24	GNF2-P10DG2B369-16GZ-100T2-145-T6-4303	ZR2RX	25	YLD888-YLD911
22	24	GNF2-P10DG2B371-14GZ-100T2-145-T6-4300	ZR4RX	25	YLD832-YLD855
23	8	GNF2-P10DG2B371-16GZ-100T2-145-T6-4301	ZR4RX	25	YLD880-YLD887
24	32	GNF2-P10DG2B369-16GZ-100T2-145-T6-4303	ZR4RX	25	YLD912-YLD943
25	8	GNF2-P10DG2B370-12GZ-100T2-145-T6-4437	ZR2RX	26	YLL555-YLL562
26	56	GNF2-P10DG2B346-13GZ-100T2-145-T6-4435-LTD	ZR2RX	26	YLL423-YLL478
27	44	GNF2-P10DG2B343-14GZ-100T2-145-T6-4436-LTD	ZR2RX	26	YLL479-YLL522
28	8	GNF2-P10DG2B346-13GZ-100T2-145-T6-4435-LTD	ZR4RX	26	YLL415-YLL422
29	32	GNF2-P10DG2B370-12GZ-100T2-145-T6-4437	ZR4RX	26	YLL523-YLL554
SUM =	560				

TODI NF183597 Rev.0
Page 3 of 18

ATTACHMENT 2: Oyster Creek Cycle 26 Fuel Bundle Identification Array

J/I (PANAC)	1	2	3	4	5	6	7	8	9	10	11	12	13	
1									JYN462	JYN509	JYN454	JYN382	JYN445	52
2								JYN438	JYN469	JYX323	YLD929	YLD937	YLD873	50
3					JYN534	JYN413	JYN422	JYN398	YLD905	YLD825	YLD809	YLD913	JYX363	48
4				JYN501	JYN430	JYN502	YLD921	YLD849	JYX379	YLD880	JYX402	YLD817	YLD793	46
5			JYN533	JYN429	JYX386	YLD865	YLD897	YLD833	YLD857	YLL432	YLL500	YLL508	YLL416	44
6			JYN414	JYN529	YLD864	JYX338	YLD801	JYX299	YLL492	JYX307	YLL440	JYX427	JYX347	42
7			JYN421	YLD920	YLD896	YLD800	YLL479	YLL484	YLD841	YLL556	JYX291	YLL540	YLD889	40
8		JYN437	JYN397	YLD848	YLD832	JYX298	YLL483	JYX419	YLL424	JYX435	YLL532	JYX395	YLL516	38
9	JYN461	JYN470	YLD904	JYX378	YLD856	YLL491	YLD840	YLL423	JYX354	YLL524	JYX411	YLL456	JYX315	36
10	JYN525	JYX322	YLD824	YLD881	YLL431	JYX306	YLL555	JYX434	YLL523	JYX339	YLL448	JYX370	YLL548	34
11	JYN453	YLD928	YLD808	JYX403	YLL499	YLL439	JYX290	YLL531	JYX410	YLL447	JYX387	YLL464	JYX330	32
12	JYN381	YLD936	YLD912	YLD816	YLL507	JYX426	YLL539	JYX394	YLL455	JYX371	YLL463	JYX355	YLL472	30
13	JYN446	YLD872	JYX362	YLD792	YLL415	JYX346	YLD888	YLL515	JYX314	YLL547	JYX331	YLL471	JYX418	28
14	JYN451	YLD879	JYX369	YLD799	YLL422	JYX353	YLD895	YLL522	JYX321	YLL554	JYX336	YLL478	JYX425	26
15	JYN388	YLD943	YLD919	YLD823	YLL514	JYX433	YLL546	JYX401	YLL462	JYX376	YLL470	JYX360	YLL477	24
16	JYN460	YLD935	YLD815	JYX408	YLL506	YLL446	JYX297	YLL538	JYX417	YLL454	JYX392	YLL469	JYX337	22
17	JYN528	JYX329	YLD831	YLD886	YLL438	JYX313	YLL562	JYX441	YLL530	JYX344	YLL453	JYX377	YLL553	20
18	JYN468	JYN475	YLD911	JYX385	YLD863	YLL498	YLD847	YLL430	JYX361	YLL529	JYX416	YLL461	JYX320	18
19		JYN444	JYN404	YLD855	YLD839	JYX305	YLL490	JYX424	YLL429	JYX440	YLL537	JYX400	YLL521	16
20			JYN428	YLD927	YLD903	YLD807	YLL482	YLL489	YLD846	YLL561	JYX296	YLL545	YLD894	14
21			JYN419	JYN532	YLD871	JYX345	YLD806	JYX304	YLL497	JYX312	YLL445	JYX432	JYX352	12
22			JYN540	JYN436	JYX393	YLD870	YLD902	YLD838	YLD862	YLL437	YLL505	YLL513	YLL421	10
23				JYN508	JYN435	JYN507	YLD926	YLD854	JYX384	YLD887	JYX409	YLD822	YLD798	8
24					JYN539	JYN420	JYN427	JYN403	YLD910	YLD830	YLD814	YLD918	JYX368	6
25								JYN443	JYN476	JYX328	YLD934	YLD942	YLD878	4
26									JYN467	JYN516	JYN459	JYN387	JYN452	2
	1	3	5	7	9	11	13	15	17	19	21	23	25	X/Y (SITE)

TODI NF183597 Rev.0
Page 4 of 18

J/I (PANAC)	14	15	16	17	18	19	20	21	22	23	24	25	26	
1	JYN448	JYN383	JYN455	JYN512	JYN463									52
2	YLD874	YLD938	YLD930	JYX324	JYN472	JYN439								50
3	JYX364	YLD914	YLD810	YLD826	YLD906	JYN399	JYN423	JYN416	JYN535					48
4	YLD794	YLD818	JYX405	YLD883	JYX380	YLD850	YLD922	JYN503	JYN431	JYN504				46
5	YLL417	YLL509	YLL501	YLL433	YLD858	YLD834	YLD898	YLD866	JYX389	JYN432	JYN536			44
6	JYX348	JYX428	YLL441	JYX308	YLL493	JYX300	YLD802	JYX341	YLD867	JYN530	JYN415			42
7	YLD890	YLL541	JYX292	YLL557	YLD842	YLL485	YLL480	YLD803	YLD899	YLD923	JYN424			40
8	YLL517	JYX396	YLL533	JYX436	YLL425	JYX420	YLL486	JYX301	YLD835	YLD851	JYN400	JYN440		38
9	JYX316	YLL457	JYX412	YLL525	JYX357	YLL426	YLD843	YLL494	YLD859	JYX381	YLD907	JYN471	JYN464	36
10	YLL549	JYX373	YLL449	JYX340	YLL526	JYX437	YLL558	JYX309	YLL434	YLD882	YLD827	JYX325	JYN526	34
11	JYX333	YLL465	JYX388	YLL450	JYX413	YLL534	JYX293	YLL442	YLL502	JYX404	YLD811	YLD931	JYN456	32
12	YLL473	JYX356	YLL466	JYX372	YLL458	JYX397	YLL542	JYX429	YLL510	YLD819	YLD915	YLD939	JYN384	30
13	JYX421	YLL474	JYX332	YLL550	JYX317	YLL518	YLD891	JYX349	YLL418	YLD795	JYX365	YLD875	JYN447	28
14	JYX422	YLL475	JYX335	YLL551	JYX318	YLL519	YLD892	JYX350	YLL419	YLD796	JYX366	YLD876	JYN450	26
15	YLL476	JYX359	YLL467	JYX375	YLL459	JYX398	YLL543	JYX430	YLL511	YLD820	YLD916	YLD940	JYN385	24
16	JYX334	YLL468	JYX391	YLL451	JYX414	YLL535	JYX294	YLL443	YLL503	JYX407	YLD812	YLD932	JYN457	22
17	YLL552	JYX374	YLL452	JYX343	YLL527	JYX438	YLL559	JYX310	YLL435	YLD885	YLD828	JYX326	JYN527	20
18	JYX319	YLL460	JYX415	YLL528	JYX358	YLL427	YLD844	YLL495	YLD860	JYX382	YLD908	JYN474	JYN465	18
19	YLL520	JYX399	YLL536	JYX439	YLL428	JYX423	YLL487	JYX302	YLD836	YLD852	JYN401	JYN441		16
20	YLD893	YLL544	JYX295	YLL560	YLD845	YLL488	YLL481	YLD804	YLD900	YLD924	JYN425			14
21	JYX351	JYX431	YLL444	JYX311	YLL496	JYX303	YLD805	JYX342	YLD868	JYN531	JYN418			12
22	YLL420	YLL512	YLL504	YLL436	YLD861	YLD837	YLD901	YLD869	JYX390	JYN433	JYN537			10
23	YLD797	YLD821	JYX406	YLD884	JYX383	YLD853	YLD925	JYN506	JYN434	JYN505				8
24	JYX367	YLD917	YLD813	YLD829	YLD909	JYN402	JYN426	JYN417	JYN538					6
25	YLD877	YLD941	YLD933	JYX327	JYN473	JYN442								4
26	JYN449	JYN386	JYN458	JYN513	JYN466									2
	27	29	31	33	35	37	39	41	43	45	47	49	51	X/Y (SITE)

