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NUREG-2245

Technical Review of the 2017 Edition of ASME Code, Section III, Division 5, "High Temperature Reactors"

Office of Nuclear Reactor Regulation

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Manuscript Completed: January 2023
Date Published: January 2023

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ABSTRACT

This NUREG documents the U.S. Nuclear Regulatory Commission (NRC) staff's technical evaluation of the 2017 Edition of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code), Section III, "Rules for Construction of Nuclear Facility Components," Division 5, "High Temperature Reactors," and select associated Code Cases for acceptability and endorsement. As of this writing, the absence of a code of construction endorsed by the NRC for nuclear reactors operating above 425 degrees Celsius (800 degrees Fahrenheit) is a significant obstacle for advanced non-light-water-reactor designs. Review of an elevated temperature code of construction during a licensing review of a new nuclear power plant would result in substantial cost and a longer schedule for the requested action. This report documents the NRC's technical review and findings that support its endorsement of ASME Code, Section III, Division 5.

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This report documents the NRC staff's technical review and findings that support the agency's endorsement of ASME Code, Section III, Division 5 and associated Code Cases N-861 and N-862. The NRC staff ensures its licensing reviews are performed in accordance with its safety and security mission and contracted with Pacific Northwest National Laboratory, Oak Ridge National Laboratory, Argonne National Laboratory, and NUMARK Associates, Inc., to perform technical reviews of ASME Code, Section III, Division 5. As indicated throughout this NUREG, the NRC staff relied on portions of the recommendations in the contractor reports and exercised its own independent technical expertise to form the basis for the findings in this report.

ABBREVIATIONS AND ACRONYMS

ADAMS	Agencywide Documents Access and Management System
AIA	Authorized Inspection Agency
ANL	Argonne National Laboratory
ANLWR	advanced nonlight-water reactor
AOD	argon oxygen decarburization
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
C	Celsius
CFR	*Code of Federal Regulations*
CMTR	certified material test report
DOE	U.S. Department of Energy
dpa	displacements per atom
EARRTH	Environmental Assessment Reactor Review Team Home
EDND	equivalent DIDO nickel dose
EPP	elastic-perfectly plastic
EPRI	Electric Power Research Institute
F	Fahrenheit
FN	ferrite number
FR	*Federal Register*
GCA	Graphite Core Assembly
GCC	Graphite Core Component
GDC	general design criterion/criteria
GTAW	gas tungsten arc welding
IAP	implementation action plan
IEC	International Electrotechnical Commission
ILAC	International Laboratory Accreditation Cooperation
ISO	International Organization for Standardization
ISSC	isochronous stress-strain curve
LMP	Larson-Miller Parameter
LWR	light-water reactor
MD	management directive
MDS	Material Data Sheet
MeV	megaelectron volt
MOU	memorandum of understanding
MRA	Mutual Recognition Arrangement
NDE	nondestructive examination
NIMS	National Institute for Materials Science
NRC	U.S. Nuclear Regulatory Commission

N&T	normalized and tempered
ORNL	Oak Ridge National Laboratory
PAW	plasma arc welding
PE	professional engineer
PNNL	Pacific Northwest National Laboratory
POF	Probability of Failure
PWHT	postweld heat treatment
RG	regulatory guide
SEE	standard error of the estimate
SER	safety evaluation report
SFA	special filler (ASME)
SI	système international (d'unités)
SRC	Structural Reliability Class
SRS	stress-range splitting
SS	stainless steel
SSC	structure, system, and component
TLR	technical letter report
UTS	ultimate tensile strength

1 INTRODUCTION

1.1 NRC Use of Codes and Standards

The U.S. Nuclear Regulatory Commission (NRC) participates in codes and standards activities in accordance with Management Directive (MD) 6.5, "NRC Participation in the Development and Use of Consensus Standards" (NRC, 2016a). This MD implements the National Technology Transfer and Advancement Act of 1995 (Public Law -104113) and the Office of Management and Budget Circular No. A-119, "Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities," issued on January 27, 2016 (OMB, 2016). NRC MD 6.5 describes this process, which consists of three primary steps: (1) identifying and prioritizing the need for new and revised technical standards, (2) participating in codes and standards development, and (3) endorsing codes and standards. The NRC works with standards development organizations, advanced nonlight-water-reactor (ANLWR) designers, the U.S. Department of Energy (DOE), and other stakeholders to identify and facilitate new codes.

The NRC regulatory requirements for the use of codes and standards for light-water reactor (LWR) designs are contained in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic licensing of production and utilization facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion (GDC) 1, "Quality Standards and Records" (NRC, 2007). For water-cooled reactors, GDC 1 requires that structures, systems, and components (SSCs) be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. Further, GDC 1 requires that where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function. Appendix A to Part 50 also states that the GDC are generally applicable to other types of nuclear power units and are intended to provide guidance in determining the principal design criteria for such other units.

Regulatory Guide (RG) 1.232, "Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors," (NRC, 2018a) lists the NRC's proposed guidance on how the GDC in 10 CFR Part 50, Appendix A, may be adapted for non-LWR designs. Advanced Reactor Design Criterion 1 in RG 1.232 states that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function.

1.2 The American Society of Mechanical Engineers Boiler and Pressure Vessel Code

The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code) establishes standards relating to the pressure integrity of boilers, pressure vessels, transport tanks, and nuclear components. ASME Code, Section III, "Rules for Construction of Nuclear Facility Components," establishes rules for the materials, design, construction, testing, and quality assurance of mechanical systems and components and their supports of high-temperature reactors.[1]

ASME Code, Section III, Division 1, establishes rules for components where material strength and deformation are time independent and the maximum allowable temperature is 425 degrees Celsius (C) (800 degrees Fahrenheit (F)). The NRC incorporates by reference portions of the ASME Code, Section III, Division 1, in 10 CFR 50.55a, “Codes and standards” (NRC, 2020). In addition, the NRC reviews and endorses Code Cases, which are alternatives or additions to existing ASME Code requirements. The NRC endorses Code Cases in three RGs, which are incorporated by reference in 10 CFR 50.55a.

ANLWR designers have expressed interest in operating in thermal ranges that vary widely between 425 and 1,000 degrees C (800 and 1,832 degrees F), but as of July 2021, there is no NRC-endorsed code of construction for nuclear reactors operating above 425 degrees C (800 degrees F). The NRC staff recognizes that the absence of an NRC-endorsed code of construction for nuclear reactors operating above 425 degrees C (800 degrees F) is a significant obstacle for ANLWR designers as the review of an elevated temperature code of construction during a licensing review of a new nuclear power plant would result in substantial costs and a longer review schedule for the requested action.

ASME Code, Section III, Division 5, “High Temperature Reactors,” extends the rules in ASME Code, Section III, Division 1, to provide consensus standards for the construction of metallic nuclear plant components that would operate within the creep regime (time dependent), which would include temperatures above 425 degrees C (800 degrees F). In addition, ASME Code, Section III, Division 5, provides new rules for the construction of certain nuclear plant components using graphite and composite materials.

1.3 NRC Advanced Reactor Efforts

The NRC has been tasked with being prepared to support the review of future ANLWR design certifications and other licensing applications and is taking steps to develop its regulatory infrastructure for ANLWRs.

In December 2016, the NRC issued its “NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light-Water Mission Readiness” (Advanced Reactor Vision and Strategy Document) (NRC, 2016b), in response to increasing interest in advanced reactor designs. To achieve the goals and objectives stated in the Advanced Reactor Vision and Strategy Document, the NRC staff developed implementation action plans (IAPs). The IAPs identified the specific activities that the NRC staff planned to conduct in the near-term (within 5 years), mid-term (5 to 10 years), and long-term (beyond 10 years) timeframes. On July 12, 2017, the NRC staff issued its final near-term, mid-term and long-term IAPs (NRC, 2017).

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[1] In this report, the NRC staff uses the nomenclature of the ASME Code. In general, the ASME Code is written in mandatory terms. In particular, ASME Code “rules” or “requirements” do not impose regulatory requirements unless incorporated into 10 CFR 50.55a or otherwise imposed through an NRC regulation, order, or license. Unless otherwise noted, this document refers to “rules” or “requirements” in the sense used in the ASME Code. The same is true of ASME Code provisions that use mandatory language, e.g., where a Code provision states that an action “shall” be taken. While this NUREG often uses ASME Code nomenclature to describe the provisions of ASME Code, Section III, Division 5, such description does not mean that Division 5 or any portion of it is legally binding. Legally binding NRC requirements in NRC regulations will be identified as such in this NUREG.

The near-term IAPs address six individual strategies:

(1) Acquire or develop sufficient knowledge, technical skills, and capacity to perform ANLWR regulatory reviews.

(2) Acquire or develop sufficient computer codes and tools to perform ANLWR regulatory reviews.

(3) Develop guidance for a flexible ANLWR regulatory review process within the bounds of existing regulations, including the use of conceptual design reviews and staged-review processes.

(4) Facilitate industry codes and standards needed to support the ANLWR life cycle (including fuels and materials).

(5) Identify and resolve technology-inclusive policy issues that impact the regulatory reviews, siting, permitting, and licensing of ANLWR nuclear power plants.

(6) Develop and implement a structured, integrated strategy to communicate with internal and external stakeholders having an interest in ANLWR technologies.

IAP 4 supports the objective of enhancing ANLWR technical readiness and optimizing regulatory readiness. The staff intends to enhance the NRC's technical readiness for possible ANLWR designs by applying its established process for adapting its regulatory framework to ensure that it facilitates the use of codes and standards.

NRC, RG 1.232 provides guidance on how the GDC may be adapted for ANLWR designs. The NRC staff, recognizing the importance of codes and standards, used the text from GDC 1 verbatim in the development of RG 1.232.

1.4 Review of ASME Code, Section III, Division 5, and Associated Code Cases

The existence of robust and comprehensive rules for design of high-temperature reactor systems and components in the ASME Code, endorsed by the NRC for use by prospective ANLWR vendors, would improve the efficiency and effectiveness of the NRC's review process. An integral part of this framework will be the endorsement of codes and standards that are applicable to the construction, inspection, and operation of ANLWRs.

In a letter dated June 21, 2018, ASME requested that the NRC review and endorse the 2017 Edition of the ASME Code, Section III, Division 5, as well as two Code Cases (ASME, 2018). The NRC responded in a letter dated August 16, 2018, that it was initiating efforts to endorse (with limitations and conditions, if necessary) the 2017 Edition of the ASME Code, Section III, Division 5, in a new RG as one way of meeting the NRC's regulatory requirements (NRC, 2018b).

The result of the NRC's review of ASME Code, Section III, Division 5, and associated Code Cases is a revision to RG 1.87, "Guidance for Construction of Class 1 Components in Elevated-Temperature Reactors" (NRC, 1975), which the staff is not currently planning to incorporate by reference into 10 CFR 50.55a. One reason for this decision is that the NRC staff expects that there will be continued, significant revisions to Division 5 between Editions. NRC reviews of future editions of ASME Code, Section III, Division 5, may take a different approach to endorsement.

This NUREG is the NRC's technical evaluation of the 2017 Edition of the ASME Code, Section III, Division 5, and associated Code Cases with the objective of endorsement. This review does not consider ASME Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," or the ASME Operations and Management Code for high-temperature components. The categorization of SSCs is also not within the scope of this review.

The organization of the NUREG reflects the NRC staff's approach to reviewing the technical adequacy of ASME Code, Section III, Division 5, and associated Code Cases:

- Section 2 describes the staff's approach to reviewing ASME Code, Section III, Division 5. The staff focused on the finding required for a license application of "reasonable assurance of adequate protection" for its review. Three contractors developed technical letter reports (TLRs) that assessed the technical adequacy of the ASME Code. The staff used these TLRs as inputs to its review to make its determination of the adequacy of ASME Code, Section III, Division 5 to govern the design and other aspects of the systems and components to which it applies. Finally, this section mentions two ASME/NRC task groups focused on metallic materials and graphite and ceramics.

- Section 3 is the technical review of the 2017 Edition of the ASME Code, Section III, Division 5. The NRC staff also reviewed certain portions of the 2019 Edition of ASME Code, Section III, Division 5 that addressed issues identified in the 2017 Edition.

- Section 4 is the technical review of the associated Code Cases, N-861, "Satisfaction of Strain Limits for Division 5 Class A Components at Elevated Temperature Service Using Elastic-Perfectly Plastic Analysis," and N-862, "Calculation of Creep-Fatigue for Division 5 Class A Components at Elevated Temperature Service Using Elastic-Perfectly Plastic Analysis."

- Section 5 summarizes the NRC findings that are exceptions or limitations in the RG.

2 OVERVIEW

2.1 Review Approach

The NRC ensures it performs its licensing reviews in accordance with its safety and security mission. The NRC staff is issuing a RG that endorses the use of ASME Code, Section III, Division 5 (hereafter referred to as ASME Code III-5).[2] The staff basis for the RG is the information and evaluation in this document. New or novel designs or design features may need additional review or design standards, or both. Furthermore, the staff plans to consider any technical areas that ASME Code III-5 does not address and that could lead to a demonstrably increased likelihood or consequence of failure.

The staff's technical evaluation of ASME Code III-5 factors in the consideration of margin. Note that the ASME Code, including all Sections and Divisions, will be collectively called the "ASME Code" when a specific Section or Division does not need to be called out and a general reference to the ASME Code only is needed. If the ASME Code is sufficiently conservative in a particular area such that it provides significant margin to relevant limits, and sufficient data exist to support the ASME Code values, then the depth of the staff review of the relevant Code provisions can be reduced. In contrast, where the ASME Code includes lesser margin and less supporting data, the depth of the review in that area should be increased to ensure the staff has an adequate basis for endorsing the ASME Code and formulating any associated exceptions or limitations. In any case, this NUREG documents the staff evaluation of each individual provision of the ASME Code III-5 to determine whether the provision is adequate to assure the mechanical/structural integrity of an SSC designed and constructed in accordance with that provision with respect to the aspect addressed by that provision. If the provision is adequate, the staff endorses it, but if the provision is inadequate, the NRC staff cannot endorse it. In this NUREG, the NRC staff documents the basis for its conclusions.

Similarly, this NUREG incorporates the staff's efforts to make safety evaluations more succinct and includes only the information necessary to establish the NRC staff's safety findings. Therefore, this report provides a concise basis for its conclusions while also maintaining clarity and completeness. This report focuses on why and how the NRC staff reached its conclusions without unnecessary historical or tangential information.

The NRC's research to establish the scope of the review includes a historical survey of previous high-temperature design rules and NRC approvals. Section 2.2 of this report discusses the specific historical findings relevant to this review.

This report considers the adequacy of the technical basis provided in the ASME Code, including the quality and quantity of underlying data, within the context of the selected safety margins. This report also considers previous NRC historical findings, current operating experience, and international experience, including similar design rules, as applicable.

The NRC staff and contractors conducted the ASME Code review by examining the pertinent portions of ASME Code III-5, relevant Code Cases, and supporting documentation (see Section 2.4). The NRC contracted with Pacific Northwest National Laboratory (PNNL), Oak Ridge National Laboratory (ORNL), Argonne National Laboratory (ANL), and NUMARK

2 In general, reference to the ASME Code will be in the form (for example) "ASME-III-1-NH," where III indicates Section III, 1 indicates Division 1, and NH indicates Subsection NH. References may also indicate Articles, Subarticles, or other lower levels. See Section 2.4 of this report for more details.

Associates, Inc. (NUMARK), to perform technical reviews of ASME Code III-5. The NRC staff evaluated the recommendations in the contractor reports and used its own independent technical expertise to form the basis for the findings in this report.

Excessive conservatism in ASME Code III-5 may be noted but will not prevent the NRC from endorsement. The NRC will review the Class A rules on the assumption that the components covered by these rules have safety-significant functions.

2.2 Historical Basis

The NRC researched previous high-temperature design rules and NRC approvals to establish the scope of the review. These reviews included historical RGs, Code Cases, and safety evaluation reports (SERs). ASME Code III-5 was first issued as part of the 2011 Addenda to the 2010 Edition of the ASME Code to address the construction of high temperature reactors, such as high temperature gas-cooled reactors and liquid metal reactors. The rules therein are intended to encompass both low and elevated temperature operating conditions as well as both metallic and non-metallic materials. ASME Code III-5 rules for non-metallic components are standalone, while the rules for metallic materials are essentially a compilation of rules directly incorporated into the Code from existing Code Cases or provided by reference to existing ASME Code, Section III, Division 1 (hereafter referred to as ASME Code III-1), including subsections.

The rules provided in ASME Code III-1 have been endorsed by the NRC for many years and are incorporated by reference in 10 CFR 50.55a. These rules apply to components that operate at temperatures that are typically 370 degrees C (700 degrees F) or less for carbon and martensitic steels and 425 degrees C (800 degrees F) or less for austenitic or high nickel alloys, where creep effects are insignificant. Metallic material behavior considerations are limited to either elastic or elastic-plastic response, which, in effect, provides protection against only time independent failure modes such as ductile rupture, gross distortion, and fatigue. With this in mind, it was recognized that Division 1 rules alone would not provide adequate guidance for the construction of metallic components subject to elevated temperature service because they do not address time-dependent phenomena such as creep and relaxation, which are unique to operating at temperatures and load conditions typically found in high temperature reactors.