ATTACHMENT 3: Oyster Creek Cycle 26 Fuel IAT Map

J/I	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	
1									13	7	6	10	6	6	10	6	7	13									52
2								6	13	17	24	24	12	12	24	24	17	13	6								50
3					14	6	6	10	21	11	11	24	17	17	24	11	11	21	10	6	6	14					48
4				7	6	7	24	22	8	23	15	11	11	11	11	15	23	8	22	24	7	6	7				46
5			14	6	8	12	21	22	12	26	27	27	28	28	27	27	26	12	22	21	12	8	6	14			44
6			6	14	12	17	11	20	27	20	26	9	17	17	9	26	20	27	20	11	17	12	14	6			42
7			6	24	21	11	27	27	22	25	20	29	21	21	29	20	25	22	27	27	11	21	24	6			40
8		6	10	22	22	20	27	15	26	9	29	8	27	27	8	29	9	26	15	27	20	22	22	10	6		38
9	13	13	21	8	12	27	22	26	17	29	15	26	20	20	26	15	29	17	26	22	27	12	8	21	13	13	36
10	14	17	11	23	26	20	25	9	29	17	26	8	29	29	8	26	17	29	9	25	20	26	23	11	17	14	34
11	6	24	11	15	27	26	20	29	15	26	8	26	17	17	26	8	26	15	29	20	26	27	15	11	24	6	32
12	10	24	24	11	27	9	29	8	26	8	26	17	26	26	17	26	8	26	8	29	9	27	11	24	24	10	30
13	6	12	17	11	28	17	21	27	20	29	17	26	15	15	26	17	29	20	27	21	17	28	11	17	12	6	28
14	6	12	17	11	28	17	21	27	20	29	17	26	15	15	26	17	29	20	27	21	17	28	11	17	12	6	26
15	10	24	24	11	27	9	29	8	26	8	26	17	26	26	17	26	8	26	8	29	9	27	11	24	24	10	24
16	6	24	11	15	27	26	20	29	15	26	8	26	17	17	26	8	26	15	29	20	26	27	15	11	24	6	22
17	14	17	11	23	26	20	25	9	29	17	26	8	29	29	8	26	17	29	9	25	20	26	23	11	17	14	20
18	13	13	21	8	12	27	22	26	17	29	15	26	20	20	26	15	29	17	26	22	27	12	8	21	13	13	18
19		6	10	22	22	20	27	15	26	9	29	8	27	27	8	29	9	26	15	27	20	22	22	10	6		16
20			6	24	21	11	27	27	22	25	20	29	21	21	29	20	25	22	27	27	11	21	24	6			14
21			6	14	12	17	11	20	27	20	26	9	17	17	9	26	20	27	20	11	17	12	14	6			12
22			14	6	8	12	21	22	12	26	27	27	28	28	27	27	26	12	22	21	12	8	6	14			10
23				7	6	7	24	22	8	23	15	11	11	11	11	15	23	8	22	24	7	6	7				8
24					14	6	6	10	21	11	11	24	17	17	24	11	11	21	10	6	6	14					6
25								6	13	17	24	24	12	12	24	24	17	13	6								4
26									13	7	6	10	6	6	10	6	7	13									2
	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	

ATTACHMENT 4: Oyster Creek Cycle 26 Fuel Bundle Exposure, Uranium Mass, & Enrichment

Bundle Serial ID	Bundle Type (IAT)	EOC Bundle Exp (GWd/MT)	Initial Weight (MT)	Initial Enrich (fraction)
JYN461	13	46.7913	0.180885	0.037016
JYN525	14	47.0963	0.180771	0.036880
JYN453	6	47.0508	0.180840	0.037038
JYN381	10	47.5784	0.180944	0.037066
JYN446	6	48.3574	0.180928	0.037036
JYN451	6	48.4346	0.180956	0.036993
JYN388	10	47.6153	0.180856	0.037038
JYN460	6	47.0528	0.180856	0.037001
JYN528	14	47.2909	0.180918	0.036880
JYN468	13	46.8265	0.180816	0.036971
JYN437	6	47.1013	0.180940	0.037017
JYN470	13	45.9430	0.180771	0.036983
JYX322	17	35.2095	0.181064	0.037105
YLD928	24	27.9412	0.180415	0.036866
YLD936	24	27.4603	0.180413	0.036864
YLD872	12	28.1927	0.180246	0.037090
YLD879	12	28.1668	0.180377	0.037078
YLD943	24	27.4484	0.180419	0.036864
YLD935	24	27.9199	0.180438	0.036856
JYX329	17	35.2612	0.181013	0.037096
JYN475	13	46.0372	0.180897	0.036996
JYN444	6	47.1046	0.180924	0.037018
JYN533	14	47.6656	0.181162	0.036891
JYN414	6	45.8782	0.180841	0.037004
JYN421	6	48.7544	0.180808	0.036971
JYN397	10	44.9803	0.180819	0.037039
YLD904	21	28.2190	0.180318	0.036853
YLD824	11	28.7219	0.180544	0.037086
YLD808	11	31.0810	0.180407	0.037103
YLD912	24	31.6330	0.180307	0.036856
JYX362	17	43.1786	0.180983	0.037061
JYX369	17	43.2291	0.180955	0.037072
YLD919	24	31.6384	0.180394	0.036872
YLD815	11	31.0659	0.180434	0.037088
YLD831	11	28.6980	0.180544	0.037080
YLD911	21	28.1943	0.180311	0.036851
JYN404	10	44.9880	0.180895	0.037045
JYN428	6	48.7623	0.180855	0.037046
JYN419	6	45.9307	0.180967	0.037029