In the 1970s, to facilitate the construction of high temperature reactors, ASME developed five Code Cases that were intended to replace, or supplement in some cases, Section III, Division 1:

- Code Case 1592, “Class 1 Components in Elevated Service”
- Code Case 1593, “Fabrication and Installation of Elevated Temperature Components”
- Code Case 1594, “Examination of Elevated Temperature Nuclear Components”
- Code Case 1595, “Testing of Elevated Temperature Nuclear Components”
- Code Case 1596, “Protection Against Overpressure of Elevated Temperature Components”

It was intended that these Code Cases could also be used as a guide, with justification provided by an applicant, to supplement other Section III Subsections and Appendices used to design components operating at high temperatures. Code Cases 1593, 1594, 1595, and 1596 were approved by ASME on November 5, 1973. Code Case 1592 was approved by ASME on April 29, 1974. Subsequently, the NRC staff endorsed the five Code Cases, in their Revision 0 forms, with conditions, via RG 1.87, Revision 1. The ASME subsequently incorporated these five Code Cases into ASME Code III-1 with the creation of ASME Code III-1-NH. This report uses these Code Cases as a basis for the review of the 2017 Edition of the ASME Code III-5.

ASME subsequently developed the following ASME Code III-1 Code Cases intended to provide rules for Class 1, 2, and 3 components that would be subject to elevated temperature service:

- Code Case N-201-5, "Class CS Components in Elevated Temperature Service"
- Code Case N-253-14, "Construction of Class 2 or Class 3 Components for Elevated Temperature Service"
- Code Case N-254, "Fabrication and Installation of Elevated Temperature Components, Class 2 and 3"
- Code Case N-257, "Protection Against Overpressure of Elevated Temperature Components, Classes 2 and 3"
- Code Case N-467, "Testing of Elevated Temperature Components, Classes 2 and 3"
- Code Case N-499-2, "Use of SA-533 Grade B, Class 1 Plate and SA-508 Class 3 Forgings and their Weldments for Limited Elevated Temperature Service"

The staff notes that the NRC staff has not reviewed or endorsed Code Cases N-201, N-253-14, N-254, N-257, N-467, and N-499-2. The ASME combined these Code Cases and the rules provided in ASME Code III-1-NH to create the rules in ASME Code III-5 for metallic components of high temperature reactors, i.e., those which operate at elevated temperatures (typically above 370 ºC [700 ºF] for carbon and martensitic steels and above 425 degrees C (800 degrees F) for austenitic or high nickel alloys). Metallic components of high temperature reactors intended to operate at low temperature would use the appropriate portions of ASME Code III-1-NB, III-1-NC, III-1-ND, III-1-NF, and III-1-NG, which are directly referenced in Division 5.

Ultimately, ASME Code III-5 provides rules in addition to the ASME Code III-1 rules in order to facilitate the design and construction of high temperature reactor systems and their supporting systems, which may not operate at elevated temperature if designed in accordance with ASME Code III-1. This is accomplished by providing standalone rules for metallic components or by referencing the rules of ASME Code III-1, as supplemented by ASME Code III-5. It is also accomplished by providing new standalone rules for non-metallic materials, such as graphite, that are unique to high temperature reactors and not covered by ASME Code III-1. In light of the above, the following insights are provided:

- Some of the rules provided in ASME Code III-5 appear either exactly as originally written in the previous elevated temperature rules and Code Cases, or similar to their original wording with the same objective as the previous rules, or are enhanced or improved using updated information.
- Those portions of ASME Code III-5 regarding low temperature service that reference ASME Code III-1 are acceptable because the ASME Code III-1 rules are currently incorporated by reference into NRC regulations.
- ASME Code III-5-HB is for Class A metallic components, which are analogous to ASME Code III-1, Class 1 components. ASME Code III-5-HBA is based on ASME Code III-1-NB requirements as written. ASME Code III-5-HBB is based on ASME Code III-1-NH, which was based, in part, on Code Cases 1592, 1593, 1594, 1595, and 1596 and their revisions, as well as ASME Code III-1-NB.
- ASME Code III-5-HC is for Class B metallic components, which are analogous to ASME Code III-1, Class 2 and 3 components. ASME Code III-5-HCA is based on ASME Code III-1-NC requirements as written. ASME Code III-5-HCB is based on Code Cases N-253-

14, N-254, N-467 and N-257, and ASME Code III-1-NC, Article NC-5000, “Examination.” The NRC has not reviewed or endorsed these code cases.

- ASME Code III-5-HF is for Class A and Class B metallic supports, which are analogous to ASME Code III-1 supports for Class 1, 2, and 3 components. The rules of ASME Code III-5-HFA are provided by reference to ASME Code III-1-NF, except for those paragraphs replaced by corresponding numbered paragraphs in ASME Code III-5. There are no provisions for elevated temperature.
- ASME Code III-5-HG is for Class A metallic core supports, which are analogous to ASME Code III-1 core support structures. ASME Code III-5-HGA is based on ASME Code III-I-NG requirements as written. ASME Code III-5-HGB is based Code Case N-201. The NRC staff has not reviewed or endorsed Code Case N-201.

2.3 Contractor Review Assignments

In October 2018, the NRC staff initiated efforts to review the 2017 Edition of the ASME Code III-5, with the objective of endorsing it, if technically adequate. To that end, the NRC staff sent the ASME Code III-5 standard and the technical background documents to PNNL, ORNL, and NUMARK for a peer review and expert recommendation on the technical adequacy ASME Code III-5. This NUREG documents the staff’s review of the 2017 Edition of ASME III-5 and associated Code Cases N-861 and N-862, and uses portions of the recommendations in the following contractor reports and the NRC staff’s independent technical expertise to form the basis for the findings.

- Pacific Northwest National Laboratory Technical Input for the Nuclear Regulatory Commission Review of the 2017 Edition of ASME Section III, Division 5, "High Temperature Reactors" (PNNL, 2020);
- Oak Ridge National Laboratory Technical Input for the Nuclear Regulatory Commission Review of the 2017 Edition of the ASME Boiler and Pressure Vessel Code, Section III, Division 5, "High Temperature Reactors" (ORNL, 2020);
- Technical Input for the U.S. Nuclear Regulatory Commission Review of the 2017 Edition of ASME Boiler and Pressure Vessel Code, Section III, Division 5, “High-Temperature Reactors” HBB-T, HBB-II, HCB-I, HCB-II, and HCB-III for Metallic Components (NUMARK, 2020a);
- Technical Input for the U.S. Nuclear Regulatory Commission Review of the 2017 Edition of ASME Boiler and Pressure Vessel Code, Section III, Division 5, "High Temperature Reactors": Subsection HH, "Class A Nonmetallic Core Support Structures," Subpart A, "Graphite Materials" (NUMARK, 2020b);
- Technical Input for the U.S. Nuclear Regulatory Commission Review of the 2017 Edition of ASME Boiler and Pressure Vessel Code, Section III, Division 5, "High-Temperature Reactors." Review of Code Case N-861 and N-862: Elastic-Perfect Plastic Methods for Satisfaction of Strain Limits and Creep-Fatigue Damage Evaluation in BPV-III-5 Rules (NUMARK, 2020c); and
- Historical Context and Perspective on Allowable Stresses and Design Parameters in ASME Section III, Division 5, Subsection HB, Subpart B (ANL/AMD-21/1) (ANL, 2021).

  ANL, 2021 references the following report developed by MPR Associates, Inc.

  - MPR Report 0300-0003-RPT-001, Revision 1, Impact of Tertiary Creep on Time Dependent Allowable Stresses for Type 304H and 316H Stainless Steels (MPR, 2021)

2.4 Report Organization

This NUREG uses the same nomenclature as the ASME Code. The text below summarizes the organization of ASME Code III-5.

ASME Code, Section III, consists of Divisions. Divisions are broken down into Subsections. Subsections are divided into Subparts, Articles, subarticles, paragraphs, and, where necessary, subparagraphs and subsubparagraphs.

Articles are designated by the applicable letters indicated above for the Subsections, followed by Arabic numbers, such as HBB-1000. Where possible, Articles dealing with the same topics are given the same number in each Subsection.

Subarticles are numbered in units of 100, such as HBB-1100.

Subsubarticles are numbered in units of 10, such as HBB-2130, and generally have no text. When a number such as HBB-1110 is followed by text, it is considered a paragraph.

Paragraphs are numbered in units of 1, such as HBB-2121.

Subparagraphs, when they are major subdivisions of a paragraph, are designated by adding a decimal followed by one or more digits to the paragraph number, such as HBB-1132.1. When they are minor subdivisions of a paragraph, subparagraphs may be designated by lowercase letters in parentheses, such as HBB-2121(a).

Subsubparagraphs are designated by adding lowercase letters in parentheses to the major subparagraph numbers, such as HBB-1132.1(a). When further subdivisions of minor subparagraphs are necessary, subsubparagraphs are designated by adding Arabic numerals in parentheses to the subparagraph designation, such as HBB-2121(a)(1).

Figure 2-1, below, provides the organization of ASME Code III-5 and details that for each section on metallic components, there are subparts for low temperature and elevated temperature service. There are separate general requirements subparts for metallic and graphite and composite materials.

Class	Subsection	Subpart	Subsection ID	Title	Scope
General Requirements					
Class A, B, & SM	HA	A	HAA	Metallic Materials	Metallic
Class SN		B	HAB	Graphite and Composite Materials	Nonmetallic
Class A Metallic Pressure Boundary Components					
Class A	HB	A	HBA	Low Temperature Service	Metallic
Class A		B	HBB	Elevated Temperature Service	Metallic
Class B Metallic Pressure Boundary Components					
Class B	HC	A	HCA	Low Temperature Service	Metallic
Class B		B	HCB	Elevated Temperature Service	Metallic
Class A and Class B Metallic Supports					
Class A & B	HF	A	HFA	Low Temperature Service	Metallic
Class SM Metallic Core Support Structures					
Class SM	HG	A	HGA	Low Temperature Service	Metallic
Class SM		B	HGB	Elevated Temperature Service	Metallic
Class SN Nonmetallic Core Components					
Class SN	HH	A	HHA	Graphite Materials	Graphite
Class SN		B	HHB	Composite Materials	Composite

Figure 2-1 Organization of ASME Code Section III, Division 5, "High Temperature Reactors"

3 TECHNICAL REVIEW OF 2017 EDITION OF ASME CODE, SECTION III, DIVISION 5

This section of the NUREG documents the NRC staff's technical review of the 2017 Edition of the ASME Code III-5, which uses the recommendations in the contractor reports, the five Code Cases accepted for use, with conditions, in NRC RG 1.87, Revision 1, and NRC staff independent technical expertise to form the basis for the findings in this report. The NRC staff also reviewed certain values in the 2019 Edition of ASME Code, Section II, Part D and Mandatory Appendix HBB-I-14 of the 2019 Edition of the ASME Code III-5 and endorsed them for limited use where the 2019 Edition addressed issues identified in the 2017 Edition.

RG 1.87 Revision 1 explicitly states that Section III Code Cases 1592, 1593, 1594, 1595, and 1596 may be used in conjunction with ASME Code III-1-NB. The NRC staff compared the Articles of ASME Code III-5-HBB to the related areas of Code Cases 1592, 1593, 1594, 1595, and 1596 as an approach to validate the information present in III-5-HBB since III-5 is for high-temperature Class A components, which are analogous to high-temperature Section III-1 components addressed by the code cases. In the same manner, the staff compared the Articles from ASME Code III-5-HCB to ASME Code III-1-NC and III-5-HBB since III-5 HCB is for high-temperature Class B components, which are analogous to Class 2 components in Section III-1 NC, but operate at high temperatures (like components addressed by Section III-5 HBB). The staff compared ASME Code III-5-HGB to ASME Code III-5-HBB because core support structures operate at the same high temperature range as that established for Class A components under ASME Code III-5-HBB. In performing these comparisons, the staff and/or contractor may have noted differences in provision structure, numbering, references, and other non-substantive differences. For the purposes of this NUREG, only substantive differences are evaluated further. If the staff has determined that there are no substantive differences or no difference at all between an ASME Code III-5 provision and the corresponding ASME Code III-1 or Code Case provision, in this NUREG the staff will denote the ASME Code III-5 provision as technically equivalent to the corresponding ASME Code III-1 or the Code Case provision. When using ASME Code III-5, where Division 5 references ASME Code III-1, applicants and licensees should follow any applicable conditions for Division 1 that are identified in 10 CFR 50.55a.

When evaluating the provisions of the 2017 Edition of ASME Code III-5-HAA and -HAB, the staff compared these to the 2017 Edition of the ASME Code III-NCA, which the NRC endorsed in its final rule to incorporate by reference the 2015 and 2017 Editions of the ASME Code III-1 in 10 CFR 50.55a. Any differences identified are being proposed as exceptions or limitations to ensure consistency.

Similarly, the staff compared the 2017 Edition of ASME Code III-5-HAA and -HAB to the 2019 Edition of ASME Code III-5-HAA and -HAB to ensure consistency with those items that were corrected in the 2019 Edition. Any differences identified are being proposed as exceptions or limitations to address those items that were corrected in the 2019 Edition.

3.1 <u>Subsection HA General Requirements, Subpart A Metallic Materials (HAA)</u>

3.1.1 Article HAA-1000 Introduction

HAA-1100 General

HAA-1110 Scope

Subsubarticle HAA-1110 has minor subparagraphs, (a) through (e). Subparagraph HAA-1110(a) indicates, in part, that the rules of ASME Code III-5-HAA are contained in ASME Code III-NCA, except for those paragraphs or subparagraphs replaced by corresponding numbered ASME Code III-5-HAA paragraphs or subparagraphs, or new numbered paragraphs or subparagraphs added to ASME Code III-5-HAA.

In the final rule incorporating by reference the 2015–2017 Editions of the ASME Code III-1 into 10 CFR 50.55a, the NRC staff imposed a new condition related to the use of Certifying Engineers. Specifically, the 2017 Edition of the ASME Code III-NCA updated the following Subsections to replace the term “Registered Professional Engineer” with the term “Certifying Engineer” to be consistent with the ASME Code, Section III, Mandatory Appendix XXIII, “Qualifications and Duties of Certifying Engineers Performing Certification Activities”:

- ASME Code III-NCA, Paragraph NCA-3255, “Certification of the Design Specifications”
- ASME Code III-NCA, Subsubarticle NCA-3360, “Certification of the Construction Specification, Design Drawings, and Design Report”
- ASME Code III-NCA, Subparagraph NCA-3551.1, “Design Report”
- ASME Code III-NCA, Subparagraph NCA-3551.2, “Load Capacity Data Sheet”
- ASME Code III-NCA, Subparagraph NCA-3551.3, “Certifying Design Report Summary”
- ASME Code III-NCA, Paragraph NCA-3555, “Certification of Design Report”
- ASME Code III-NCA, Table NCA-4134.17-2, “Nonpermanent Quality Assurance Records”
- ASME Code III-NCA, Paragraph NCA-5125, “Duties of Authorized Nuclear Inspector Supervisors”
- ASME Code III-NCA, Subarticle NCA-9200, “Definitions”

The NRC reviewed these changes and determined that the use of a Certifying Engineer instead of a Registered Professional Engineer applies only to non-U.S. nuclear facilities. As such, use of a Certifying Engineer does not apply to nuclear facilities regulated by the NRC.

Subsubarticle HAA-1110 serves the same purpose as ASME Code III-NCA, Subsubarticle NCA-1110, “General.” Subsubarticle HAA-1110 is technically equivalent to Subsubarticle NCA-1110, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a with one exception. Specifically, the NRC only allows use of Certifying Engineers who are also

Registered Professional Engineers (PEs), while Subsubarticle HAA-1110 allows the use of Certifying Engineers who are not Registered PEs. Therefore, the staff finds Subsubarticle HAA-1110 to be acceptable with the following exception:

> The NRC staff does not endorse paragraph XXIII-1223 from Mandatory Appendix XXIII in ASME Code, Section III, "Appendices." When applying the 2017 and later editions of ASME Code Section III, the NRC does not endorse applicant and licensee use of a Certifying Engineer who is not a Registered Professional Engineer qualified in accordance with paragraph XXIII-1222 for Code-related activities that are applicable to NRC-regulated facilities.

The NRC staff also noted that, in the 2019 Edition of the ASME Code III-5, ASME changed the equivalent name used for Division 1, Class CS (core support structures constructed in accordance with the rules of III-1-NG). Specifically, while in the 2017 Edition, Division 5, Class CS provisions are referred to as Class A, in the 2019 Edition, Division 1, Class CS provisions are referred to as Division 5, Class SM. This change is also reflected in the 2019 Edition of the ASME Code III-5-HAA, Subsubarticle HAA-2120 and Paragraph HAA-2131.

HAA-1120 Definitions

Subsubarticle HAA-1120 indicates that Article HAA-9000, "Glossary," includes definitions of key terms used in this Division for metallic components. If any conflicts exist with definitions found in Division 1 or in other documents referenced in Division 5, the definitions in HAA-9000 will prevail. If there are terms not defined in Article HAA-9000, then the definitions in Divisions 1 and 2, Article NCA-9000, shall apply. Section 3.1.6 of this NUREG includes the NRC staff's evaluation of HAA-9000. Subsubarticle HAA-1120 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-NCA, Subsubarticle 1120, "Definitions," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds Subsubarticle HAA-1120 acceptable.

HAA-1130 Limits of These Rules

Subsubarticle HAA-1130 has four subparagraphs, (a) through (d). HAA-1130(a) describes the limits of ASME Code III-5 and lists different mechanisms of deterioration (e.g., radiation effects, corrosion) not covered by ASME Code III-5.

HAA-1130(b) lists the items (e.g., valve operators, controllers, pump impellers) not covered by ASME Code III-5 unless they are pressure-retaining parts or act as core support structures or supports. If these types of items are in a support load path, the provisions of HFA-1100 would apply. HAA-1130(c) provides an additional list of items to which ASME Code III-5 does not apply (instruments or permanently sealed fluid-filled tubing systems).

HAA-1130(d) explains that, excluding Subsections HF and HH and this Subsection HA, the Subsections of ASME Code III-5 are divided into two subparts: Subpart A, which addresses the rules for low-temperature service, and Subpart B, which addresses the rules for elevated temperature service. Further, Subsubarticle HAA-1130 includes Table HAA-1130-1, "Values of T_{max} for Various Classes of Permitted Materials," which indicates the maximum temperature limits for carbon steel, low alloy steel, martensitic stainless steel (SS), austenitic SS, nickel-chromium-iron, and nickel-copper at which the low -temperature service rules apply. The service rules for elevated temperature apply at temperatures above those listed in Table HAA-1130-1 for the materials listed above.

Subsubarticle HAA-1130 serves the same purpose and is technically equivalent to the corresponding provisions in ASME Code III-NCA, Subsubarticle NCA-1130, “Limits of These Rules,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HAA-1130(a) through (d) acceptable.

The staff also finds Table HAA-1130-1 to be acceptable as written because the maximum temperature limits are consistent with the staff’s understanding of the temperature limits, above which creep and other time-dependent effects on materials properties and behavior become significant. Further, these temperature limits do not otherwise impact other technical requirements.

3.1.2 Article HAA-2000 Classification of Components and Supports

HAA-2100

HAA-2120 Purpose of Classifying Items of a Nuclear Power Plant

Subsubarticle HAA-2120 describes the basis for having different levels of importance associated with the function of each item as related to the safe operation of the nuclear power plant. Essentially, having different ASME Code classes allows for a choice of rules that provide assurance of structural integrity and quality commensurate with the relative importance assigned to the items of the nuclear power plant.

Subsubarticle HAA-2120 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-NCA, Subsubarticle NCA-2120, “Purpose of Classifying Items of a Nuclear Power Plant,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds Subsubarticle HAA-2120 acceptable. Further, Subsubarticle HAA-2120 does not contain any technical requirements and does not otherwise impact other requirements.

HAA-2130 Classification and Rules of Division 5

HAA-2131 Code Classes and Rules of Division 5

Paragraph HAA-2131 has two subparagraphs, (a) and (b). HAA-2131(a) identifies the applicable subsections containing the rules of construction for Class A and Class B components. Specifically, Subsections HB or HG apply to Class A components, and Subsection HC applies to Class B components. HAA-2131(b) indicates that the rules of construction for supports for Class A and Class B items and internal structures are in Subsections HF and HG, respectively.

Paragraph HAA-2131 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-NCA, Paragraph NCA-2131, “Code Classes and Rules of Division 1,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HAA-2131 acceptable.

HAA-2133 Multiple Code Class Components

Paragraph HAA-2133 has two subparagraphs, (a) and (b). HAA-2133(a) indicates that compartments (e.g., heat exchangers) may be assigned different ASME Code classes, provided any interactions between compartments are taken into account and specified in the Design Specifications. HAA-2133(b) specifies that supports for multiple ASME Code class components shall be constructed in accordance with Subsection HF, which is the most restrictive ASME Code class.

Paragraph HAA-2133 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-NCA, Paragraph NCA-2133, “Multiple Code Class Components,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds Paragraph HAA-2133 acceptable.

HAA-2134 Optional Use of Code Classes

Paragraph HAA-2134 has three subparagraphs, (a) through (c). These three subparagraphs provide an alternative to the rules of Subsection HC by allowing an item designated as Class B to be constructed under the rules of Subsection HB used for the construction of Class A items, which are more restrictive.

Paragraph HAA-2134 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-NCA, Paragraph NCA-2134, “Optional Use of Code Classes,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, with respect to allowing the construction of an item with more restrictive rules. Therefore, the staff finds Paragraph HAA-2134 acceptable.

3.1.3 Article HAA-3000 Responsibilities and Duties

HAA-3200

HAA-3250 Provision of Design Specifications

HAA-3252 Contents of Design Specifications

The 2017 Edition of the ASME Code III-5, indicates that the rules of Subpart HAA are contained in ASME Code III-NCA, except for a few paragraphs that were replaced with corresponding numbered Subpart HAA paragraphs or subparagraphs. The 2017 Edition of the ASME Code III-5, did not replace any of the corresponding ASME Code III-NCA paragraphs. However, the NRC staff noted that, in the 2019 Edition of the ASME Code III-5, ASME included Paragraph HAA-3252 (replacing ASME Code III-NCA, Paragraph NCA-3252, “Contents of Design Specifications.”)

Paragraph HAA-3252 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-NCA, Paragraph NCA-3252, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a except HAA-3252 removes Subparagraph NCA-3252(b), which dealt with concrete. This is acceptable because ASME Code III-5 does not address concrete. Further, Paragraph HAA-3252 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAA-3252 acceptable.

3.1.4 Article HAA-7000 Reference Standards

HAA-7100 General Requirements

Subarticle HAA-7100 states that the standards and specifications referenced in ASME Code III-5 associated with metallic components are listed in Table HAA-7100-1, "Standards and Specifications Referenced in ASME Code III-5 Associated with Metallic Components," unless they are already shown in ASME Code III-NCA, Table NCA-7100-2, "Standards and Specifications Referenced in Division 1." The respective Subparts of ASME III-5-HAA address the standards and specifications associated with nonmetallic components.

Table HAA-7100-1 lists only one additional standard not shown in Table NCA-7100-2: American Society for Testing and Materials (ASTM) E112, "Standard Test Methods for Determining Average Grain Size," 1996 Edition (R2004) (ASTM, E112). ASTM, E112 is used to determine the average grain size in metallic materials.

Subarticle HAA-7100 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-NCA, Subarticle NCA-7100, "General Requirements," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAA-7100 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds HAA-7100 acceptable.

The staff finds Table HAA-7100-1 to be acceptable as written because ASTM E112 represents an acceptable way of measuring grain size in metallic components.

3.1.5 Article HAA-8000 Nameplates, Stamping with the Certification Mark, and Reports

HAA-8100 Authorization to Perform Code Activities

HAA-8110 General

Subsubarticle HAA-8110 states that the rules for certificates, nameplates, the Certification Mark, and Data Reports for metallic components, metallic supports, and metallic core support structures under ASME Code III-5 shall be the same as those established for Division 1 metallic components and metallic core support structures. The only difference is the use of ASME Code III-5 terminology (e.g., Class A and Class B rather than Class 1 and Class 2).

HAA-8110 also explains that authorization to use the official Certification Mark or to certify work by other alternatives provided in Subsection HA, Subpart A, can be granted for a 3-year period in accordance with the provisions in this Article. In addition, it also explains that to certify Owner's[3] Data Report Forms (N-3), authorization can be granted in accordance with the provisions in this Article.

Subsubarticle HAA-8110 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-NCA, Subsubarticle NCA-8110, "General," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAA-8110 does not contain any technical requirements and

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[3] ASME Code III-NCA, Subarticle NCA-9200, "Definitions," defines "Owner" as the organization legally responsible for the construction and/or operation of a nuclear facility including but not limited to one who has applied for, or has been granted, a construction permit or operating license by the regulatory authority having lawful jurisdiction.

does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAA-8110 acceptable.

3.1.6 Article HAA-9000 Glossary

HAA-9100 Introduction

Subarticle HAA-9100 indicates that the Article provides definitions used in ASME Code III-5 for metallic pressure boundary components and metallic core support structures. It also states that if any conflicts exist with definitions found elsewhere, the definitions in this Article shall prevail. HAA-9100 states further that if there are terms not defined in this Article, then the definitions in ASME Code III-NCA, Article NCA-9000 shall apply.

Subarticle HAA-9100 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-NCA, Subarticle NCA-9100, “Introduction,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subarticle HAA-9100 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subarticle HAA-9100 acceptable.

HAA-9200 Definitions

Subarticle HAA-9200 defines four terms used throughout ASME Code III-5: elevated temperature service, low -temperature service, negligible creep, and zone of elevated temperature service. The staff finds Subarticle HAA-9200 to be acceptable because (1) Table HAA-1130-1 is adequately referenced in the definitions for elevated temperature service and low-temperature service, and (2) they are technically sound.

3.2 <u>Subsection HA General Requirements, Subpart B Graphite Materials (HAB)</u>

3.2.1 Article HAB-1000 Introduction

HAB-1100 General

HAB-1110 Scope

Subsubarticle HAB-1110 has minor subparagraphs (a) and (b). These two subparagraphs provide a generic list of what is included in Subpart B and in Subsection HH, “Class A Nonmetallic Core Support Structures,” Subpart A, “Graphite Materials,” as well as a list of the mandatory appendices.

Subsubarticle HAB-1110 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-1110, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-1110 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-1110 acceptable.

HAB-1120 Definitions

Subsubarticle HAB-1120 indicates that Article HAB-9000, "Glossary," includes definitions of key terms used in ASME Code III-5-HAB and ASME Code III-5-HHA. If a term is not defined in Article HAB-9000, the definition in Article NCA-9000 will apply.

Subsubarticle HAB-1120 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-1120, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-1120 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-1120 acceptable.

HAB-1130 Limits of These Rules

Subsubarticle HAB-1130 states that the rules of Subpart B and Subsection HH, Subpart A, provide requirements for new construction and include consideration of mechanical and thermal stresses due to cyclic operation, which includes deterioration that may occur due to radiation effects and oxidation.

Subsubarticle HAB-1130 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-1130, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-1130 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-1130 acceptable.

HAB-1140 Use of Code Editions, Addenda, and Cases

Subsubarticle HAB-1140 has two subparagraphs, (1) and (2), as well several subsubparagraphs under HAB-1140(2) that provide rules for the use of ASME Code editions, ASME Code addenda, and Code Cases. Specifically, HAB-1140 states that some types of information shall be documented in the Design Specifications based on the ASME Code edition, ASME Code addenda, and Code Cases that will be used for construction. In addition, HAB-1140 provides conditions for the use of materials for construction that were produced and certified in accordance with ASME Code editions and addenda other than the one specified for construction of an item.

Subarticle HAB-1140 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subarticle NCA-1140, "Use of Code Editions, Addenda, and Cases," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-1140 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-1140 acceptable.

HAB-1150 Units of Measurement

Subarticle HAB-1150 provides the rules for units of measurement (e.g., U.S. Customary units, système international [d'unités] [SI units], or any local customary units) to demonstrate compliance with all of the provisions of the 2017 Edition of the ASME Code III-5. HAB-1150 states that, in general, a single system of units shall be used for all aspects of the design except where it is impractical. When components are manufactured at different locations where local customary units are different from those used for the general design, the local units may be used for the design and documentation of that component.

HAB-1150 also provides rules for using single equations and separate equations and how to handle the results obtained from these equations. Depending on the fabricator's practice, production, measurement and test equipment, drawings, and other fabrication documents may be in U.S. Customary, SI, or local customary units. HAB-1150 states that when values are shown in different units, any conversions necessary for verification of ASME Code compliance and to ensure that dimensional consistency is maintained shall be in accordance with the following: (1) conversion factors shall be accurate to at least four significant figures, and (2) the results of conversions of units shall be expressed to a minimum of three significant figures. Further, HAB-1150 states that all entries on a Data Report shall be in units consistent with the fabrication drawings of the component using U.S. Customary, SI, or local customary units.

Subarticle HAB-1150 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subarticle NCA-1150, "Units of Measurement," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subarticle HAB-1150 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subarticle HAB-1150 acceptable.

HAB-1200 General Requirements for Items and Installation

HAB-1210 Graphite Core Assembly

Subarticle HAB-1210 states that a Graphite Core Assembly (GCA) shall require the following documents: (1) Design Specification, (2) Design Report, (3) Data Reports, and (4) other documents as specified in Article HAB-3000, "Responsibilities and Duties."

Subarticle HAB-1210 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subarticle NCA-1210, "Components," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subarticle HAB-1210 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subarticle HAB-1210 acceptable.

HAB-1220 Materials

Subarticle HAB-1220 provides that materials be manufactured in accordance with ASME Code III-5-HAA, Article HHA-2000, "Materials."

Subarticle HAB-1220 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subarticle NCA-1220, "Materials," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subarticle HAB-1220 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subarticle HAB-1220 acceptable.

HAB-1280 Installation

HAB-1281 Activities and Requirements

Paragraph HAB-1281 states that the requirements related to installation, governing, materials, machining, examination, testing, inspection, and reporting shall be in accordance with ASME Code III-5-HAA, and certification shall be as required in ASME Code III-5, Article HAB-8000, “Certificates and Data Reports.”

Paragraph HAB-1281 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-1281, “Activities and Requirements,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-1281 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds HAB-1281 acceptable.

HAB-1283 Services

Paragraph HAB-1283 indicates that installation may be performed by organizations that are not Graphite Core Certificate Holders, as provided for in ASME Code III-5, Paragraph HAB-3125, “Subcontracted Services.”

Paragraph HAB-1283 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-1283, “Services,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-1283 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-1283 acceptable.

3.2.2 Article HAB-2000 Classification of Graphite Core Components

HAB-2100 General Requirements

HAB-2110 Scope

Subsubarticle HAB-2110 indicates that ASME Code III-5-HHA provides the rules for the design and construction of Graphite Core Components (GCCs) and GCAs.

Subarticle HAB-2110 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-2110, “Scope,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-2110 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-2110 acceptable.

HAB-2130 Code Classes and Rules of Division 5

Subsubarticle HAB-2130 states that GCCs shall be assigned to Structural Reliability Classes (SRCs) in the Design Specification in accordance with ASME Code III-5, Paragraph HHA-3111, “Classification of Graphite Core Components.”

Subsubarticle HAB-2130 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-2130, “Classification and Rules of this Section,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-2130 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-2130 acceptable.

HAB-2131 Code Classes and Design Rules for Graphite Core Components

Paragraph HAB-2131 gives the reference to rules for items constructed in accordance with ASME Code III-5-HH and GCCs assigned to SRCs in the Design Specification. Paragraph HAB-2131 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-2131, “Code Classes and Rules of Division 1,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-2131 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-2131 acceptable.

HAB-2140 Design Basis

HAB-2141 Consideration of Plant and System Operating and Test Conditions

Paragraph HAB-2141 has two subparagraphs, (a) and (b). HAB-2141(a) states that the design of the Core Components must consider the system operating and test conditions to which they will be subjected to satisfy the applicable systems’ safety criteria. Paragraph HAB-2141(b) indicates that the definition of plant and system operating and test conditions and the determination of their significance to the design and functionality of Core Components is beyond the scope of this Subpart and Subsection HH, and may be found in the requirements of regulatory and enforcement authorities having jurisdiction at the site.

Paragraph HAB-2141 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-2141, “Consideration of Plant and System Operating and Test Conditions,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-2141 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-2141 acceptable.

HAB-2142 Establishment of Design and Services and Test Loadings and Limits

Paragraph HAB-2142 has subparagraphs (a) and (b). HAB-2142(a) states that the Design and Service Loadings shall be identified considering all plant or system operating and test conditions anticipated for the intended service like the GCA. Paragraph HAB-2141(b) states that the selection of Design and Service Limits for each GCC shall be established in accordance with HAB-2142.4, “Design and Service Limits.” The rules of this Subpart and Subsection HH, Subpart A, do not ensure functionality. When assurance of functionality is necessary, it is the responsibility of the Owner to define the appropriate limiting parameters by referring to documents that specify the necessary functionality.

Paragraph HAB-2142 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-2142, “Establishment of Design and Services and Test Loadings and Limits,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-2142 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-2142 acceptable.

HAB-2142.1 Design Loadings

Subparagraph HAB-2142.1 states that Design Loadings for GCCs and GCAs shall be as defined in ASME Code III-5-HAA, Paragraph HHA-3123, "Design Loadings."

Subparagraph HAB-2142.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-2142.1, "Design Loadings," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-2142.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-2142.1 acceptable.

HAB-2142.2 Service Loadings

Subparagraph HAB-2142.2 states that when the Design Specification or Subsection HH, Subpart A, requires computations to demonstrate compliance with specified Service Limits, the Design Specification shall provide information from which Service Loadings can be identified (pressure, temperature, mechanical loads, cycles, or transients). Subparagraph HAB-2142.2 also states that the Design Specification shall designate the appropriate Service Limit (HAB-2142.4) to be associated with each Service Loading or combination of Service Loadings.