JYN540	14	47.7202	0.181000	0.036878
JYN501	7	47.3498	0.180795	0.036899
JYN429	6	44.6650	0.180914	0.036991
JYN529	14	42.2695	0.180882	0.036876
YLD920	24	27.4228	0.180421	0.036866
YLD848	22	29.2999	0.180549	0.037109
JYX378	8	44.8288	0.180675	0.036927
YLD881	23	31.2113	0.180360	0.037077
JYX403	15	46.9403	0.180663	0.037160
YLD816	11	32.7881	0.180477	0.037103
YLD792	11	32.6462	0.180476	0.037100
YLD799	11	32.6869	0.180409	0.037105
YLD823	11	32.7571	0.180571	0.037092
JYX408	15	46.9685	0.180746	0.037182
YLD886	23	31.2930	0.180373	0.037080
JYX385	8	44.8688	0.180675	0.036957
YLD855	22	29.2650	0.180620	0.037115
YLD927	24	27.4035	0.180413	0.036868
JYN532	14	42.2820	0.181096	0.036895
JYN436	6	44.6691	0.180912	0.037004
JYN508	7	47.3109	0.180898	0.036878
JYN534	14	47.6497	0.181186	0.036883
JYN430	6	44.4073	0.180948	0.037021
JYX386	8	40.1257	0.180689	0.036950
YLD864	12	28.3874	0.180331	0.037081
YLD896	21	30.6601	0.180305	0.036862
YLD832	22	31.8674	0.180541	0.037099
YLD856	12	31.5925	0.180333	0.037083
YLL431	26	16.8696	0.180710	0.034588
YLL499	27	17.8470	0.180610	0.034378
YLL507	27	17.9508	0.180526	0.034361
YLL415	28	17.0129	0.180802	0.034558
YLL422	28	17.0061	0.180803	0.034594
YLL514	27	17.9331	0.180491	0.034370
YLL506	27	17.8062	0.180729	0.034359
YLL438	26	16.8367	0.180738	0.034586
YLD863	12	31.6397	0.180358	0.037075
YLD839	22	31.8582	0.180528	0.037116
YLD903	21	30.6213	0.180325	0.036856
YLD871	12	28.3465	0.180335	0.037092
JYX393	8	40.1549	0.180567	0.036945
JYN435	6	44.6145	0.180910	0.037006
JYN539	14	47.7421	0.180974	0.036871
JYN413	6	45.9948	0.180756	0.037000

JYN502	7	44.9950	0.180802	0.036895
YLD865	12	28.3737	0.180349	0.037085
JYX338	17	41.8157	0.181108	0.037098
YLD800	11	32.7274	0.180516	0.037084
JYX298	20	45.6360	0.181269	0.037053
YLL491	27	17.0019	0.180551	0.034387
JYX306	20	44.1676	0.181211	0.037062
YLL439	26	18.5264	0.180697	0.034572
JYX426	9	44.7833	0.180649	0.037184
JYX346	17	44.4934	0.181069	0.037058
JYX353	17	44.5266	0.180972	0.037066
JYX433	9	44.7559	0.180754	0.037186
YLL446	26	18.4791	0.180800	0.034561
JYX313	20	44.1772	0.181120	0.037089
YLL498	27	16.9705	0.180516	0.034372
JYX305	20	45.6561	0.181209	0.037069
YLD807	11	32.7196	0.180492	0.037087
JYX345	17	41.8993	0.180865	0.037066
YLD870	12	28.3263	0.180307	0.037088
JYN507	7	45.0657	0.180806	0.036880
JYN420	6	45.9565	0.180962	0.037014
JYN422	6	48.6226	0.180838	0.036993
YLD921	24	27.4097	0.180460	0.036868
YLD897	21	30.6819	0.180310	0.036861
YLD801	11	32.7223	0.180507	0.037085
YLL479	27	17.0117	0.180544	0.034372
YLL483	27	17.7602	0.180552	0.034368
YLD840	22	34.4626	0.180564	0.037114
YLL555	25	18.8889	0.180792	0.036976
JYX290	20	43.2128	0.181331	0.037106
YLL539	29	18.1641	0.180677	0.036984
YLD888	21	34.7157	0.180372	0.036860
YLD895	21	34.7338	0.180292	0.036853
YLL546	29	18.0942	0.180766	0.036963
JYX297	20	43.2096	0.181285	0.037071
YLL562	25	18.8547	0.180759	0.036995
YLD847	22	34.4445	0.180537	0.037117
YLL490	27	17.7204	0.180425	0.034404
YLL482	27	16.9472	0.180531	0.034374
YLD806	11	32.7282	0.180412	0.037103
YLD902	21	30.6202	0.180246	0.036860
YLD926	24	27.3851	0.180371	0.036867
JYN427	6	48.7491	0.180854	0.037044
JYN438	6	46.7672	0.180935	0.037015

JYN398	10	44.8150	0.180889	0.037028
YLD849	22	29.3201	0.180606	0.037108
YLD833	22	31.6552	0.180518	0.037099
JYX299	20	45.6437	0.181246	0.037045
YLL484	27	17.7907	0.180577	0.034372
JYX419	15	48.2107	0.180746	0.037178
YLL423	26	18.6980	0.180753	0.034604
JYX434	9	43.2434	0.180742	0.037213
YLL531	29	18.1953	0.180699	0.036989
JYX394	8	42.7113	0.180557	0.036936
YLL515	27	18.4323	0.180536	0.034359
YLL522	27	18.4274	0.180438	0.034361
JYX401	8	42.7385	0.180634	0.036955
YLL538	29	18.1391	0.180677	0.036960
JYX441	9	43.2669	0.180616	0.037193
YLL430	26	18.6839	0.180659	0.034566
JYX424	15	48.2397	0.180634	0.037186
YLL489	27	17.7201	0.180444	0.034403
JYX304	20	45.6197	0.181183	0.037072
YLD838	22	31.8546	0.180477	0.037107
YLD854	22	29.2622	0.180618	0.037121
JYN403	10	44.9218	0.180869	0.037058
JYN443	6	47.1285	0.180906	0.036992
JYN462	13	46.8231	0.180805	0.037003
JYN469	13	45.7639	0.180774	0.036986
YLD905	21	28.2960	0.180282	0.036846
JYX379	8	44.7244	0.180721	0.036964
YLD857	12	31.5714	0.180313	0.037083
YLL492	27	17.0837	0.180564	0.034390
YLD841	22	34.3358	0.180563	0.037118
YLL424	26	18.7500	0.180762	0.034604
JYX354	17	42.4193	0.180987	0.037075
YLL523	29	17.1289	0.180726	0.036985
JYX410	15	45.3287	0.180792	0.037177
YLL455	26	18.4172	0.180728	0.034558
JYX314	20	46.8374	0.180960	0.037070
JYX321	20	46.8404	0.180927	0.037078
YLL462	26	18.3917	0.180710	0.034554
JYX417	15	45.3668	0.180656	0.037160
YLL530	29	17.2251	0.180674	0.036995
JYX361	17	42.4970	0.180940	0.037069
YLL429	26	18.6871	0.180687	0.034572
YLD846	22	34.4469	0.180528	0.037123
YLL497	27	16.9617	0.180648	0.034371

YLD862	12	31.6431	0.180319	0.037071
JYX384	8	44.8613	0.180668	0.036974
YLD910	21	28.1812	0.180339	0.036845
JYN476	13	46.0016	0.180996	0.036985
JYN467	13	46.8525	0.180784	0.036988
JYN509	7	45.8381	0.180834	0.036886
JYX323	17	34.5627	0.181008	0.037085
YLD825	11	28.7401	0.180503	0.037088
YLD880	23	31.3415	0.180345	0.037076
YLL432	26	16.9735	0.180626	0.034585
JYX307	20	44.0520	0.181211	0.037057
YLL556	25	19.0264	0.180757	0.036966
JYX435	9	42.8704	0.180732	0.037200
YLL524	29	17.1724	0.180727	0.036984
JYX339	17	44.0875	0.180968	0.037070
YLL447	26	18.4052	0.180799	0.034578
JYX371	8	48.0557	0.180648	0.036922
YLL547	29	17.7631	0.180717	0.036968
YLL554	29	17.7460	0.180784	0.036964
JYX376	8	48.1056	0.180609	0.036942
YLL454	26	18.3937	0.180723	0.034578
JYX344	17	44.5069	0.180964	0.037083
YLL529	29	17.2271	0.180733	0.036992
JYX440	9	43.2925	0.180499	0.037174
YLL561	25	18.8723	0.180753	0.036973
JYX312	20	44.1475	0.181152	0.037066
YLL437	26	16.8377	0.180739	0.034582
YLD887	23	31.2919	0.180362	0.037081
YLD830	11	28.6645	0.180542	0.037104
JYX328	17	35.2568	0.181036	0.037069
JYN516	7	45.8050	0.180858	0.036857
JYN454	6	47.0448	0.180882	0.036991
YLD929	24	28.0211	0.180444	0.036863
YLD809	11	31.0860	0.180415	0.037107
JYX402	15	47.0036	0.180705	0.037185
YLL500	27	17.9618	0.180560	0.034370
YLL440	26	18.6669	0.180683	0.034574
JYX291	20	42.4912	0.181339	0.037101
YLL532	29	18.3131	0.180738	0.036981
JYX411	15	45.3085	0.180718	0.037179
YLL448	26	18.4315	0.180792	0.034587
JYX387	8	46.4990	0.180674	0.036947
YLL463	26	18.7416	0.180821	0.034582
JYX331	17	47.1711	0.181025	0.037069

JYX336	17	47.2424	0.180949	0.037064
YLL470	26	18.7059	0.180779	0.034580
JYX392	8	46.6144	0.180578	0.036949
YLL453	26	18.4077	0.180657	0.034578
JYX416	15	45.3017	0.180679	0.037195
YLL537	29	18.1883	0.180713	0.036968
JYX296	20	43.2442	0.181311	0.037095
YLL445	26	18.5003	0.180737	0.034573
YLL505	27	17.8178	0.180638	0.034357
JYX409	15	46.9826	0.180703	0.037185
YLD814	11	31.0527	0.180490	0.037082
YLD934	24	27.9165	0.180399	0.036848
JYN459	6	47.0484	0.180923	0.036991
JYN382	10	46.9554	0.180962	0.037068
YLD937	24	27.5554	0.180422	0.036869
YLD913	24	31.5841	0.180291	0.036860
YLD817	11	32.8022	0.180478	0.037084
YLL508	27	18.0691	0.180422	0.034351
JYX427	9	44.7431	0.180643	0.037156
YLL540	29	18.2964	0.180649	0.036988
JYX395	8	42.6552	0.180591	0.036923
YLL456	26	18.4910	0.180643	0.034560
JYX370	8	48.0884	0.180629	0.036913
YLL464	26	18.7501	0.180867	0.034577
JYX355	17	43.3861	0.181006	0.037067
YLL471	26	18.7088	0.180769	0.034560
YLL478	26	18.6844	0.180825	0.034607
JYX360	17	43.7634	0.180909	0.037068
YLL469	26	18.7096	0.180749	0.034575
JYX377	8	48.0993	0.180655	0.036959
YLL461	26	18.4082	0.180708	0.034558
JYX400	8	42.7886	0.180687	0.036956
YLL545	29	18.1485	0.180701	0.036973
JYX432	9	44.7015	0.180798	0.037184
YLL513	27	17.9274	0.180527	0.034363
YLD822	11	32.7394	0.180595	0.037097
YLD918	24	31.6334	0.180379	0.036859
YLD942	24	27.4512	0.180423	0.036860
JYN387	10	47.5847	0.180846	0.037057
JYN445	6	48.3269	0.180967	0.037031
YLD873	12	28.2644	0.180264	0.037090
JYX363	17	42.7492	0.181054	0.037051
YLD793	11	32.4134	0.180525	0.037097
YLL416	28	17.1023	0.180812	0.034562

JYX347	17	44.3304	0.181120	0.037031
YLD889	21	34.7511	0.180342	0.036858
YLL516	27	18.5141	0.180549	0.034369
JYX315	20	46.8702	0.180989	0.037079
YLL548	29	17.7942	0.180808	0.036948
JYX330	17	47.2091	0.180996	0.037083
YLL472	26	18.7158	0.180790	0.034576
JYX418	15	48.0746	0.180694	0.037180
JYX425	15	48.0784	0.180665	0.037191
YLL477	26	18.6809	0.180790	0.034597
JYX337	17	47.2216	0.181034	0.037070
YLL553	29	17.7512	0.180746	0.036965
JYX320	20	46.8314	0.180990	0.037084
YLL521	27	18.4269	0.180489	0.034362
YLD894	21	34.7344	0.180304	0.036848
JYX352	17	44.5040	0.180959	0.037074
YLL421	28	16.9910	0.180755	0.034594
YLD798	11	32.6632	0.180446	0.037104
JYX368	17	43.1878	0.181014	0.037076
YLD878	12	28.1661	0.180345	0.037066
JYN452	6	48.3690	0.180966	0.036985
JYN448	6	48.3978	0.180843	0.037034
YLD874	12	28.2375	0.180317	0.037078
JYX364	17	43.2605	0.181011	0.037059
YLD794	11	32.7562	0.180468	0.037109
YLL417	28	17.0808	0.180749	0.034561
JYX348	17	44.5129	0.181164	0.037020
YLD890	21	34.8123	0.180336	0.036860
YLL517	27	18.4960	0.180505	0.034357
JYX316	20	46.8684	0.180989	0.037067
YLL549	29	17.7924	0.180742	0.036960
JYX333	17	47.2210	0.181061	0.037049
YLL473	26	18.7018	0.180810	0.034581
JYX421	15	48.0658	0.180603	0.037143
JYX422	15	48.0469	0.180635	0.037179
YLL476	26	18.6873	0.180755	0.034599
JYX334	17	47.0472	0.181031	0.037054
YLL552	29	17.7518	0.180725	0.036963
JYX319	20	46.8249	0.180969	0.037072
YLL520	27	18.4231	0.180463	0.034349
YLD893	21	34.6975	0.180340	0.036848
JYX351	17	44.4371	0.180959	0.037084
YLL420	28	16.9791	0.180733	0.034574
YLD797	11	32.6599	0.180435	0.037107