Subparagraph HAB-2142.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-2142.2, "Service Loadings," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-2142.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-2142.2 acceptable.

HAB-2142.4 Design and Service Limits

Subparagraph HAB-2142.4 has three subsubparagraphs, (a), (b), and (c). Subsubparagraph HAB-2142.4(a) states that the limits for Design Loadings shall meet the requirements of ASME Code III-5-HHA. Subsubparagraph HAB-2142.4(b) describes the four Services Limits (A through D) that may be defined in the Design Specification. Subsubparagraph HAB-2142(c) states that GCCs may be designed using more restrictive Service Limits than specified in the Design Specification.

Subparagraph HAB-2142.4 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-2142.4, "Design, Service, and Test Limits," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-2142.4 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds HAB-2142.4 acceptable.

HAB-2143 Acceptance Criteria

Paragraph HAB-2143 has three subparagraphs, (a), (b), and (c). HAB-2143(a) states that the GCCs shall comply with the design rules for Design and Service Loadings identified in Subsection HH, Subpart A. HAB-2143(b) indicates that, if there is a Service Level loading without acceptance criteria in Subsection HH, Subpart A, it is the Owner's responsibility to define such acceptance criteria. HAB-2143(c) states that design documentation shall be completed in accordance with the requirements of ASME Code III-5-HAB and ASME Code III-5-HHA.

Paragraph HAB-2143 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-2143, "Acceptance Criteria," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-2143 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-2143 acceptable.

3.2.3 Article HAB-3000 Responsibilities and Duties

HAB-3100 General

HAB-3110 Responsibilities Versus Legal Liabilities

Subsubarticle HAB-3110 indicates that the parties involved in the design and construction of GCCs and GCAs have specific responsibilities for complying with the ASME Code. Subsubarticle HAB-3110 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3110, "Responsibilities Versus Legal Liabilities," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subarticle HAB-3110 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subarticle HAB-3110 acceptable.

HAB-3120 Certification

HAB-3121 Types of Certificates

Paragraph HAB-3121 states that ASME Code III-5, Table HAB-8100-1, "Certificates Issued by the Society for Construction of Nuclear Graphite Core Components and Assemblies" lists the types of certificates issued by ASME associated with GCCs and GCAs and the responsibilities assumed by each Certificate Holder. Paragraph HAB-3121 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3121, "Types of Certificates," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3121 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3121 acceptable.

HAB-3125 Subcontracted Services

Paragraph HAB-3125 has three subparagraphs, (a), (b), and (c). HAB-3125(a) indicates that services may be subcontracted that are both within and beyond the scope of ASME Code III-5-HAB and ASME Code III-5-HHA. HAB-3125(a) states that subcontracts for activities that require certificates shall only be made to Certificate Holders. HAB-3125(b) indicates that the Designer has the right to subcontract stress analysis or the complete design, or a portion of a GCA or the material testing for generating the Material Data Sheets (MDSs). However, the Designer is responsible for the design of the GCA and for the Design Output Documents. HAB-3125(c) states that the Quality Assurance Manual shall describe the manner in which the Certificate Holder controls and accepts the responsibility for the subcontracted services.

Paragraph HAB-3125 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3125, "Subcontracted Services," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3125 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3125 acceptable.

HAB-3126 Subcontracted Calibration Services

Paragraph HAB-3126 lists the provisions that a GC Certificate Holder, a Graphite Material Organization, or an approved supplier should meet to accept the laboratory accreditation provided by accrediting bodies that are recognized by the International Laboratory Accreditation Cooperation (ILAC) as an alternative to performing a survey and audit of subcontracted calibration services performed by laboratories.

HAB-3126 states, among other things, that the laboratories must be accredited to the 2005 edition of International Organization for Standardization/International Electrotechnical Commission (ISO/IEC) 17025, "General Requirements for the Competence of Testing and Calibration Laboratories." ISO/IEC issued the 2017 edition of ISO/IEC 17025 in November 2017, and all laboratories that provide calibration and testing services are now expected to be accredited to the 2017.

As documented in the NRC staff's SER, dated November 23, 2020 (NRC, 2020b), the NRC staff determined that the ILAC accreditation process is an acceptable alternative to on-site commercial-grade surveys for the commercial-grade dedication of calibration and testing services. (Such surveys are known as "commercial-grade surveys.") The NRC staff's recognition of the ILAC accreditation process allows licensees and suppliers of basic components to take credit for the ILAC accreditation process in lieu of performing an on-site commercial-grade survey as part of the commercial-grade dedication process of calibration and testing services. In its initial recognition of the ILAC accreditation process, the NRC staff determined that as part of the on-site renewal assessments performed by the accrediting bodies, the critical characteristics for calibration and testing services would be verified as part of the on-site renewal assessment. Due to the travel restrictions caused by the COVID-19 pandemic, accrediting bodies are performing remote accreditation assessments. While use of remote accreditation assessments were determined by the nuclear industry to be acceptable during extenuating circumstances, it is necessary to impose a limitation on the use of remote assessment for laboratories performing calibrations and testing for licensees and suppliers of basic components. Accredited calibration or testing services performed on behalf of licensees and suppliers of basic components cannot be accepted from laboratories who have not undergone an on-site accreditation assessment within the past 48 months of the date of services. Such laboratories cannot be used by licensees and suppliers of basic components if their accreditation is based on consecutive remote accreditation assessments. Due to the travel restrictions caused by the COVID-19 pandemic, the NRC approved an overall 25 percent extension (9 months) prior to the end of the 90-day grace period for triennial audits or surveys during periods where performance of such activities is not feasible as a result of extenuating circumstances. With the added assurance that remote renewal accreditations are performed on a 24 month schedule, the NRC staff concluded that the on-site accreditation assessments within 48 months meet the standard for performing commercial-grade surveys as part of the commercial-grade dedication process.

Paragraph HAB-3126 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3126, "Subcontracted Calibration Services," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except Paragraph HAB-3126 omitted several criteria and actions included in NCA-3126 that are needed for the implementation of the ILAC accreditation process. However, the 2019 Edition of the ASME Code III-5, did contain some of these criteria and actions. Therefore, the staff finds HAB-3126 to be acceptable with the following limitations, for consistency with the 2019 Edition of ASME Code III-5 and the staff's SER dated November 23, 2020:

- Accreditation should be in accordance with the 2017 edition of the ISO/IEC 17025, and should be from an accredited body recognized by the ILAC MRA.

- The procurement documents should specify that the service will be provided in accordance with the accredited ISO/IEC 17025 program and scope of accreditation.

- At receipt inspection, the GC Certificate Holder or Graphite Material Organization should be responsible for confirming that the supplier's documentation certifies that the services (subcontracted calibration or testing, as applicable) were performed in accordance with the supplier's ISO/IEC 17025 program and scope of accreditation.

- The laboratory should be accredited based on an on-site accreditation assessment performed by the selected Accrediting Body within the past 48 months. The laboratory's accreditation should not be based on two consecutive remote accreditation assessments.

- The procurement document should also specify that performance of the procured services is contingent on the laboratory's accreditation being achieved through an on-site accreditation assessment by the Accreditation Body within the past 48 months.

HAB-3127 Subcontracted Testing Services

Paragraph HAB-3127 lists the provisions that a GC Certificate Holder, a Graphite Material Organization, or an approved supplier should meet to accept the laboratory accreditation provided by accrediting bodies that are recognized by ILAC as an alternative to performing a survey and audit of subcontracted testing services. Because these are the same provisions as in Paragraph HAB-3126, which the staff accepted on the basis described above, the staff finds Paragraph HAB-3127 to be acceptable with the following limitations:

- Accreditation should be in accordance with the 2017 edition of the International Organization for Standardization (ISO)/ International Electrotechnical Commission (IEC) 17025, "General Requirements for the Competence of Testing and Calibration Laboratories," and should be from an accredited body recognized by the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA).

- The procurement documents should specify that the service will be provided in accordance with the accredited ISO/IEC 17025 program and scope of accreditation.

  At receipt inspection, the GC Certificate Holder or Graphite Material Organization should be responsible for confirming that the supplier's documentation certifies that the services (subcontracted calibration or testing, as applicable) were performed in accordance with the supplier's ISO/IEC 17025 program and scope of accreditation.

- The laboratory should be accredited based on an on-site accreditation assessment performed by the selected Accrediting Body within the past 48 months. The laboratory's accreditation should not be based on two consecutive remote accreditation assessments.

- The procurement document should also specify that performance of the procured services is contingent on the laboratory's accreditation being achieved through an on-site accreditation assessment by the Accreditation Body within the past 48 months.

HAB-3200 Owner's Responsibilities

HAB-3220 Categories of the Owner's Responsibilities

Subparagraphs HAB-3220(a) through (r) list the responsibilities of the Owner. HAB-3220 also states that the activities necessary to provide compliance with responsibilities assigned to the Owner by subparagraphs (e) through (r) may be performed on the Owner's behalf by a designee; however, the responsibility for compliance remains with the Owner. Subsubarticle HAB-3220 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3220, "Categories of the Owner's Responsibilities," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except Subsubarticle HAB-3220 did not include a provision stating that when the Owner assigns any of the responsibilities listed in this section, such assignment shall contain, as a minimum, the name and address of the designee, the responsibilities being assigned, and the applicable nuclear facility or facilities. Therefore, the staff finds Subsubarticle HAB-3220 to be acceptable with the following limitation, for consistency with ASME Code III-NCA, Subsubarticle NCA-3220:

- When using HAB-3220, the applicant or licensee should also apply the following provision from NCA-3220, "When the Owner assigns any of the responsibilities listed in [NCA-3220] (e) through (u) above, such assignment shall contain, as a minimum, the name and address of the designee, the responsibilities being assigned, and the applicable nuclear facility or facilities," replacing the reference to NCA-3220(e) through (u) with HAB-3220(e) through (r).

HAB-3230 Owner's Certificate

Subsubarticle HAB-3230 states that the Owner, after receipt of notification from the regulatory authority that an application for a construction permit or combined license for a specific plant has been docketed, shall obtain an Owner's certificate from ASME for unit(s) docketed concurrently for each site before beginning field installation. The information to be supplied by the Owner when submitting applications is given in forms issued by ASME. ASME Code, Section III, NCA-8130, states that a written agreement with an Authorized Inspection Agency (AIA) is required before application.

Subsubarticle HAB-3230 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3230, "Owner's Certificate," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3230 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3230 acceptable.

HAB-3240 Provisions of Adequate Supporting Structures

Subsubarticle HAB-3240 indicates that it is the responsibility of the Owner to ensure that intervening elements, foundations, and building structures adequate to support the items covered by ASME Code III-5-HAB and ASME Code III-5-HAA are provided and to ensure that jurisdictional boundary interfaces for ASME Code items are defined and compatible. Loads imposed upon structures outside the scope of Subpart B and Subsection HH, Subpart A, by items covered by Subpart B and Subsection HH, Subpart A, shall be defined in the Design Specification.

Subsubarticle HAB-3240 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3240, "Provision of Adequate Supporting Structures," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3240 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3240 acceptable.

HAB-3250 Provision of Design Specifications

HAB-3251 Provision and Correlation

Subsubarticle HAB-3250 indicates that it is the responsibility of the Owner to provide, or cause to be provided, Design Specifications for GCCs and GCAs. HAB-3250 states that the Owner, either directly or through its designee, shall be responsible for the proper correlation of all Design Specifications. HAB-3250 states further that the applicable data from Construction Specification and Design Drawings shall be provided in sufficient documented detail to form the basis for GCC Machining and Installation in accordance with this Subpart and Subsection HH, Subpart A.

Paragraph HAB-3251 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3251, “Provision and Correlation,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3251 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3251 acceptable.

HAB-3252 Contents of Design Specification

Paragraph HAB-3252 calls for the Design Specifications to include detail sufficient to provide a complete basis for a component’s design in accordance with ASME Code III-5-HAB and ASME Code III-5-HAA. Paragraph HAB-3252 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3252, “Contents of Design Specifications,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3252 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3252 acceptable.

HAB-3254 Boundaries of Jurisdiction

Paragraph HAB-3254 has three subparagraphs, (a), (b), and (c). HAB-3254 states that the Design Specifications shall include (a) the locations of each such boundary, (b) the forces, moments, strains, or displacements that are imposed at each such boundary, and (c) the structural characteristics of the attached components or structures, whether or not they are within the jurisdiction of ASME Code III-5-HAB and ASME Code III-5-HAA.

Paragraph HAB-3254 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3254, “Boundaries of Jurisdiction,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3254 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3254 acceptable.

HAB-3255 Certification of the Design Specifications

Paragraph HAB-3255 states that the Design Specifications shall be certified to be correct and complete and to be in compliance with the requirements of Subsubarticle HAB-3250 by one or more Certifying Engineers, competent in the applicable field of design and related nuclear power plant requirements and qualified in accordance with the requirements of Section III Appendices, Mandatory Appendix XXIII. HAB-3255 does not require these Certifying Engineers to be independent of the organization preparing the Design Specifications. Table HAB-3255-1, “Document Distribution for Design and Construction of Graphite Core Components and Assemblies,” shows the document distribution for design and construction.

As discussed under Subsubarticle HAA-1110 above, the NRC determined that the use of a Certifying Engineer does not apply to nuclear facilities regulated by the NRC. Therefore, the staff finds Paragraph HAB-3255 to be acceptable with the following exception:

> The NRC staff does not endorse paragraph XXIII-1223 from Mandatory Appendix XXIII in ASME Code, Section III, “Appendices.” When applying the 2017 and later editions of ASME Code Section III, the NRC does not

endorse applicant and licensee use of a Certifying Engineer who is not a Registered Professional Engineer qualified in accordance with paragraph XXIII-1222 for Code-related activities that are applicable to NRC-regulated facilities.

Table HAB-3255-1, “Document Distribution for Design and Construction of Graphite Core Components and Assemblies,” lists the type of documents (e.g., Design Specification, Construction Specification) and the persons responsible for preparing, reviewing, certifying, and approving, and also for receiving a copy. Table HAB-3255.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Table NCA-3200-1, “Document Distribution for Division 2 Construction,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-3255.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds HAB-3255.1 acceptable.

HAB-3256 Filing of Design Specifications

Paragraph HAB-3256 states that the Design Specifications in their entirety shall become a principal document governing the design and construction of items. HAB-3256 states that a copy of the Design Specification(s) shall be made available to the Authorized Nuclear Inspector (Graphite) at the manufacturing site before construction begins, and a copy shall be filed at the location of the installation and made available to the enforcement authorities having jurisdiction over the plant installation before the GCA is placed in service. Table HAB-3255-1 shows the document distribution for construction.

Paragraph HAB-3256 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3256, “Filing of Design Specifications,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3256 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3256 acceptable.

HAB-3260 Review of Design Report

Subsubarticle HAB-3260 has two subparagraphs, (a) and (b). HAB-3260(a) states that the Owner or designee shall review the Design Report that the Designer provides to determine that all the Design and Service Loadings as stated in the Design Specification have been evaluated and that the acceptance criteria explicitly provided for in Subpart B and Subsection HH, Subpart A, or additional acceptance criteria permitted by Subpart B and Subsection HH, Subpart A, when established in the Design Specification, associated with the specified Design and Service Loadings, have been considered. The responsibility for the method of analysis and the accuracy of the Design Report remains with the Designer.

HAB-3260(b) states that the Owner or designee shall provide Documentation to indicate that the review required by (a) above has been conducted. Before the certification of the component, a copy of this documentation shall be attached to the copy of the Design Report that is made available to the Authorized Nuclear Inspector (Graphite). HAB-3260(b) states that a copy of this documentation shall be included with the Design Report, which is filed at the location of the installation in accordance with HAB-4134.17 and made available to the regulatory and enforcement authorities having jurisdiction at the site of the nuclear power plant installation. Table HAB-3255-1 shows the document distribution for design and construction.

Subsubarticle HAB-3260 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3260, “Review of Design Report,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3260 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3260 acceptable.

HAB-3280 Owner’s Data Report and Filing

Subsubarticle HAB-3280 states that the Owner or designee shall prepare the form N-3 (ASME Code Section III Appendices, Mandatory Appendix V, “Certificate Holder’s Data Report Forms, Instructions, and Application Forms for Certificates of Authorization for Use of Certification Mark”). Subsubarticle HAB-3280 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3280, “Owner’s Data Report and Filing,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3280 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3280 acceptable.

HAB-3290 Owner’s Responsibility for Records

Subsubarticle HAB-3290 states that the Owner shall be responsible for designating the records to be maintained (HAB-4134.17). HAB-3290 states further that the Owner shall also be responsible for continued maintenance of the records required by this Subpart and Subsection HH, Subpart A, and Section XI, at the power plant site, the GC Certificate Holder’s facility, or other locations determined by the Owner. The Owner shall advise the enforcement authority in writing about the location of the records.

Subsubarticle HAB-3290 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3290, “Owner’s Responsibility for Records,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3290 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3290 acceptable.

HAB-3300 Responsibilities of a Designer

HAB-3320 Categories of the Designer’s Responsibility

Subsubarticle HAB-3320 lists the responsibilities of the Designer in (a) through (k). Subsubarticle HAB-3320 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3320, “Categories of the Designer’s Responsibilities,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3320 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3320 acceptable.

HAB-3330 Obtaining a Certificate

Subsubarticle HAB-3330 indicates that a G Certificate[4] (Subarticle HAB-8100, "Authorization to Perform Code Activities") shall be obtained for the design of any GCCs intended to be in compliance with the requirements of ASME Code III-5-HAB and ASME Code III-5-HAA. Subsubarticle HAB-3330 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3530, "Obtaining a Certificate," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3330 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3330 acceptable.

HAB-3340 Design Drawings and Construction Specifications

HAB-3341 Design Drawings

Paragraph HAB-3341 indicates that the Design Drawings shall contain all details necessary to construct the item in accordance with the requirements of the Design Specification, the Construction Specification, and this Subpart and Subsection HH, Subpart A.

Paragraph HAB-3341 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph, NCA-3341, "Design Drawings," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-3341 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3341 acceptable.

HAB-3342 Construction Specification

Paragraph HAB-3342 lists the contents of the Construction Specification in (a) through (k). Paragraph HAB-3342 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3342, "Construction Specification," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3342 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds HAB-3342 acceptable.

HAB-3350 Requirements for Design Output Documents

HAB-3351 General

Paragraph HAB-3351 indicates that the drawings used for construction shall comply with the Design Specifications and the rules of this Subpart and Subsection HH, Subpart A, and shall be in agreement with the other Design Output Documents.

Paragraph HAB-3351 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3551, "General," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions.

[4] Certificate: a Certificate of Authorization, Graphite Quality Systems Certificate (Materials), or Owner's Certificate issued by the Society.

Further, Paragraph HAB-3351 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds HAB-3351 acceptable.

HAB-3352 Design Report

Paragraph HAB-3352 has two subparagraphs, (a) and (b). HAB-3352(a) states that the Designer shall prepare a Design Report in sufficient detail to show that the applicable stress or Probability of Failure (POF) limits are satisfied when the component is subject to the loading conditions specified in the Design Specification and this Subpart and Subsection HH, Subpart A. HAB-3352(a) also indicates that the Design Report prepared by the Designer shall contain calculations and sketches substantiating that the design is in accordance with the Design Specification and this Subpart and Subsection HH, Subpart A.

HAB-3252(b) states that the drawings used for construction shall be in agreement with the Design Report before it is certified and shall be identified and described in the Design Report. It is the responsibility of the Designer to furnish a Design Report for the GCA. HAB-3352(b) also indicates that the Design Report shall be certified by a Certifying Engineer.

As discussed under Subsubarticle HAA-1110 above, the NRC determined that the use of a Certifying Engineer does not apply to U.S. nuclear facilities regulated by the NRC. Therefore, the staff finds Paragraph HAB-3352 to be acceptable with the following exception:

> The NRC staff does not endorse paragraph XXIII-1223 from Mandatory Appendix XXIII in ASME Code, Section III, “Appendices.” When applying the 2017 and later editions of ASME Code Section III, the NRC does not endorse applicant and licensee use of a Certifying Engineer who is not a Registered Professional Engineer qualified in accordance with paragraph XXIII-1222 for Code-related activities that are applicable to NRC-regulated facilities.

HAB-3353 Material Data Sheet

Paragraph HAB-3353 indicates that the Designer shall complete the required testing and generate the MDSs as described in ASME Code III-5, Subarticle HHA-2200, “Material Properties for Design.” HAB-3353 also indicates that the Designer shall certify the MDSs.

The staff finds Paragraph HAB-3353 to be acceptable as written because it contains no technical requirements and is needed to support the provisions of Subarticle HHA-2200, which the NRC staff determined to be acceptable as described in Section 3.24.2 of this NUREG.

HAB-3354 Modification of Documents and Reconciliation with Design Report

Paragraph HAB-3354 indicates that any modification of any document used for construction, as compared to the corresponding document used for design analysis, shall be reconciled with the Design Report by the person or organization responsible for the design. HAB-3354 also indicates that a revision or addendum to the Design Report shall be prepared and (if provided by HAB-3352) certified to indicate the basis on which this has been accomplished. HAB-3354 further indicates that all such revised documentation shall be filed with the completed Design Report.

Paragraph HAB-3354 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3554, "Modification of Documents and Reconciliation With Design Report," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3354 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3354 acceptable.

HAB-3355 Submittal of Design Report for Owner Review

Paragraph HAB-3355 indicates that the Designer shall submit to the Owner or designee a copy of the completed Design Report for all components for review and documentation of review to the extent required by Subsubarticle HAB-3260.

Paragraph HAB-3355 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3556, "Submittal of Design Report for Owner Review," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3355 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3355 acceptable.

HAB-3356 Availability of Design Report

Paragraph HAB-3356 indicates that the Designer shall provide the GC Certificate Holder with a copy of the completed Design Report and the drawings used for construction. These documents are to be available to the Authorized Nuclear Inspector (Graphite).

Paragraph HAB-3356 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3557, "Availability of Design Report," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3356 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3356 acceptable.

HAB-3360 Certification of the Construction Specification, Design Drawings, and Design Report

Subsubarticle HAB-3360 has two subparagraphs, (a) and (b). HAB-3360(a) indicates that the Construction Specification, Design Drawings, and Design Report shall be reviewed and certified to be correct and in accordance with the Design Specification and this Subpart and Subsection HH, Subpart A, by one or more Certifying Engineers competent in the field of design of GCCs and GCAs and qualified in accordance with the requirements of Section III Appendices, Mandatory Appendix XXIII. HAB-3360 does not require these Certifying Engineers to be independent of the organization designing the component. Table HAB-3255-1 shows the distribution of the Construction Specification, Design Drawings, and the Design Report.

HAB-3360(b) indicates that for the Designer to certify the Construction Specification and Design Drawings, the Design Specification must have been certified. HAB-3360 also indicates that for the GC Certificate Holder or Graphite Material Organization to do work in accordance with Construction Specifications and Design Drawings, these documents must have been certified.

As discussed under Subsubarticle HAA-1110 above, the NRC determined that the use of a Certifying Engineer does not apply to U.S. nuclear facilities regulated by the NRC. Therefore, the staff finds Paragraph HAB-3352 to be acceptable with the following exception:

> The NRC staff does not endorse paragraph XXIII-1223 from Mandatory Appendix XXIII in ASME Code, Section III, "Appendices." When applying the 2017 and later editions of ASME Code Section III, the NRC does not endorse applicant and licensee use of a Certifying Engineer who is not a Registered Professional Engineer qualified in accordance with paragraph XXIII-1222 for Code-related activities that are applicable to NRC-regulated facilities.

HAB-3370 Revision of Design Drawings and Construction Specification

Subsubarticle HAB-3370 indicates that Design Documents issued for use in construction shall be revised to reflect any change in the design. HAB-3370 also indicates that changes to Design Output Documents shall be reviewed and certified in accordance with HAB-3350.

Subsubarticle HAB-3370 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3370, "Revision of Design Drawings and Construction Specification," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3370 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3370 acceptable.

HAB-3380 Certification of Construction Report

Subsubarticle HAB-3380 indicates that the Construction Report shall be evaluated by the Designer, who shall certify that the Construction Report conforms to the requirements of ASME Code III-5-HAB and ASME Code III-5-HAA, and the Design Specification. HAB-3380 also indicates the following. The Designer shall also provide any supplemental analysis needed to substantiate this evaluation. Before certification, he or she shall review the file of as-built, design, shop, and field drawings to establish that the list in the Construction Report provided by the GC Certificate Holder corresponds to the as-built, design, shop, and field drawings that will be maintained as a file by the Owner. Table HAB-3255-1 shows the distribution of the Construction Report.

Subsubarticle HAB-3380 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3380, "Certification of Construction Report," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3380 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3380 acceptable.

HAB-3400 Responsibilities of a GC Certificate Holder

HAB-3420 Categories of the GC Certificate Holder's Responsibilities

Subparagraphs HAB-3420(a) through (r) list the responsibilities of the GC Certificate Holder. Subsubarticle HAB-3420 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3520, “Categories of the N Certificate Holder’s Responsibilities,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3420 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3420 acceptable.

HAB-3430 Obtaining a Certificate

Subsubarticle HAB-3430 indicates that a GC Certificate (HAB-8100) shall be obtained for the construction of any GCCs or GCAs intended to be in compliance with the requirements of ASME Code III-5-HAB and ASME Code III-5-HAA.

Subsubarticle HAB-3430 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3530, “Obtaining a Certificate,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3430 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3430 acceptable.

HAB-3440 Compliance with This Subpart and Subsection HH, Subpart A

Subsubarticle HAB-3440 indicates that the GC Certificate Holder’s responsibility for the construction of the GCCs or GCAs in accordance with both the Design Drawings and Construction Specification and with ASME Code III-5-HAB and ASME Code III-5-HAA.

Subsubarticle HAB-3440 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3540, “Compliance with this Section,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3440 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3440 acceptable.

HAB-3450 Construction Documents

HAB-3451 Construction Procedures

Paragraph HAB-3451 indicates that construction procedures shall provide sufficient detailed information about the methods of construction to enable those reviewing the procedures to determine whether the requirements of the Design Specification, the Construction Specification, and the Design Drawings will be satisfied. HAB-3451 also indicates that construction procedures shall include test procedures to be performed by the GC Certificate Holder that are needed to establish conformance with the requirements of the documents listed in Article HAB. Table HAB-3255-1 shows the distribution of procedures.

Paragraph HAB-3451 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3451, “Construction Procedures,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3451 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3451 acceptable.

HAB-3452 Shop and Field Drawings

Paragraph HAB-3452 indicates that the GC Certificate Holder shall provide shop and field drawings. Table HAB-3255-1 shows the distribution of shop and field drawings.

Paragraph HAB-3452 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3452, "Shop and Field Drawings," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3452 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3452 acceptable.

HAB-3453 Material Documentation

Paragraph HAB-3453 indicates that the GC Certificate Holder shall collect certified material test reports (CMTRs) to verify that materials comply with the Construction Specification and the requirements of ASME Code III-5-HAB and ASME Code III-5-HAA. Paragraph HAB-3453 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3453, "Material Documentation," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3453 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3453 acceptable.

HAB-3454 Contents of Construction Report

Subparagraphs HAB-3454(a) through (g) list the contents of the Construction Report. Paragraph HAB-3454 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3454, "Contents of the Construction Report," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3454 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3454 acceptable.

HAB-3455 Data Report

Paragraph HAB-3455 indicates that the GC Certificate Holder shall certify compliance with ASME Code III-5-HAB and ASME Code III-5-HAA by signing the appropriate Data Report (Article HAB-8000). Paragraph HAB-3455 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3455, "Data Report," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3455 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3455 acceptable.

HAB-3460 Responsibility for Quality Assurance

HAB-3461 Scope of Responsibilities for Quality Assurance

Paragraph HAB-3461 has two subparagraphs, (a) and (b). HAB-3461(a) indicates that the GC Certificate Holder shall be responsible for surveying, qualifying, and auditing suppliers of subcontracted services (HAB-3125), including nondestructive examination (NDE) contractors and Graphite Material Organizations. Graphite Material Organizations holding a Graphite Quality Systems Certificate (Materials) and GC Certificate Holders whose scope includes supply or manufacture and supply of material need not be surveyed or audited for work or material covered by the scope of their certificate. Subcontractors holding an appropriate certificate need not be surveyed nor audited for work within the scope of the subcontractor's certificate.

HAB-3461(b) indicates that a GC Certificate Holder may qualify vendors of subcontracted services (HAB-3125) other than those requiring a Certificate of Authorization, such as a Graphite Material Organization, for another GC Certificate Holder doing work for that GC Certificate Holder. HAB-3461(b) also indicates that the qualification documentation shall be supplied to the other GC Certificate Holder before the use of the subcontracted service or Graphite Material Organization.

Paragraph HAB-3461 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3461, "Scope of Responsibilities for Quality Assurance," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3461 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3461 acceptable.

HAB-3462 Documentation of Quality Assurance Program

Paragraph HAB-3462 indicates that the GC Certificate Holder shall be responsible for documenting its Quality Assurance Program (ASME Code III-5, Paragraph HAB-4134, "GC Certificate Holders").

Paragraph HAB-3462 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3462, "Documentation of Quality Assurance Program," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3462 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3462 acceptable.

HAB-3463 Filing of Quality Assurance Manual

Paragraph HAB-3463 indicates that the GC Certificate Holder shall file with the AIA (ASME Code III-5, Paragraph HAB-5121, "Authorized Inspection Agency") copies of the Quality Assurance Manual. HAB-3463 also indicates that the GC Certificate Holder shall keep a copy on file available to the Authorized Nuclear Inspector (Graphite) (ASME Code III-5, Paragraph HAB-5123, "Authorized Nuclear Inspector [Graphite]").

Paragraph HAB-3463 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3463, "Filing of Quality Assurance Manual,' which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3463 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3463 acceptable.

HAB-3800 Graphite Material Organization's Quality System Program

Subarticle HAB-3800 introduces the provisions of a Graphite Material Organization's Quality System Program.

Subarticle HAB-3800 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subarticle NCA-3800, "Metallic Material Organization's Quality System Program," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subarticle HAB-3800 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subarticle HAB-3800 acceptable.

HAB-3820 Certification or Qualification of Graphite Material Organizations

Subsubarticle HAB-3820 has three subparagraphs, (a), (b), and (c). HAB-3820(a) indicates that a Graphite Material Organization shall be certified by obtaining a Graphite Quality Systems Certificate issued by ASME verifying the adequacy of the Graphite Material Organization's Quality System Program. HAB-3820(b) indicates that, alternatively, the GC Certificate Holder (HAB-3461) may qualify a Graphite Material Organization not certified by ASME by evaluating the organization's Quality System Program in accordance with the requirements of HAB-3842. HAB-3820(c) indicates that a GC Certificate Holder may furnish material, machine GCCs, or perform installation when stated in the scope of its certificate. In this case, a Graphite Quality Systems Certificate is not required, nor is the user of the material, GCCs, or installation services required to survey, qualify, or audit such a GC Certificate Holder.

Subsubarticle HAB-3820 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3820, "Certification or Qualification of Material Organizations," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3820 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3820 acceptable.

HAB-3830 Responsibilities of Graphite Material Organizations

Subparagraphs HAB-3830(a) through (h) list the responsibilities of Graphite Material Organizations.

Subsubarticle HAB-3830 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subsubarticle NCA-3830, "Responsibilities of Material Organizations," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subsubarticle HAB-3830 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subsubarticle HAB-3830 acceptable.

HAB-3840 Evaluation of the Program

HAB-3841 Evaluation by the Society

Paragraph HAB-3841 lists the responsibilities of ASME for the evaluation of a Graphite Material Organization's Quality System Program.

Paragraph HAB-3841 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-3841, “Evaluation by the Society,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-3841 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-3841 acceptable.

HAB-3842 Evaluation by Parties Other Than the Society

HAB-3842.1 Qualification of Graphite Material Organizations

Subparagraph HAB-3842.1 has two subsubparagraphs, (a) and (b). HAB-3842.1(a) indicates that the qualification of Graphite Material Organizations by parties other than ASME shall be limited to the manufacture of material, machining of GCCs, and the installation of GCAs, or subcontracted services to the GC Certificate Holder performing the evaluation, or their designee. HAB-3842.1(b) indicates that when a GC Certificate Holder has qualified a Graphite Material Organization, it is not necessary for another party to requalify that organization for materials or services to be furnished to the party that performed the evaluation.

Subparagraph HAB-3842.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-3842.1, “Qualification of Material Organizations,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3842.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3842.1 acceptable.

HAB-3842.2 Evaluation of the Qualified Material Organization’s Program by GC Certificate Holders

Subsubparagraphs HAB-3842.2(a) through (g) list provisions for the evaluation of a Graphite Material Organization’s Quality System Program by a GC Certificate Holder. Subparagraph HAB-3842.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-3842.2, “Evaluation of the Qualified Material Organization’s Program by Certified Material Organizations or Certificate Holders,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except Subparagraph HAB-3842.2 did not include several provisions in NCA-3842.2 regarding the frequency of the audits.

Therefore, the staff finds Subparagraph HAB-3842.2 to be acceptable with the following limitation:

> When using HAB-3842.2(g), the applicant or licensee should also apply the provisions from NCA-3842.2(h) and NCA-3842.2(i), replacing the references to NCA 4259.1(a) through (c) with HAB-3859.1(a) through (e) and references to Material Organization with Graphite Material Organization.

HAB-3850 Quality System Program Requirements

HAB-3851 Responsibility and Organization

HAB-3851.1 General

Subparagraph HAB-3851.1 has two subsubparagraphs, (a) and (b). HAB-3851.1(a) indicates that the Graphite Material Organization shall establish a Quality System Program to control quality during manufacture or during other work it proposes to perform, and to trace material under its control. HAB-3851.1(a) also indicates that the Program shall be planned, documented, implemented, and maintained in accordance with the requirements of Subsubarticle HAB-3850. HAB-3851.1(b) indicates that the Program shall include consideration of the technical aspects and provide for planning and accomplishment of activities affecting quality. HAB-3851.1(b) also indicates that the Program shall provide for any special controls, processes, test equipment, tools, and skills to attain the required quality and to verify quality.