JYX367	17	43.1568	0.181045	0.037069
YLD877	12	28.1457	0.180312	0.037075
JYN449	6	48.3112	0.180957	0.037037
JYN383	10	47.5977	0.180914	0.037077
YLD938	24	27.5089	0.180329	0.036871
YLD914	24	31.6962	0.180338	0.036861
YLD818	11	32.8089	0.180482	0.037089
YLL509	27	18.0018	0.180406	0.034336
JYX428	9	44.7523	0.180712	0.037201
YLL541	29	18.2076	0.180639	0.037003
JYX396	8	42.8235	0.180594	0.036896
YLL457	26	18.4536	0.180680	0.034567
JYX373	8	48.1220	0.180583	0.036919
YLL465	26	18.7294	0.180829	0.034587
JYX356	17	43.7423	0.181017	0.037071
YLL474	26	18.6939	0.180777	0.034586
YLL475	26	18.6875	0.180800	0.034594
JYX359	17	43.7380	0.180934	0.037052
YLL468	26	18.6991	0.180806	0.034569
JYX374	8	48.0115	0.180621	0.036930
YLL460	26	18.3819	0.180741	0.034559
JYX399	8	42.7855	0.180630	0.036907
YLL544	29	18.1251	0.180696	0.036967
JYX431	9	44.6190	0.180738	0.037192
YLL512	27	17.8707	0.180410	0.034356
YLD821	11	32.6995	0.180610	0.037108
YLD917	24	31.6061	0.180427	0.036878
YLD941	24	27.4427	0.180426	0.036848
JYN386	10	47.5723	0.180909	0.037058
JYN455	6	47.0339	0.180919	0.036984
YLD930	24	27.9346	0.180489	0.036863
YLD810	11	31.0987	0.180436	0.037102
JYX405	15	46.9953	0.180721	0.037163
YLL501	27	17.8793	0.180466	0.034363
YLL441	26	18.5476	0.180714	0.034580
JYX292	20	43.2692	0.181318	0.037115
YLL533	29	18.2307	0.180659	0.036998
JYX412	15	45.3158	0.180765	0.037183
YLL449	26	18.4280	0.180772	0.034579
JYX388	8	46.6409	0.180589	0.036940
YLL466	26	18.7212	0.180838	0.034580
JYX332	17	47.2195	0.181029	0.037055
JYX335	17	47.0755	0.180952	0.037060
YLL467	26	18.7044	0.180788	0.034572

JYX391	8	46.5964	0.180592	0.036922
YLL452	26	18.3581	0.180660	0.034589
JYX415	15	45.2568	0.180713	0.037184
YLL536	29	18.1471	0.180720	0.036970
JYX295	20	43.2028	0.181321	0.037104
YLL444	26	18.4263	0.180718	0.034560
YLL504	27	17.7479	0.180588	0.034356
JYX406	15	46.8755	0.180684	0.037191
YLD813	11	31.0278	0.180493	0.037094
YLD933	24	27.8927	0.180406	0.036851
JYN458	6	47.0372	0.180886	0.037003
JYN512	7	45.7916	0.180877	0.036862
JYX324	17	35.2609	0.181041	0.037065
YLD826	11	28.6710	0.180531	0.037085
YLD883	23	31.3223	0.180373	0.037083
YLL433	26	16.8806	0.180627	0.034592
JYX308	20	44.1635	0.181117	0.037075
YLL557	25	18.9065	0.180757	0.036958
JYX436	9	43.3048	0.180640	0.037212
YLL525	29	17.2571	0.180737	0.036989
JYX340	17	44.5228	0.180962	0.037067
YLL450	26	18.4234	0.180752	0.034581
JYX372	8	48.1106	0.180625	0.036917
YLL550	29	17.7642	0.180748	0.036970
YLL551	29	17.7581	0.180747	0.036962
JYX375	8	48.0181	0.180657	0.036935
YLL451	26	18.3540	0.180732	0.034600
JYX343	17	44.3587	0.181029	0.037070
YLL528	29	17.0527	0.180758	0.036986
JYX439	9	43.2361	0.180529	0.037175
YLL560	25	18.8327	0.180763	0.036964
JYX311	20	44.0779	0.181150	0.037063
YLL436	26	16.8077	0.180734	0.034591
YLD884	23	31.2685	0.180417	0.037076
YLD829	11	28.6426	0.180575	0.037090
JYX327	17	35.2392	0.181012	0.037071
JYN513	7	45.7883	0.180879	0.036867
JYN463	13	46.8103	0.180816	0.037006
JYN472	13	45.9928	0.181008	0.036994
YLD906	21	28.2038	0.180346	0.036840
JYX380	8	44.8599	0.180709	0.036939
YLD858	12	31.6743	0.180343	0.037085
YLL493	27	16.9937	0.180595	0.034385
YLD842	22	34.4793	0.180567	0.037113

YLL425	26	18.7117	0.180753	0.034596
JYX357	17	42.4961	0.180966	0.037068
YLL526	29	17.2488	0.180785	0.036974
JYX413	15	45.3457	0.180808	0.037170
YLL458	26	18.4295	0.180717	0.034573
JYX317	20	46.8162	0.180992	0.037070
JYX318	20	46.8097	0.180985	0.037091
YLL459	26	18.3910	0.180769	0.034568
JYX414	15	45.3003	0.180693	0.037183
YLL527	29	17.0653	0.180669	0.036993
JYX358	17	42.3661	0.180895	0.037060
YLL428	26	18.6294	0.180682	0.034570
YLD845	22	34.4104	0.180518	0.037122
YLL496	27	16.9414	0.180641	0.034380
YLD861	12	31.6380	0.180315	0.037074
JYX383	8	44.8345	0.180717	0.036972
YLD909	21	28.1736	0.180342	0.036852
JYN473	13	45.9266	0.181026	0.036991
JYN466	13	46.7703	0.180825	0.036975
JYN439	6	47.0967	0.180960	0.037018
JYN399	10	44.9100	0.180857	0.037010
YLD850	22	29.2860	0.180587	0.037108
YLD834	22	31.8787	0.180523	0.037107
JYX300	20	45.6347	0.181261	0.037057
YLL485	27	17.7360	0.180559	0.034376
JYX420	15	48.2466	0.180704	0.037185
YLL426	26	18.7104	0.180755	0.034599
JYX437	9	43.2896	0.180639	0.037202
YLL534	29	18.2155	0.180700	0.036982
JYX397	8	42.7712	0.180673	0.036915
YLL518	27	18.4564	0.180441	0.034353
YLL519	27	18.4400	0.180521	0.034352
JYX398	8	42.7589	0.180643	0.036921
YLL535	29	18.1630	0.180689	0.036972
JYX438	9	43.2414	0.180577	0.037184
YLL427	26	18.6321	0.180701	0.034568
JYX423	15	48.1949	0.180695	0.037164
YLL488	27	17.7090	0.180394	0.034408
JYX303	20	45.5877	0.181226	0.037057
YLD837	22	31.8420	0.180497	0.037106
YLD853	22	29.2584	0.180556	0.037141
JYN402	10	44.9178	0.180862	0.037042
JYN442	6	47.0997	0.180881	0.036994
JYN423	6	48.7261	0.180866	0.037011