Subparagraph HAB-3851.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-4251.1, “General,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3851.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3851.1 acceptable.

HAB-3851.2 Scope and Applicability

Subparagraph HAB-3851.2 has two subparagraphs, (a) and (b). HAB-3851.2(a) indicates that the Quality System Manual shall define the specific activities included in the scope of the work the Graphite Material Organization proposes to perform. In turn, HAB-3851.2 lists these activities (1) through (6). HAB-3851.2(b) indicates that the Program shall include measures to comply with all requirements of subarticle HAB-3800, to the extent necessary to ensure compliance with the requirements of Subpart B and Subsection HH, Subpart A.

Subparagraph HAB-3851.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-4251.2, “Scope and Applicability,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3851.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3851.2 acceptable.

HAB-3851.3 Organization

Subparagraph HAB-3851.3 has five subsubparagraphs, (a) through (e). These subsubparagraphs describe provisions for organizing the Graphite Material Organization.

Subparagraph HAB-3851.3 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-4251.3, “Organization,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3851.3 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3851.3 acceptable.

HAB-3852 Personnel

HAB-3852.1 Indoctrination, Training, and Qualification of Personnel

Subparagraph HAB-3852.1 has three subsubparagraphs, (a), (b), and (c). These three subsubparagraphs describe generic provisions for the training and qualification of personnel.

Subparagraph HAB-3852.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-4252.1, “Indoctrination, Training, and Qualification of Personnel,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3852.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3852.1 acceptable.

HAB-3852.2 Personnel Records

Subparagraph HAB-3852.2 has three subsubparagraphs, (a), (b), and (c). These three subsubparagraphs describe provisions for training and qualification records.

Subparagraph HAB-3852.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-4252.2, “Personnel Records,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3852.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3852.2 acceptable.

HAB-3853 Program Documentation

HAB-3853.1 Quality System Manual

Subparagraph HAB-3853.1 has three subsubparagraphs, (a), (b), and (c). These three subsubparagraphs describe provisions for documenting the Quality Systems Manual. Subparagraph HAB-3853.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-4253.1, “Quality System Manual,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except Subparagraph HAB-3853.1 did not include additional provisions in NCA-4253.1 for documenting the Quality Systems Manual. Therefore, the staff finds Subparagraph HAB-3853.1 to be acceptable with the following limitation:

> When using HAB-3853.1, the applicant or licensee should also apply NCA-4253.1(d), replacing the reference to Material Organization with Graphite Material Organization.

HAB-3853.2 Procedures, Instructions, and Drawings

Subparagrah HAB-3853.2 has two subsubparagraphs, (a) and (b). HAB-3853.2(a) indicates that activities affecting quality shall be prescribed by and performed in accordance with documented instructions, procedures, or drawings of a type appropriate to the circumstances. HAB-3853.2(b) indicates that these documents shall include or reference appropriate acceptance criteria for determining that the prescribed activities have been satisfactorily completed.

Subparagraph HAB-3853.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4253.2, “Procedures, Instructions, and Drawings,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-3853.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3853.2 acceptable.

HAB-3853.3 Document Control

Subparagraph HAB-3853.3 indicates that the preparation, issue, and change of documents that specify quality requirements or prescribe activities affecting quality, such as Quality System Program Manuals, purchase specifications, instructions, procedures, and drawings, shall be controlled to ensure that the correct documents are being used at the location where the activity is performed. HAB-3853.3 also indicates that such documents, including changes thereto, shall be reviewed for adequacy and approved for release by authorized personnel.

Subparagraph HAB-3853.3 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4253.3, “Document Control,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-3853.3 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3853.3 acceptable.

HAB-3853.4 Quality Assurance Records

Subparagraph HAB-3853.4 indicates that records that furnish documentary evidence of quality shall be specified, prepared, controlled, and maintained. HAB-3853.4 also indicates that records shall be legible, identifiable, and retrievable and shall be protected against damage, deterioration, or loss. HAB-3853.4 indicates further that requirements and responsibilities for record transmittal, distribution, retention, maintenance, and disposition shall be established and documented.

Subparagraph HAB-3853.4 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4253.4, “Quality Assurance Records,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-3853.4 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3853.4 acceptable.

HAB-3853.5 Records of Examinations and Tests

Subparagraph HAB-3853.5 indicates that all characteristics required to be reported by the material specification and this Subpart and Subsection HH, Subpart A, shall be verified and the results recorded. HAB-3853.5 also indicates that records shall be traceable to the document and revision to which an inspection, examination, or test was performed.

Subparagraph HAB-3853.5 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4253.5, “Records of Examinations and Tests,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-3853.5 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3853.5 acceptable.

HAB-3855 Control of Purchased Materials and Services

HAB-3855.1 General

HAB-3855.1 has two subsubparagraphs, (a) and (b). HAB-3855.1(a) indicates that measures shall be established to ensure that all purchased material and subcontracted services conform to the requirements of this Subpart and Subsection HH, Subpart A. HAB-3855.1(b) also indicates that these measures shall be designed to prevent the use of incorrect or defective material or materials that have not received the required examinations or tests.

Subparagraph HAB-3855.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4255.1, “General,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3855.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3855.1 acceptable.

HAB-3855.2 Sources of Materials and Services

HAB-3855.2 has four subsubparagraphs, (a), (b), (c), and (d). These four subsubparagraphs describe the provisions for furnishing material, machining services, installation, and other services, such as tests and examinations.

Subparagraph HAB-3855.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4255.2, “Sources of Materials and Services,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-3855.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3855.2 acceptable.

HAB-3855.3 Approval and Control of Suppliers of Subcontracted Services

Subparagraph HAB-3855.3 has five subsubparagraphs, (a), (b), (c), (d) and (e). These five subparagraphs describe the provisions the Graphite Material Organization or the GC Certificate Holder, or both, use for approving and controlling their suppliers of subcontracted services, including suppliers of calibration and testing services. Subparagraph HAB-3855.3 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-4255.3, “Approval and Control of Suppliers of Subcontracted Services,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except Subparagraph HAB-3855.3 did not include the paragraph in NCA-4255.3(b) regarding the responsibilities of the Material Organization or the Certificate Holder. Therefore, the staff finds Subparagraph HAB-3855.3 to be acceptable with the following limitation:

- When using HAB-3855.3(b), the applicant or licensee should also apply NCA-4255.3(b), replacing the reference to Material Organization with Graphite Material Organization and the reference to Certificate Holder to GC Certificate Holder.

In addition, Subparagraph HAB-3855.3 states the same provisions stated in HAB-3126 and HAB-3127, which the NRC staff accepted for the reasons stated in the evaluation of HAB-3126 above, and based on limitations stated there. Accordingly, the staff finds HAB-3855.3 to be acceptable with the following limitations:

- Accreditation should be in accordance with the 2017 edition of the ISO/IEC 17025, and should be from an accredited body recognized by the ILAC MRA.

- The procurement documents should specify that the service will be provided in accordance with the accredited ISO/IEC 17025 program and scope of accreditation.

- At receipt inspection, the GC Certificate Holder or Graphite Material Organization should be responsible for confirming that the supplier's documentation certifies that the services (subcontracted calibration or testing, as applicable) were performed in accordance with the supplier's ISO/IEC 17025 program and scope of accreditation.

- The laboratory should be accredited based on an on-site accreditation assessment performed by the selected Accrediting Body within the past 48 months. The laboratory's accreditation should not be based on two consecutive remote accreditation assessments.

- The procurement document should also specify that performance of the procured services is contingent on the laboratory's accreditation being achieved through an on-site accreditation assessment by the Accreditation Body within the past 48 months.

HAB-3855.4 Procurement Document Control

Subparagraph HAB-3855.4 has four subsubparagraphs, (a), (b), (c), and (d). These four subsubparagraphs describe provisions for the procurement documents issued by the Graphite Material Organization.

Subparagraph HAB-3855.4 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4255.4, "Procurement Document Control," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-3855.4 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3855.4 acceptable.

HAB-3856 Identification, Marking, and Material Control

HAB-3856.1 General

Subparagraph HAB-3856.1 has three subsubparagraphs, (a), (b), and (c). HAB-3856.1(a) indicates that Control shall be established to ensure that only correct and accepted material is used. HAB-3856.1(a) also indicates that identification shall be maintained on these materials or on documents traceable to these materials, or in a manner that ensures the identification is established and maintained. HAB--3856.1(b) indicates that measures shall be designated for controlling and identifying material, including that material which is partially processed, throughout the manufacturing process; during the performance of tests, examinations, and treatments; and during receipt, storage, handling, and shipment. HAB-3856.1(c) indicates that Identification marking shall be transferred to all pieces when material is divided.

Subparagraph HAB-3856.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4256.1, "General," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3856.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3856.1 acceptable.

HAB-3856.2 Marking Method

Subparagraph HAB-3856.2 indicates that materials shall be marked by any method acceptable to the purchaser that will not result in harmful contamination or sharp discontinuities and will identify these materials in accordance with the material specification.

HAB-3856.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4256.2, "Marking Method," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3856.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3856.2 acceptable.

HAB-3856.3 Identification of Completed Material

Subparagraph HAB-3856.3 has five subsubparagraphs, (a), (b), (c), (d), and (e). These five subsubparagraphs describe the provisions for the identification of completed material, including machined GCCs by the GCC Manufacturer.

Subparagraph HAB-3856.3 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4256.3, "Identification of Completed Material," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3856.3 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3856.3 acceptable.

HAB-3857 Process Control

HAB-3857.1 General

Subparagraph HAB-3857.1 indicates that processes affecting the quality of materials or services shall be controlled. HAB-3857.1 also indicates that special processes that control or verify quality shall be performed by qualified personnel using qualified procedures in accordance with specific requirements, as applicable.

Subparagraph HAB-3857.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4257.1, "General," which the

NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3857.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3857.1 acceptable.

HAB-3857.2 Manufacturing Process Control

Subparagraph HAB-3857.2 indicates that operations shall be performed under a controlled system, such as process sheets, shop procedures, checklists, travelers, or equivalent procedures. HAB-3857.2 also indicates that measures shall be established to ensure that processes are controlled in accordance with the material specification and the rules of this Subpart and Subsection HH, Subpart A.

Subparagraph HAB-3857.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4257.2, “Manufacturing Process Control,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3857.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3857.2 acceptable.

HAB-3857.4 Handling, Storage, Shipping, and Preservation

Subparagraph HAB-3857.4 indicates that instructions shall be in place for handling, storage, shipping, and preservation of material to prevent damage or deterioration.

Subparagraph HAB-3857.4 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4257.4, “Handling, Storage, Shipping, and Preservation,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3857.4 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3857.4 acceptable.

HAB-3858 Control of Examinations, Tests, and Nonconforming Material

HAB-3858.1 Inspection, Examination, and Test Control

HAB-3858.1 has three subsubparagraphs, (a), (b), and (c). HAB-3858.1(a) indicates that inspections, examinations, and tests shall be created to ensure conformance with the requirements of the material specification and this Subpart and Subsection HH, Subpart A. HAB-3858.1(b) indicates that inspections or examinations necessary to verify conformance of material or an activity to specified Code provisions shall be planned. HAB-3858.1(b) also indicates that characteristics to be inspected or examined, and inspection or examination methods to be employed, shall be specified. HAB-3858.1(b) indicates further that inspection or examination results shall be documented. HAB-3858.1(c) indicates that tests necessary to verify conformance to specified Code provisions shall be planned. HAB-3858.1(c) also indicates that characteristics to be tested and test methods to be employed shall be specified and that test results shall be documented, and their conformance with acceptance criteria shall be evaluated.

HAB-3858.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4258.1, “Inspection, Examination, and Test Control,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-3858.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3858.1 acceptable.

HAB-3858.2 Control of Measuring and Test Equipment

Subparagraph HAB-3858.2 has three subsubparagraphs, (a), (b), and (c). HAB-3858.2(a) indicates that procedures shall be in effect to ensure that tools, gages, instruments, and other measuring and testing devices used to verify compliance with the material specification and this Subpart and Subsection HH, Subpart A, are calibrated and properly adjusted at specific periods or use intervals to maintain accuracy within necessary limits. Periodic checks on equipment may be performed to determine that calibration is maintained. HAB-3858.2(b) indicates that calibration shall be against certified equipment having known valid relationships and documented traceability to nationally recognized standards, where such standards exist. HAB-3858.2(b) also indicates that if no known nationally recognized standards exist, the basis for calibration shall be documented. HAB-3858.2(c) indicates that control measures shall include provisions for measuring and test equipment identification and for determining calibration status by equipment marking or on records traceable to the equipment.

HAB-3858.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4258.2, “Control of Measuring and Test Equipment,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3858.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3858.2 acceptable.

HAB-3858.3 Discrepancies in Measuring or Testing Equipment

Subparagraph HAB-3858.3 has two subsubparagraphs, (a) and (b). HAB-3858.3(a) indicates that when discrepancies in excess of tolerances for measuring or testing equipment are found at calibration, appropriate corrective action shall be taken, and material measured or tested since the previous calibration shall be reviewed to determine that all applicable requirements have been met. HAB-3858.3(b) indicates that, when periodic checks on equipment are performed to determine that calibration is maintained, potential material discrepancies need only be resolved to the previous check, provided (1) calibration procedures describe the methods used and frequency of periodic checking, and (2) the calibration discrepancy was found by a periodic check.

Subparagraph HAB-3858.3 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4258.3, “Discrepancies in Measuring or Testing Equipment,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3858.3 does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3858.3 acceptable.

HAB-3858.4 Inspection and Test Status

Subparagraph HAB-3858.4 indicates that measures shall be undertaken so that the status and results of any necessary inspections, examinations, or tests can be determined at any time. HAB-3858.4 also indicates that status shall be maintained through indicators such as physical location and tags, marking, shop travelers, stamps, inspection records, or other suitable means and that the authority for application and removal of such indicators shall be specified.

Subparagraph HAB-3858.4 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4258.4, “Inspection and Test Status,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3858.4 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3858.4 acceptable.

HAB-3858.5 Control of Nonconforming Material

Subparagraph HAB-3858.5 has three subsubparagraphs, (a), (b), and (c). HAB-3858.5(a) indicates that adequate control measures shall prevent the use of material that does not conform to the material specification, Subpart B, and Subsection HH, Subpart A. HAB-3858.5(b) indicates that material with nonconformances shall be identified, segregated when practical, and reviewed for acceptance or rejection in accordance with documented procedures. HAB-3858.5(b) also indicates that the responsibility and authority for the disposition of nonconformances in these materials shall be defined. HAB-3858.5(c) indicates that measures that control further processing of nonconforming or defective material pending a decision on its disposition shall be developed and maintained and that these control measures shall extend to notification of other affected organizations, as appropriate.

Subparagraph HAB-3858.5 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4258.5, “Control of Nonconforming Material,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3858.5 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3858.5 acceptable.

HAB-3859 Audits and Corrective Action

HAB-3859.1 Audits

Subparagraph HAB-3859.1 has five subsubparagraphs, (a), (b), (c), (d), and (e). These subsubparagraphs describe provisions for conducting internal and external audits.

Subparagraph HAB-3859.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4259.1, “Audits,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3859.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3859.1 acceptable.

HAB-3859.2 Corrective Action

Subparagraph HAB-3859.2 has three subsubparagraphs, (a), (b), and (c). HAB-3859.2(a) indicates that measures shall be taken to ensure that conditions adverse to quality, such as failures, malfunctions, deviations, defective material and equipment, nonconformances, and quality system deficiencies, are promptly identified and reported to appropriate levels of management. HAB-3859.2(a) also indicates that these measures shall also ensure that the cause of conditions adverse to established quality levels are determined and corrected. HAB-3859.2(b) indicates that the identification of significant or recurring conditions adverse to quality, the cause of the condition, and the corrective action taken shall be documented and reported to appropriate levels of management. HAB-3859.2(c) indicates that these Code provisions shall also extend to the performance of the approved supplier's corrective action measures.

Subparagraph HAB-3859.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4259.2, "Corrective Action," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-3859.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3859.2 acceptable.

HAB-3860 Certification Requirements

HAB-3861 Certification Requirements for Graphite Material Organizations

Subparagraph HAB-3861 has three subsubparagraphs, (a), (b), and (c). HAB-3861(a) indicates that the Graphite Material Organization whose scope of activities includes Material Manufacture (HAB-3830(a)) shall provide a Certified Material Test Report (HAB-3862) for the material. HAB-3861(b) indicates that the Graphite Material Organization shall transmit all certifications called for by HAB-3862.1(b), received from other Graphite Material Organizations or approved suppliers in accordance with (a) above, to the purchaser at the time of shipment. HAB-3861(c) indicates that GC Certificate Holder shall complete all operations not completed by the Graphite Material Organization and shall provide a CMTR for all operations performed by it or its approved suppliers. HAB-3861(c) also indicates that the GC Certificate Holder shall certify that the contents of the report are correct and accurate and that all test results and operations performed by the GC Certificate Holder or approved suppliers are in compliance with the provisions of the material specification, Subpart B, and Subsection HH, Subpart A. HAB-3861(c) also states an alternative for the GC Certificate Holder to provide a CMTR for the operations it performed and at least one CMTR from each of its approved suppliers for the operations each supplier performed.

Subparagraph HAB-3861 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-3861, "Certification Requirements for Material Organizations," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3861 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3861 acceptable.

HAB-3862 Certification of Material

HAB-3862.1 Material Certification

Subparagraph HAB-3862.1 has six subsubparagraphs, (a), (b), (c), (d), (e), and (f). These six subsubparagraphs describe the provisions for material certification and use of the CMTR.

Subparagraph HAB-3862.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-3862.1, "Material Certification," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3862.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3862.1 acceptable.

HAB-3862.2 Quality System Program Statement

Subparagraph HAB-3862.2 has three subsubparagraphs, (a), (b), and (c). HAB-3862.2(a) indicates that, when the Graphite Material Organization holds a Graphite Quality Systems Certificate, the certificate number and expiration date shall be shown on the CMTR or on a certification included with the documentation that accompanies the material. HAB-3862.2(b) indicates that, when the Graphite Material Organization has been qualified by a party other than ASME, the revision and date of the applicable written Quality System Program shall be shown on the CMTR or on a certification included with the documentation that accompanies the material. HAB-3862.2(c) indicates that the inclusion of the Graphite Quality Systems Certificate number and expiration date or reference to the revision and date of the applicable written Quality System Program shall be considered the Graphite Material Organization’s certification that all activities have been performed in accordance with the applicable provisions of this subarticle.

Subparagraph HAB-3862.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-3862.2, “Quality System Program Statement,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-3862.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-3862.2 acceptable.

3.2.4 Article HAB-4000 Quality Assurance

HAB-4100 Requirements

HAB-4110 Scope and Applicability

Paragraph HAB-4110 has two subparagraphs, - (a) and (b). HAB-4110(a) states that this Article provides the requirements for planning, managing, and conducting Quality Assurance Programs for controlling the quality of activities performed under this Subpart and Subsection HH, Subpart A, and the rules governing the evaluation of such programs before the issuance of certificates for the design and construction of the GCA. HAB-4110(b) states that the GC Certificate Holders shall comply with the requirements of ASME NQA-1, Part I, as modified and supplemented by HAB-4120(d) and HAB-4134.

Paragraph HAB-4110 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-4110, “Scope and Applicability,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-4110 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-4110 acceptable.

HAB-4120 Definitions

Paragraph HAB-4120 has four subparagraphs, (a), (b), (c), and (d). These subparagraphs indicate that the definitions in Article HAB-9000 apply; definitions in Article NCA-9000 apply unless defined in Article HAB-9000; the terms and definitions in NQA-1 apply unless defined in Article HAB-9000 or NCA-9000; and for a list of terms defined in NQA-1, NCA-9000, and HAB-9000, the definitions in NCA-9000 and HAB-9000 shall apply.

Paragraph HAB-4120 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-4120, "Definitions," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-4120 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-4120 acceptable.

HAB-4130 Establishment and Implementation

HAB-4131 Graphite Material Organizations

Paragraph HAB-4131 states that the requirements of HAB-3800 apply.

HAB-4131 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-4131, "Material Organizations, Division 1," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-4131 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds HAB-4131 acceptable.

In addition, the NRC staff notes that Article HAB-4000 omits a paragraph related to the Owner's Quality Assurance Program that is included in NCA-4133, "Owner's Quality Assurance Program," from the 2017 Edition of ASME Code III-1, which was incorporated by reference in 10 CFR 50.55a. Therefore, the staff finds Article HAB-4000 to be acceptable with the following limitation:

> When using HAB-4000, the applicant or licensee should also apply NCA-4133, replacing the reference to Material Organization with Graphite Material Organization, the reference to N type Certificate Holder with GC Certificate Holder, and the reference to Quality System Certificate with Graphite Quality System Certificate.

HAB-4134 GC Certificate Holders

HAB-4134.1 Organization

Subparagraph HAB-4134.1 states that the provisions of NQA-1, Requirement 1, apply.

Subparagraph HAB-4134.1 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4131.1, "Organization," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.1 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.1 acceptable.

HAB-4134.2 Quality Assurance Program

Subparagraph HAB-4134.2 has four subsubparagraphs, (a), (b), (c), and (d). HAB--4134.2(a) states that the provisions of NQA-1, Requirement 2, apply. It further states that the Quality Assurance Manual shall also include a statement of policy and authority indicating management support and the review of written procedures and monitoring of the activities related to the Quality Assurance Program.

HAB-4134.2(b) states that in lieu of Requirement 2, paragraph 301, all NDE personnel shall be qualified on the basis of education, experience, training, and examination in accordance with of HHA-5220.

HAB-4134.2(c) states, in part, that the controls used in the Quality Assurance Program shall be documented in the Quality Assurance Manual. It also describes the provisions for making copies of the Quality Assurance Manual, as well as drawings and process sheets, available to the Authorized Nuclear Inspector (Graphite).

HAB-4134.2(d) indicates that the GC Certificate Holder shall be responsible for advising its AIA of any proposed changes to the Quality Assurance Manual, as well as for gaining acceptance of the Authorized Nuclear Inspector Supervisor (Graphite) before the changes are implemented.

Subparagraph HAB-4134.2 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.2, "Quality Assurance Program," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.2 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.2 acceptable.

HAB-4134.3 Design Control

Subparagraph HAB-4134.3 has four subsubparagraphs, (a), (b), (c), and (d). HAB--4134.3(a) states that the provisions of NQA-1, Requirement 3, shall apply except that provisions for welding and brazing are not applicable to graphite. HAB-4134.3(b) states that measures shall be established to ensure that applicable provisions of the Design Specifications, Subpart B, and Subsection HH, Subpart A, for items are correctly translated into specifications, drawings, procedures, and instructions.

HAB-4134.3(c) and HAB-4134.1(d) state that design documents shall be verified for adequacy and compliance with the Design Specification, this Subpart, and Subsection HH, Subpart A, and that paragraph 601 of NQA-1, "Configuration Management of Operating Facilities," is not applicable, respectively.

Subparagraph HAB-4134.3 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.3, "Design Control," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.3 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.3 acceptable.

HAB-4134.4 Procurement Document Control

Subparagraph HAB-4134.4 states that the provisions of NQA-1, Requirement 4, shall apply, except that procurement documents shall obligate suppliers to provide a Quality Assurance Program consistent with the applicable provisions of this Subpart and Subsection HH, Subpart A.

Subparagraph HAB-4134.4 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.4, "Procurement Document Control," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-4134.4 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds HAB-4134.4 acceptable.

HAB-4134.5 Instructions, Procedures, and Drawings

Subparagraph HAB-4134.5 states that the provisions of NQA-1, Requirement 5, shall apply.

Subparagraph HAB-4134.5 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.5, "Instructions, Procedures, and Drawings," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.5 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.5 acceptable.

HAB-4134.6 Document Control

Subparagraph HAB-4134.6 states that the provisions of NQA-1, Requirement 6, shall apply.

Subparagraph HAB-4134.6 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.6, "Document Control," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except that Subparagraph HAB-4134.6 omits additional information on subcontracted services or the use of electronic controls that is included in Subparagraph NCA-4134.6 from the 2017 Edition of ASME Code III-1. Therefore, the staff finds Subparagraph HAB-4134.6 to be acceptable with the following limitation:

> When using HAB-4134.6, the applicant or licensee should also apply NCA-4134.6, replacing the reference to NCA with HAB and replacing the reference to Certificate Holder with GC Certificate Holder.

HAB-4134.7 Control of Purchased Items and Services

Subparagraph HAB-4134.7 states that the provisions of NQA-1, Requirement 7, shall apply except for the exemptions listed in subsubparagraphs (a) through (e). HAB-4134.7 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Subparagraph NCA-4134.7, "Control of Purchased Items and Services," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except Subparagraph HAB-4134.7 did not include two exceptions included in NCA-4134.7.

Therefore, the staff finds Subparagraph HAB-4134.7 to be acceptable with the following limitation and exception:

> When using HAB-4134.7, the applicant or licensee should also apply NCA-4134.7(e) and NCA-4134.7(g), replacing the reference to NCA with HAB, except that the provision that says "see NCA-4255.5 for unqualified source material" is not applicable to HAB-4134.7, and therefore the NRC staff does not endorse that provision for use in connection with HAB-4134.7.

HAB-4134.8 Identification and Control of Items

Subparagraph HAB-4134.8 has two subsubparagraphs, (a) and (b). HAB-4134.8(a) states that the provisions of NQA-1, Requirement 8, shall apply. HAB-4134(b) states, in part, that all characteristics to be reported in accordance with the material specifications, Subpart B, and Subsection HH, Subpart A, shall appear on checklists, and each such characteristic shall be examined by accepted procedures and the results recorded.

Subparagraph HAB-4134.8 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.8, "Identification and Control of Items," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.8 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.8 acceptable.

HAB-4134.9 Control of Processes

Subparagraph HAB-4134.9 has two subparagraphs, (a) and (b). HAB-4134.9(a) states that the provisions of NQA-1, Requirement 9, shall apply, except for the provisions for welding and brazing since they are not applicable to graphite. HAB-4134.9(b) states, in part, that the GC Certificate Holder shall prepare instructions, procedures, drawings, checklists, travelers, or other appropriate documents, including the document numbers and revisions to which the process conforms, with space provided for reporting results of completion of specific operations at checkpoints of manufacture or installation.

Subparagraph HAB-4134.9 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.9, "Control of Processes," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.9 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.9 acceptable.

HAB-4134.10 Inspection

Subparagraph HAB-4134.10 has three subparagraphs, (a), (b), and (c). HAB-4134.10(a) states that the provisions of NQA-1, Requirement 10, shall apply, except for paragraph 700, "Inspections During Operations." HAB-4134.10(b) states, in part, that the GC Certificate Holder shall prepare process sheets, travelers, or checklists, including the document numbers and revision to which the examination or test is to be performed, with space provided for recording results of examinations and tests. HAB-4134.10(c) states that the controlling documents (HAB-4134.9) shall indicate mandatory hold points at which witnessing is required by the GC Certificate Holder's representative or the Authorized Nuclear Inspector (Graphite). Work shall not proceed beyond these hold points without the consent of the GC Certificate Holder's representative or the Authorized Nuclear Inspector (Graphite), as appropriate.

Subparagraph HAB-4134.10 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.10, "Inspection," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.10 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.10 acceptable.

HAB-4134.11 Test Control

Subparagraph HAB-4134.11 states that the provisions of NQA-1, Requirement 11, shall apply.

Subparagraph HAB-4134.11 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.11, "Test Control," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.11 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.11 acceptable.

HAB-4134.12 Control of Measuring and Test Equipment

Subparagraph HAB-4134.12 has two subsubparagraphs, (a) and (b). HAB-4134.12(a) states that the provisions of NQA-1, Requirement 12, shall apply. HAB-4134.12(b) states that the GC Certificate Holder may perform periodic checks on equipment to determine that calibration is maintained. When periodic checking is used, discrepancies need only be resolved to the prior check, provided the discrepancy is discovered by the periodic check. HAB-4134.12(b) also states that the GC Certificate Holder's Quality Assurance Program shall include the methods and frequency of periodic checking, when used.

HAB-4134.12 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.12, 'Control of Measuring and Test Equipment," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.12 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.12 acceptable.

HAB-4134.13 Handling, Storage, and Shipping

Subparagraph HAB-4134.13 states that the provisions of NQA-1, Requirement 13, shall apply.

Subparagraph HAB-4134.13 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.13, "Handling, Storage, and Shipping," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.13 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.13 acceptable.

HAB-4134.14 Inspection and Test Status

Subparagraph HAB-4134.14 states that the provisions of NQA-1, Requirement 14, shall apply for inspections and tests but not for operating status.

Subparagraph HAB-4134.14 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.14, "Inspection and Test Status," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.14 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.14 acceptable.

HAB-4134.15 Control of Nonconforming Items

Subparagraph HAB-4134.15 states that the provisions of NQA-1, Requirement 15, shall apply, except that the definition of "repair" given in Article NCA-9000 shall apply in lieu of "repair" and "rework" given in NQA-1.

Subparagraph HAB-4134.15 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.15, "Control of Nonconforming Items," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. NCA-4134.15 defines "repair" in accordance with NCA-9000 the same way that HAB-4134.15 does. Further, Subparagraph HAB-4134.15 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.15 acceptable.

HAB-4134.16 Corrective Action

Subparagraph HAB-4134.16 has two subsubparagraphs, (a) and (b). HAB-4134.16(a) states that the provisions of NQA-1, Requirement 16, shall apply. HAB-4134.16(b) states that the requirements shall also extend to the performance of the subcontractor's corrective action measures.

Subparagraph HAB-4134.16 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.16, "Corrective Action," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.16 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.16 acceptable.

HAB-4134.17 Quality Assurance Records

Subparagraph HAB-4134.17 has four subsubparagraphs, (a) "General," (b) "Records Index," (c) "Lifetime Records," and (d) "Nonpermanent Records." HAB-4134.17(a) states that the provisions of NQA-1, Requirement 17, shall apply except for paragraphs 400, "Classification"; 500, "Receipt Control of Records"; and 600, "Storage." HAB-4134.17(a) also indicates that such records shall be classified and maintained as provided by this Subpart and Subsection HH, Subpart A.

HAB-4134.17(b) states that records shall be indexed and that the records and the indices thereto shall be accessible to the Owner, the Owner's designee, and the Authorized Nuclear Inspector (Graphite).

HAB-4134.17(c) states that the records listed in Table HAB-4134.17-1 shall be classified as lifetime records. HAB-4134.17(c) also states that the GC Certificate Holder shall be responsible for the retention and maintenance of these records while they are under its control and that the Owner shall be responsible for retention and maintenance of those records that are transferred to it.

HAB-4134.17(d) states that the records listed in Table HAB-4134.17-2 shall be classified as nonpermanent records and the GC Certificate Holder shall be responsible for their retention for the period specified in Table HAB-4134.17-2. In no case need nonpermanent records be retained for longer than 10 years after completion of the applicable ASME Code Data Report.

Subparagraph HAB-4134.17 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.17, "Quality Assurance Records," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.17 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.17 acceptable.

Table HAB-4134.17-1, "Lifetime Quality Assurance Records," and Table HAB-4134.17-2, "Nonpermanent Quality Assurance Records," serve the same purpose as the corresponding tables for metallic components in ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-4134.17 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Table HAB-4134.17-1 and Table HAB-4134.17-2 acceptable.

HAB-4134.18 Audits

Subparagraph HAB-4134.18 has three subsubparagraphs, (a), (b), and (c). HAB-4134.18(a) states that the provisions of NQA-1, Requirement 18, shall apply. HAB-4134.18(b) states that the results of audits shall be made available to the Authorized Nuclear Inspector (Graphite). HAB-4134.18(c) states that the GC Certificate Holder's Quality Assurance Manual shall specify the audit frequency. HAB-4134.18(c) also states that the GC Certificate Holder's audit frequency shall be commensurate with its schedule of activities and shall be such that each ongoing ASME Code activity is audited at least once annually.

Subparagraph HAB-4134.18 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Subparagraph NCA-4134.18, "Audits," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Subparagraph HAB-4134.18 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Subparagraph HAB-4134.18 acceptable.

3.2.5 Article HAB-5000 Authorized Inspection

HAB-5100 Introduction

HAB-5110 Applicability

Paragraph HAB-5110 has two subparagraphs, (a) and (b). These two subparagraphs state that this Article provides the requirements for the AIA's inspection of items in accordance with this Subpart and Subsection HH, Subpart A, and that, when preservice examinations are required, the AIA's inspection of the preservice examinations shall be made in accordance with Section XI, as applicable.

Paragraph HAB-5110 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5110, "Applicability," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5110 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5110 acceptable.

HAB-5120 Performance of Inspection

HAB-5121 Authorized Inspection Agency

Paragraph HAB-5121 has two subparagraphs, (a) and (b). These two subparagraphs indicated that the AIA (1) shall be accredited by ASME in accordance with ASME QAI-1, "Qualification for Authorized Inspection," (2) shall notify ASME when it enters into an agreement with an Owner or a GC Certificate Holder, or whenever the agreement is terminated, and (3) shall also notify the enforcement authority whenever an agreement is terminated.

Paragraph HAB-5121 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5151, "Authorized Inspection Agency," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5121 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5121 acceptable.

HAB-5122 Authorized Nuclear Inspector Supervisor (Graphite)

Paragraph HAB-5122 indicates that the AIA shall employ Authorized Nuclear Inspector Supervisors (Graphite) qualified in accordance with ASME QAI-1 to supervise the Authorized Nuclear Inspectors (Graphite).

Paragraph HAB-5122 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5122, "Authorized Nuclear Inspector Supervisor," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5122 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5122 acceptable.

HAB-5123 Authorized Nuclear Inspector (Graphite)

Paragraph HAB-5123 indicates that the AIA shall employ an Authorized Nuclear Inspector (Graphite) qualified in accordance with ASME QAI-1 to perform inspections called for by Subpart B and Subsection HH, Subpart A. HAB-5123 also indicates that the inspections call for by this Subpart and Subsection HH, Subpart A, shall be performed by an Authorized Nuclear Inspector (Graphite) and that the Authorized Nuclear Inspector (Graphite) shall not be in the employ of a GC Certificate Holder.