YLD922	24	27.4071	0.180369	0.036875
YLD898	21	30.6300	0.180332	0.036860
YLD802	11	32.7473	0.180475	0.037084
YLL480	27	16.9752	0.180507	0.034375
YLL486	27	17.7359	0.180582	0.034382
YLD843	22	34.4743	0.180556	0.037109
YLL558	25	18.9016	0.180755	0.036966
JYX293	20	43.2147	0.181368	0.037108
YLL542	29	18.1733	0.180714	0.036992
YLD891	21	34.7475	0.180372	0.036850
YLD892	21	34.7241	0.180326	0.036849
YLL543	29	18.1533	0.180693	0.036984
JYX294	20	43.2177	0.181326	0.037108
YLL559	25	18.8529	0.180735	0.036978
YLD844	22	34.4300	0.180538	0.037110
YLL487	27	17.7127	0.180421	0.034398
YLL481	27	16.9480	0.180509	0.034369
YLD805	11	32.6698	0.180456	0.037097
YLD901	21	30.6160	0.180272	0.036848
YLD925	24	27.3493	0.180410	0.036864
JYN426	6	48.7193	0.180869	0.037023
JYN416	6	45.9160	0.180940	0.036989
JYN503	7	45.0245	0.180789	0.036892
YLD866	12	28.3478	0.180322	0.037082
JYX341	17	41.8646	0.181001	0.037059
YLD803	11	32.7547	0.180450	0.037089
JYX301	20	45.6097	0.181253	0.037065
YLL494	27	16.9922	0.180614	0.034378
JYX309	20	44.1749	0.181156	0.037071
YLL442	26	18.5303	0.180724	0.034580
JYX429	9	44.7575	0.180783	0.037199
JYX349	17	44.4822	0.181147	0.037037
JYX350	17	44.5041	0.181009	0.037043
JYX430	9	44.7614	0.180712	0.037188
YLL443	26	18.5050	0.180713	0.034579
JYX310	20	44.1491	0.181169	0.037075
YLL495	27	16.9514	0.180650	0.034379
JYX302	20	45.5589	0.181238	0.037040
YLD804	11	32.6742	0.180482	0.037089
JYX342	17	41.8461	0.181063	0.037080
YLD869	12	28.2802	0.180322	0.037089
JYN506	7	45.0556	0.180823	0.036877
JYN417	6	45.9172	0.180947	0.036982
JYN535	14	47.6703	0.181174	0.036881

JYN431	6	44.5828	0.180945	0.037012
JYX389	8	40.1566	0.180608	0.036949
YLD867	12	28.3649	0.180351	0.037084
YLD899	21	30.6292	0.180307	0.036852
YLD835	22	31.8857	0.180497	0.037111
YLD859	12	31.6737	0.180329	0.037080
YLL434	26	16.8676	0.180702	0.034601
YLL502	27	17.8634	0.180458	0.034369
YLL510	27	17.9597	0.180495	0.034359
YLL418	28	17.0242	0.180762	0.034563
YLL419	28	17.0262	0.180703	0.034568
YLL511	27	17.9546	0.180438	0.034353
YLL503	27	17.8463	0.180460	0.034349
YLL435	26	16.8405	0.180712	0.034594
YLD860	12	31.6518	0.180340	0.037085
YLD836	22	31.8715	0.180499	0.037096
YLD900	21	30.6251	0.180262	0.036852
YLD868	12	28.3021	0.180349	0.037082
JYX390	8	39.9972	0.180603	0.036909
JYN434	6	44.5889	0.180987	0.036996
JYN538	14	47.7226	0.180958	0.036875
JYN504	7	47.3102	0.180779	0.036899
JYN432	6	44.6346	0.180945	0.037014
JYN530	14	42.2638	0.180996	0.036877
YLD923	24	27.4076	0.180420	0.036869
YLD851	22	29.2723	0.180559	0.037121
JYX381	8	44.8622	0.180691	0.036968
YLD882	23	31.3245	0.180365	0.037075
JYX404	15	46.9712	0.180730	0.037173
YLD819	11	32.7664	0.180514	0.037088
YLD795	11	32.6858	0.180485	0.037105
YLD796	11	32.6929	0.180470	0.037108
YLD820	11	32.7636	0.180488	0.037097
JYX407	15	46.9106	0.180726	0.037188
YLD885	23	31.3014	0.180370	0.037078
JYX382	8	44.8372	0.180726	0.036972
YLD852	22	29.2669	0.180540	0.037136
YLD924	24	27.3770	0.180412	0.036874
JYN531	14	42.2964	0.181041	0.036893
JYN433	6	44.6610	0.180908	0.037005
JYN505	7	47.2923	0.180866	0.036894
JYN536	14	47.6667	0.181143	0.036882
JYN415	6	45.8819	0.180959	0.036975
JYN424	6	48.7400	0.180833	0.037010

JYN400	10	44.9677	0.180851	0.037031
YLD907	21	28.2041	0.180342	0.036837
YLD827	11	28.6941	0.180541	0.037080
YLD811	11	31.0758	0.180423	0.037099
YLD915	24	31.6537	0.180397	0.036867
JYX365	17	43.1952	0.181066	0.037053
JYX366	17	43.1893	0.181021	0.037073
YLD916	24	31.6504	0.180346	0.036874
YLD812	11	31.0636	0.180428	0.037095
YLD828	11	28.6772	0.180623	0.037076
YLD908	21	28.1917	0.180347	0.036839
JYN401	10	44.9956	0.180849	0.037018
JYN425	6	48.7368	0.180848	0.037003
JYN418	6	45.9167	0.180939	0.036985
JYN537	14	47.6608	0.181130	0.036881
JYN440	6	47.0781	0.180946	0.037011
JYN471	13	46.0108	0.180827	0.036995
JYX325	17	35.2221	0.181070	0.037052
YLD931	24	27.9411	0.180382	0.036866
YLD939	24	27.4667	0.180338	0.036862
YLD875	12	28.1804	0.180317	0.037076
YLD876	12	28.1532	0.180328	0.037068
YLD940	24	27.4606	0.180331	0.036848
YLD932	24	27.9084	0.180444	0.036863
JYX326	17	35.2539	0.181016	0.037083
JYN474	13	45.9665	0.181023	0.036987
JYN441	6	47.0884	0.180976	0.036991
JYN464	13	46.7866	0.180853	0.036991
JYN526	14	47.2833	0.180833	0.036874
JYN456	6	46.9741	0.180960	0.037002
JYN384	10	47.5578	0.180923	0.037067
JYN447	6	48.3915	0.180952	0.037039
JYN450	6	48.4297	0.180908	0.037020
JYN385	10	47.5995	0.180850	0.037069
JYN457	6	46.9889	0.180900	0.037000
JYN527	14	47.1677	0.180921	0.036880
JYN465	13	46.7419	0.180897	0.036987

SPECIAL METALS

www.specialmetals.com

INCONEL® alloy X-750 (UNS N07750/W. Nr. 2.4669) is a precipitation-hardenable nickel-chromium alloy used for its corrosion and oxidation resistance and high strength at temperatures to 1300°F. Although much of the effect of precipitation hardening is lost with increasing temperature over 1300°F, heat-treated material has useful strength up to 1800°F. Alloy X-750 also has excellent properties down to cryogenic termperatures. Composition is shown in Table 1.

The economics of INCONEL alloy X-750 coupled with its availability in all standard mill forms has resulted in applications in a wide variety of industrial fields. In gas turbines, it is used for rotor blades and wheels, bolts, and other structural members. INCONEL alloy X-750 is used extensively in rocket-engine thrust chambers. Airframe applications include thrust reversers and hot-air ducting systems. Large pressure vessels are formed from INCONEL alloy X-750. Other applications are heat-treating fixtures, forming tools, extrusion dies, and test machine grips. For springs and fasteners, INCONEL alloy X-750 is used from sub-zero to 1200°F.

Depending on the application and the properties desired, various heat treatments are employed. For service above 1100°F, particularly where loads are to be sustained for long times, optimum properties are achieved by solution treating (2100°F) plus stabilization treating (1550°F) plus precipitation treating (1300°F). For service below 1100°F, the alloy may be strengthened by precipitation treating after hot or cold working or by precipitation treating after equalizing or solution treating. A furnace-cooling treatment is also used to develop optimum properties for some applications.

The various heat treatments and the properties developed are described under the section on Mechanical Properties.

Property values in this bulletin – the results of extensive testing – are typical of the alloy but, unless shown as limiting, should not be used as specification values.

Publication No. SMC-067

Table 1 - Limiting Chemical Composition, %

Nickel (plus Cobalt)	70.00 min.
Chromium	14.0-17.0
Iron	5.0-9.0
Titanium	2.25-2.75
Aluminum	0.40-1.00
Niobium (plus Tantalum)	0.70-1.20
Manganese	1.00 max.
Silicon	0.50 max.
Sulfur	0.01 max.
Copper	0.50 max.
Carbon	0.08 max.
Cobalt[1]	1.00 max

[1]Determination not required for routine acceptance.

Physical Constants and Thermal Properties

Some physical constants and thermal properties of INCONEL alloy X-750 are given in Tables 2 and 3.

Values for thermal expansion, thermal conductivity, specific heat, and diffusivity are from Lucks and Deem and electrical resistivity from tests conducted at Lehigh University.

Effects of temperature on modulus of elasticity and additional data on resistivity are in Tables 4 and 5. More modulus values can be found in the section on Mechanical Properties.

Table 2 – Physical Constants

Density, lb/in^3	0.299
g/cm^3	8.28
Melting Range, °F	2540-2600
°C	1393-1427
Curie Temperature, °F	
As hot-rolled	-225
Triple-heat-treated (2100°F/2 hr, A.C.,+1500°F /24 hr, A.C., + 1300°F/20 hr, A.C.)	-193
Magnetic Permeability, 70°F, 200H	
As Hot-Rolled	1.0020
Triple-heat-treated (2100°F/2 hr, A.C.,+1500°F /24 hr, A.C., + 1300°F/20 hr, A.C.)	1.0035
Emissivity, oxidized surface	
600°F	0.895
2000°F	0.925
Linear Contraction during Precipitation Treatment (1300°F/20 hr), in/in	
Hot-Rolled	0.00044
20% Cold-Rolled	0.00052
Annealed	0.00026

INCONEL® alloy X-750

INCONEL® alloy X-750

Table 3 - Thermal Properties[a]

Temperature, °F	Mean Linear Expansion, in./in./°F x 10^{-6} from 70° F to Temperature Shown	Thermal Conductivity, Btu/in./hr/sq ft/°F	Specific Heat Btu/lb/°F	Diffusivity, sq ft/hr	Electrical Resistivity, ohm/circ mil/ft
-250	6.5	67	0.073	0.150	–
-200	6.6	70	0.080	0.143	–
-100	6.7	74	0.090	0.135	–
70	–	83	0.103	0.132	731
200	7.0	89	0.109	0.133	739
400	7.2	98	0.116	0.140	746
600	7.5	109	0.120	0.148	761
800	7.8	120	0.125	0.158	771
1000	8.1	131	0.130	0.169	783
1200	8.4	143	0.137	0.173	786
1400	8.8	154	0.151	0.172	775
1600	9.3	164	0.171	0.164	761
1800	9.8	–	–	–	–

[a] Material heat-treated 2100°F/3 hr, A.C., + 1550°F/24 hr, A.C., + 1300°F/20 hr, A.C.

Table 4 - Effect of Heat Treatment on Room-Temperature Resistivity of Hot-Rolled Bar

Heat Treatment	Resistivity, ohm/circ mil/ft
As hot-rolled	759
2000°F/1 hr, A.C.	763
2100°F/1 hr, A.C.+1500°F/24 hr, A.C.+ 1300°F/20 hr, A.C.	724
1800°F/1 hr, A.C.+1350°F/8 hr,F.C. to 1150°F, hold at 1150°F for total time of 18 hr, A.C.	739

Table 5 - Modulus of Elasticity

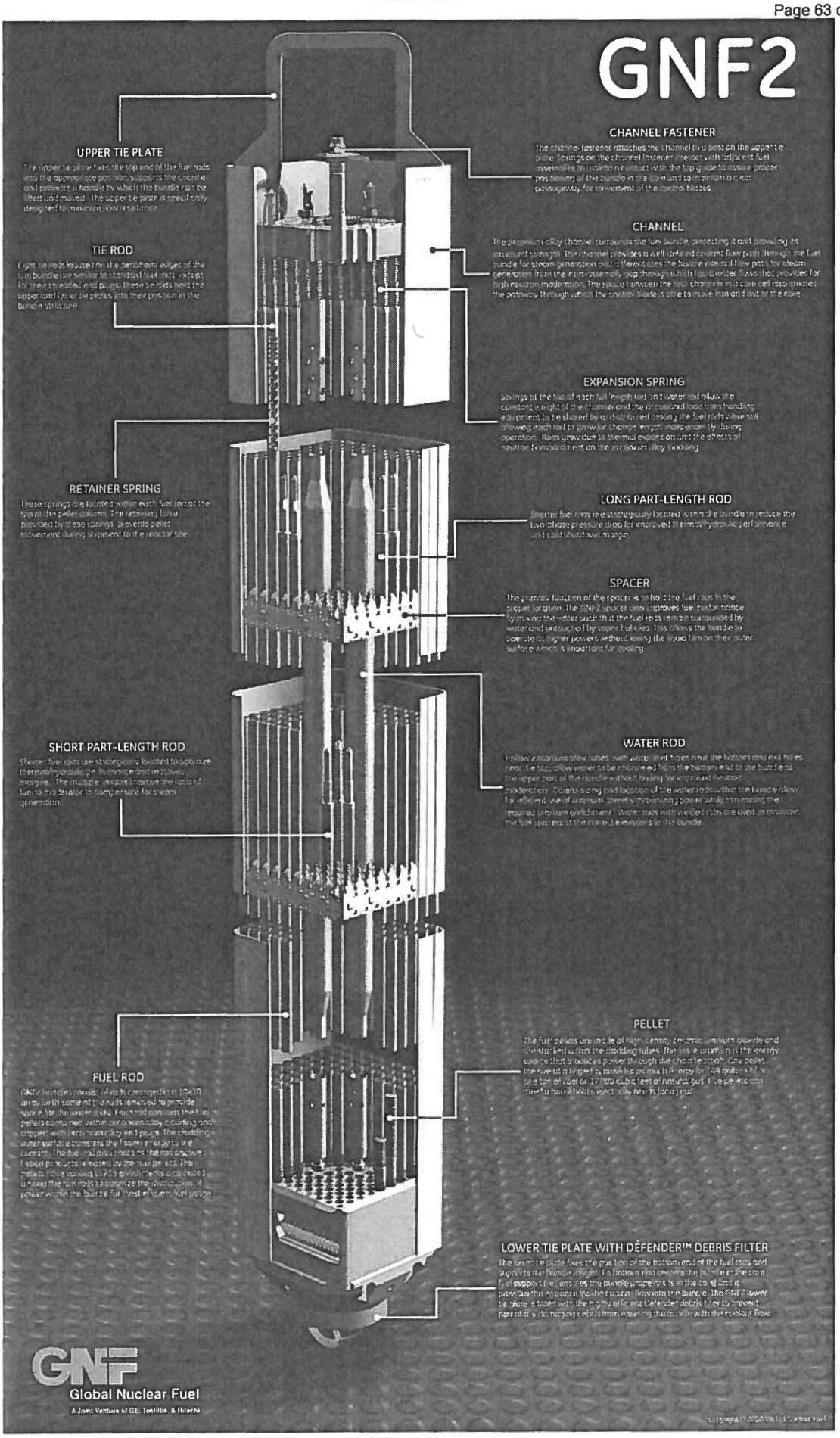
Temperature, °F	Modulus of Elasticity, 10^3 ksi		
	Tension		Torsion
	Static	Dynamic	Static
80[a]	31.0	31.0	11.0
500	28.7	29.1	10.2
1000	25.0	26.7	9.0
1200	23.0	25.5	8.1
1350	21.0	24.4	–
1500	18.5	23.2	–
1600	–	22.1	–
1800	–	20.0	–

[a] Poisson's ratio = 0.29

Mechanical Properties

INCONEL alloy X-750 may be given any one of a variety of heat treatments. Each develops special properties and puts the product form in the best condition for its intended application. In all conditions, alloy X-750 is resistant to oxidation up to 1800°F. The most often used heat treatments have been incorporated by the Society of Automotive Engineers in their AMS specifications* for various product forms. The heat treatments, specifications, and product forms are summarized in Table 6.

*AMS specifications are subject to revision. The ones referenced in this publication were current when it was released. Publisher is the Society of Automotive Engineers, Inc.


GNF2
UPPER TIE PLATE
CHANNEL FASTENER
CHANNEL
TIE ROD
EXPANSION SPRING
RETAINER SPRING
LONG PART-LENGTH ROD
SPACER
SHORT PART-LENGTH ROD
WATER ROD
PELLET
FUEL ROD
LOWER TIE PLATE WITH DEFENDER™ DEBRIS FILTER
GNF
Global Nuclear Fuel
A Joint Venture of GE, Toshiba, & Hitachi

C26Max.inp

```
'This SCALE input file was generated by
'OrigenArp Version  6.1 Compiled on Thu Oct  7 11:31:00 2010
=arp
ge10x10-8
3.4300002
3
855.37
855.37
855.37
19.002401
19.002401
19.002401
1
1
1
0.429
ft33f001
end
#origens
0$$ a4 33 a11 71 e t
ge10x10-8
3$$ 33 a3 1 27 a16 2 a33 18 e t
35$$ 0 t
56$$ 10 10 a6 3 a10 0 a13 4 a15 3 a18 1 e
57** 0 a3 1e-05 0.3333333 e
95$$ 0 t
C26Max
1 MTU
58** 19.0024 19.0024 19.0024 19.0024 19.0024 19.0024 19.0024 19.0024
 19.0024 19.0024
60** 85.537 171.074 256.611 342.148 427.685 513.222 598.759 684.296
 769.833 855.37
66$$ a1 2 a5 2 a9 2 e
73$$ 922340 922350 922360 922380
74** 305.27 34300 157.78 965236.9
75$$ 2 2 2 2
t
ge10x10-8
3$$ 33 a3 2 27 a33 18 e t
35$$ 0 t
56$$ 10 10 a6 3 a10 10 a15 3 a18 1 e
57** 855.37 a3 1e-05 0.3333333 e
95$$ 0 t
C26Max
1 MTU
```

```
58** 19.0024 19.0024 19.0024 19.0024 19.0024 19.0024 19.0024 19.0024
 19.0024 19.0024
60** 940.907 1026.444 1111.981 1197.518 1283.055 1368.592 1454.129
 1539.666 1625.203 1710.74
66$$ a1 2 a5 2 a9 2 e t
ge10x10-8
3$$ 33 a3 3 27 a33 18 e t
35$$ 0 t
56$$ 10 10 a10 10 a15 3 a18 1 e
57** 1710.74 a3 1e-05 0.3333333 e
95$$ 0 t
C26Max
1 MTU
58** 19.0024 19.0024 19.0024 19.0024 19.0024 19.0024 19.0024 19.0024
 19.0024 19.0024
60** 1796.277 1881.814 1967.351 2052.888 2138.425 2223.962 2309.499
 2395.036 2480.573 2566.11
66$$ a1 2 a5 2 a9 2 e t
54$$ a8 1 a11 0  e
56$$ a2 8 a6 1 a10 10 a14 5 a15 3 a17 2 e
57** 0 a3 1e-05 e
95$$ 0 t
C26Max
1 MTU
60** 0 0.75 1 1.25 1.5 2 3 5
61** f0.05
65$$
'Gram-Atoms  Grams  Curies  Watts-All  Watts-Gamma
 3z  1  0  0  3z  3z  3z  6z
 3z  1  0  0  3z  3z  3z  6z
 3z  1  0  0  3z  3z  3z  6z
81$$ 2 0 26 1 a7 200 e
82$$ 2 2 2 2 2 2 2 e
83**
 1.0000000e+07 8.0000000e+06 6.5000000e+06 5.0000000e+06 4.0000000e+06
 3.0000000e+06 2.5000000e+06 2.0000000e+06 1.6600000e+06 1.3300000e+06
 1.0000000e+06 8.0000000e+05 6.0000000e+05 4.0000000e+05 3.0000000e+05
 2.0000000e+05 1.0000000e+05 5.0000000e+04 1.0000000e+04 e
84**
 2.0000000e+07 6.3763000e+06 3.0119000e+06 1.8268000e+06
 1.4227000e+06 9.0718000e+05 4.0762000e+05 1.1109000e+05 1.5034000e+04
 3.0354000e+03 5.8295000e+02 1.0130000e+02 2.9023000e+01 1.0677000e+01
 3.0590000e+00 1.8554000e+00 1.3000000e+00 1.1253000e+00 1.0000000e+00
 8.0000000e-01 4.1399000e-01 3.2500000e-01 2.2500000e-01 1.0000000e-01
 5.0000000e-02 3.0000000e-02 1.0000000e-02 1.0000000e-05 e
t
56$$ 0 0 a10  1 e t
```

```
56$$ 0 0 a10  2 e t
56$$ 0 0 a10  3 e t
56$$ 0 0 a10  4 e t
56$$ 0 0 a10  5 e t
56$$ 0 0 a10  6 e t
56$$ 0 0 a10  7 e t
56$$ 0 0 a10  8 e t
56$$ f0 t
end
=opus
LIBUNIT=33
TYPARAMS=NUCLIDES
UNITS=WATTS
LIBTYPE=ALL
TIME=YEARS
NPOSITION=1 2 3 4 5 6 7 8 end
end
#shell
copy ft71f001 "C:\Users\bfroese\Desktop\Oyster Creek\C26Max.f71"
del ft71f001
end
```