Paragraph HAB-5123 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5123, “Authorized Nuclear Inspector,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5123 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5123 acceptable.

HAB-5125 Duties of Authorized Nuclear Inspector Supervisors (Graphite)

Paragraph HAB-5125 has two subparagraphs, (a) and (b). These two subparagraphs list the responsibilities of the Authorized Nuclear Inspector Supervisor (Graphite). Paragraph HAB-5125 serves the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-5125, “Duties of Authorized Nuclear Inspector Supervisors,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except HAB-5125 did not include provisions in NCA-5125 for an annual audit of the Owner’s Quality Assurance Program and, at least once per year, an audit of the GC Certificate Holder’s or Owner’s (or its designee’s) Certifying Engineer qualification activities. Therefore, the staff finds Paragraph HAB-5125 to be acceptable with the following limitation:

> When using HAB-5125, the applicant or licensee should also apply NCA-5125(h) and (i), replacing the reference to Supervisor with Authorized Nuclear Inspector Supervisor (Graphite) and the reference to Certificate Holder to GC Certificate Holder.

HAB-5130 Access for Inspection Agency Personnel

HAB-5131 Access to the GC Certificate Holder’s Facilities

Paragraph HAB-5131 has two subparagraphs, (a) and (b). These two subparagraphs indicate that the GC Certificate Holder shall arrange for the AIA personnel to have access at all times to locations where ASME Code activities are being performed on an item, including those related to the supply or manufacture of materials. These subparagraphs also indicate that the GC Certificate Holder shall keep the Authorized Nuclear Inspector (Graphite) informed of the progress of the work and shall notify him or her reasonably in advance when the item will be ready for any necessary tests or inspections. In addition, these subparagraphs indicate that the GC Certificate Holder shall provide personnel to accompany the Authorized Nuclear Inspector Supervisor (Graphite) during his or her required audits.

Paragraph HAB-5131 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5131, “Access to the Certificate Holder’s Facilities,” which the NRC has previously approved through incorporation by reference in 10

CFR 50.55a without conditions. Further, Paragraph HAB-5131 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5131 acceptable.

HAB-5132 Access to the Owner's Facilities

Paragraph HAB-5132 indicates that the Owner shall arrange for the AIA personnel to have free access to the Owner's facilities, as necessary to perform duties under the Owner's agreement with the AIA.

Paragraph HAB-5132 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5132, "Access to the Owner's Facilities," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5132 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5132 acceptable.

HAB-5200 Duties of Authorized Nuclear Inspector (Graphite)

HAB-5210 General Inspection Duties

HAB-5210 has two subparagraphs, (a) and (b). These two subparagraphs describe the inspection duties of the Authorized Nuclear Inspector (Graphite). These two subparagraphs indicate that duties include, for example, witnessing or verifying all examinations and making all the inspections required by this Subpart and Subsection HH, Subpart A, and making any other inspections and witnessing or verifying (including making measurements) any other examinations and additional investigations that, in his or her judgment, are necessary to ascertain whether the item being inspected has been constructed in compliance with the rules of this Subpart and Subsection HH, Subpart A. HAB-5210 also states that the duties of the Authorized Nuclear Inspector (Graphite) shall not be interpreted by virtue of these rules to extend to any construction provisions beyond those of this Subpart and Subsection HH, Subpart A, that may be set forth in the Design Specification, Design Drawings, or Construction Specifications.

Paragraph HAB-5210 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5210, "General Inspection Duties," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5210 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5210 acceptable.

HAB-5220 Categories of Duties for Authorized Nuclear Inspectors (Graphite)

Paragraph HAB-5220 has 10 subparagraphs, (a) through (j). These 10 subparagraphs list the duties of the Authorized Nuclear Inspector (Graphite).

Paragraph HAB-5220 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5220, "Categories of Inspector's Duties," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5220 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5220 acceptable.

HAB-5230 Scope of Work, Design, Specifications, and Design Reports

Paragraph HAB-5230 has three subparagraphs, (a), (b), and (c). These three subparagraphs indicate that the Authorized Nuclear Inspector (Graphite) shall verify items listed in HAB-5230 in the certificates as well as in the Design Specifications, Design Reports, Design Drawings, Construction Specifications, and Construction Reports.

The NRC staff notes that HAB-5230(b) also provides a link to other paragraphs in HAB-3000 on the Authorized Nuclear Inspector's (Graphite) responsibility to ensure that the documents listed above have been properly certified. In particular, the NRC staff notes that a link to HAB-3260 was not provided.

HAB-5230 serves as the same purpose as the corresponding provision for metallic components in ASME Code III-NCA, Paragraph NCA-5230, "Scope of Work, Design, Specifications, and Design," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except subparagraphs HAB-5230(b) and HAB-5230(c) differ from NCA-5230(b) and NCA-5230(c) in regard to verification that specific documentation is on file and is properly certified; certain information for which the Inspector is not responsible; qualification of the Certifying Engineer; and Design Calculations. Therefore, the staff finds HAB-5230 to be acceptable with the following limitation:

> When using HAB-5230, the applicant or licensee should also apply NCA-5230(b), (c), and (d), replacing the reference to Inspector with Authorized Nuclear Inspector (Graphite), the references to NCA with HAB (except that NCA-3550 and NCA-3555 should be replaced with HAB-3450 and HAB-3455, respectively), and the references to Certificate Holder with GC Certificate Holder.

HAB-5240 Quality Assurance Programs

HAB-5241 Stipulation of Inspections Prior to Issuance of Process Sheets or Controls

Paragraph HAB-5241 indicates that, before the issuance of process sheets or controls called for by HAB-4134.9, the GC Certificate Holder shall review them and the applicable drawings with the Authorized Nuclear Inspector (Graphite), who shall then stipulate the inspections he or she intends to make to fulfill the provisions of HAB-5210.

Paragraph HAB-5241 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5241, "Stipulation of Inspections Prior to Issuance of Process Sheets or Controls," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5241 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5241 acceptable.

HAB-5242 Monitoring of Quality Assurance Programs

Paragraph HAB-5242 has two subparagraphs, (a) and (b). These two subparagraphs indicate that the Authorized Nuclear Inspector (Graphite) shall monitor the performance of the GC Certificate Holder for conformity to the provisions of its Quality Assurance Program accepted by

ASME and the Owner's progress in compiling supporting data needed to complete the ASME Data Report Form N-3.

Paragraph HAB-5242 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5242, "Monitoring of Quality Assurance Programs," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5242 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5242 acceptable.

HAB-5243 Process Control Checklist

Paragraph HAB-5243 indicates that the Authorized Nuclear Inspector (Graphite) shall indicate on the GC Certificate Holder's process sheets or checklist his or her concurrence that compliance has been attained at each point stipulated by him or her.

Paragraph HAB-5243 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5243, "Process Control Checklist," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5243 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5243 acceptable.

HAB-5250 Qualification Records

HAB-5251 Review of Qualification Records

Paragraph HAB-5251 indicates that the Authorized Nuclear Inspector (Graphite) shall review the qualification records of the GC Certificate Holder.

Paragraph HAB-5251 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5251, "Review of Qualification Records," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5251 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5251 acceptable.

HAB-5255 Examination Procedures

Paragraph HAB-5255 indicates that the Authorized Nuclear Inspector (Graphite) shall assure himself or herself that the examination and testing procedures called for by Subpart B and Subsection HH, Subpart A, have been qualified. HAB-5255 also indicates that when there is a specific reason to question whether the examination or testing procedures are being met, the Authorized Nuclear Inspector (Graphite) may call for requalification of the procedure.

Paragraph HAB-5255 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5255, "Examination Procedures," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5255 does not contain any technical requirements and does not otherwise impact other requirements. However, the NRC staff notes that Article HAB-5000 does not contain a paragraph included in NCA-5256, "Nondestructive Examination

Personnel," that relates to the review of NDE personnel records by the Authorized Nuclear Inspector (Graphite). The NRC approved paragraph NCA-5256 from the 2017 Edition through incorporation by reference in 10 CFR 50.55a, and this provision should be applied to ensure the correct application of HAB-5000. Therefore, the staff finds Article HAB-5000 to be acceptable with the following limitation:

> When using HAB-5000, the applicant or licensee should also apply NCA-5256, Nondestructive Examination Personnel, replacing the reference to Inspector with Authorized Nuclear Inspection (Graphite), the reference to Material Organization with Graphite Material Organization, and the reference to Certificate Holder with GC Certificate Holder.

HAB-5260 Materials and Graphite Core Components

HAB-5261 Inspection of Materials for Compliance

Paragraph HAB-5261 indicates that the Authorized Nuclear Inspector (Graphite) shall assure himself or herself that all materials used comply with all applicable provisions of this Subpart and Subsection HH, Subpart A. HAB-5261 also indicates that the GC Certificate Holder shall make available to the Authorized Nuclear Inspector (Graphite) certified reports of the results of all tests performed in accordance with the material specifications and the provisions of Article HHA-2000, including certified reports of the results of all necessary tests and examinations performed.

Paragraph HAB-5261 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5261, "Inspection of Materials for Compliance," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5261 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5261 acceptable.

HAB-5262 Dimensional Check

Paragraph HAB-5262 indicates that the Authorized Nuclear Inspector (Graphite) shall be satisfied that the item is being constructed within the tolerances set by the Design Specification, Design Drawings, Construction Specifications, this Subpart, and Subsection HH, Subpart A.

Paragraph HAB-5262 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5262, "Dimensional Check," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5262 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5262 acceptable.

HAB-5270 Examination and Tests

Paragraph HAB-5270 indicates that the Authorized Nuclear Inspector (Graphite) shall witness examinations and tests, when feasible, as well as check the examination and test records to determine the acceptability of the items involved.

Paragraph HAB-5270 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5270, "Examination and Tests," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5270 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5270 acceptable.

HAB-5290 Data Reports and Construction Reports

Paragraph HAB-5290 has two subparagraphs, (a) and (b). These two subparagraphs indicate that the Authorized Nuclear Inspector (Graphite) shall review and sign the appropriate Data Reports prepared by the GC Certificate Holder only after they have been certified by a responsible representative of the GC Certificate Holder. These two subparagraphs also indicate that the Authorized Nuclear Inspector (Graphite) shall also review and separately verify that the information contained in the Construction Report is valid and corresponds to the provisions of Subpart B and Subsection HH, Subpart A, and that the Designer's review and certification of the Construction Report have taken account of all provisions of this Subpart and Subsection HH, Subpart A.

Paragraph HAB-5290 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5290, "Data Reports and Construction Reports," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except HAB-5290 does not contain a subparagraph in NCA-5290 related to the review of the N-3 Data Report Form by the Authorized Nuclear Inspector (Graphite), i.e., in Subsubparagraph NCA-5290(c) from the 2017 Edition, which was incorporated by reference in 10 CFR 50.55a. Therefore, the staff finds Paragraph HAB-5290 to be acceptable with the following limitation:

> When using HAB-5290, the applicant or licensee should also apply NCA-5290(c)(1) and (c)(2), replacing the reference to Inspector with Authorized Nuclear Inspection (Graphite) and the reference to NCA with HAB.

HAB-5300 Responsibilities of the Authorized Inspection Agency

Paragraph HAB-5300 has eight subparagraphs, (a) through (h). These eight subparagraphs list the responsibilities of the AIA.

Paragraph HAB-5300 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-5300, "Responsibilities of the Authorized Inspection Agency," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-5300 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-5300 acceptable.

3.2.6 Article HAB-7000 Reference Standards

HAB-7100 General Requirements

HAB-7100 indicates that Table HAB-7100-1 lists the standards and specifications referenced in the text of this Subpart and Subsection HH, Subpart A. This table does not include references to ASME Code requirements.

The staff finds HAB-7100 does not contain any technical requirements and does not otherwise impact other requirements.

Table HAB-7100-1 lists the standards and specifications referenced in this Subpart and Subsection HH, Subpart A. The NRC staff notes that the 2019 Edition of the ASME Code III-5, contains an additional standard, namely, the applicable edition of ISO/IEC 17025, that was not listed in the 2017 Edition of the ASME Code III-5, which is needed to support acceptance of HAB-3125 and HAB-3126.

In addition to the references listed in Table HAB-7100-1, the applicant or licensee should also include ISO/IEC 17025, issued 2017, as the acceptable standard for use.

3.2.7 Article HAB-8000 Certificates and Data Reports

HAB-8100 Authorization to Perform Code Activities

HAB-8110 General

Paragraph HAB-8110 indicates that ASME will grant authorization to certify work in this Subpart and Subsection HH, Subpart A, for a 3-year period under the provisions set forth in this Article.

Paragraph HAB-8100 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8100, “General,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8100 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8100 acceptable.

HAB-8120 Scope of Certificates

Paragraph HAB-8120 has three subparagraphs, (a), (b), and (c). These three subparagraphs indicate the scope of the certificates and describes what type of changes can be made to the certificates.

Paragraph HAB-8120 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8120, “Scope of Certificates,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8120 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8120 acceptable.

HAB-8130 Inspection Agreement Required

Paragraph HAB-8130 indicates that GC Certificate Holders and Owners are required to possess an agreement with an AIA to provide inspection and auditing services. HAB-8130 also indicates that, if the agreement is canceled or changed, the GC Certificate Holder and Owners must notify ASME.

Paragraph HAB-8130 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8130, "Inspection Agreement Required," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8130 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8130 acceptable.

HAB-8140 Quality Assurance Program Requirements

Paragraph HAB-8140 indicates that an Owner and the Certificate Holder are required to have a Quality Assurance Program that has been evaluated and accepted by ASME.

Paragraph HAB-8140 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8140, "Quality Assurance Program Requirements," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8140 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8140 acceptable.

HAB-8150 Application for Certification

Paragraph HAB-8150 indicates that any organization desiring to have a certificate shall apply by using forms issued by ASME describing the scope of ASME Code activities that will be performed.

Paragraph HAB-8150 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8150, "Application for Certification," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8150 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8150 acceptable.

HAB-8153 Code Activities Prior to Obtaining GC Certificate

Paragraph HAB-8153 indicates that ASME Code activities performed before issuance of a GC Certificate shall be subject to the acceptance of the Authorized Nuclear Inspector (Graphite).

Paragraph HAB-8153 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8150, "Application for Certification," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8153 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8153 acceptable.

HAB-8160 Evaluation

HAB-8161 Evaluation for a Certificate

Paragraph HAB-8161 has two subparagraphs, (a) and (b). These two subparagraphs indicate that an applicant for a new or renewed certificate for design or construction of GCCs or GCAs require a survey of its shop or field facilities. HAB-8161 also indicates that the purpose of the survey is to evaluate the applicant's Quality Assurance Manual and the implementation of the Quality Assurance Program. In addition, HAB-8161(b) indicates that ASME's acceptance of the Quality Assurance Program shall not be interpreted to mean endorsement of the technical capability to perform design work, such as system design or stress analysis, where the scope of the certificate includes such activities.

As explained in HAA-1110 above, the use of a Certifying Engineer instead of a Registered Professional Engineer applies only to non-U.S. nuclear facilities. As such, use of a Certifying Engineer does not apply to nuclear facilities regulated by the NRC, and the exception imposed in HAA-1110 is also applicable to HAB-8161(b).

Paragraph HAB-8161 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8161, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8161 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8161 acceptable with the exception discussed above.

HAB-8162 Evaluation for an Owner's Certificate

Paragraph HAB-8162 has two subparagraphs, (a) and (b). These two subparagraphs indicate that the Owner shall obtain an Owner's Certificate from ASME for unit(s) docketed concurrently for each nuclear power plant site before field installation after receipt of notification from the regulatory authority that an application for a construction permit or combined license for a specific plant has been docketed. In lieu of a survey, ASME will interview the Owner to verify the Owner's understanding of ASME Code responsibilities.

Paragraph HAB-8162 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8162, "Evaluation for an Owner's Certificate," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8162 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8162 acceptable.

HAB-8170 Issuance

Paragraph HAB-8170 indicates that each GC Certificate Holder or G Certificate Holder shall have agreed that each certificate is the property of ASME at all times and that it will be used in accordance with this Subpart and Subsection HH, Subpart A, and that the certificate will be promptly returned upon demand, among other provisions related to the use of the certificates.

Paragraph HAB-8170 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8170, "Issuance," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions.

Further, Paragraph HAB-8170 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8170 acceptable.

HAB-8180 Renewal

Paragraph HAB-8180 has three subparagraphs, (a), (b), and (c). These three subparagraphs state the provisions for renewing and issuing new certificates and serve the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8180, “Renewal,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except HAB-8180 does not contain or address provisions for renewal of Owners’ Certificates per NCA-8180. Therefore, the staff finds HAB-8180 to be acceptable with the following limitation:

> When using HAB-8180, the applicant or licensee should also apply NCA-8182, Owner Certificate, NCA-8182(a) and (b), replacing the reference to Authorized Nuclear Inspector Supervisor with Inspector Supervisor (Graphite).

HAB-8200 Nameplates

HAB-8200 indicates that the GCA shall not be issued with a name plate and, instead, the G-1 Data Report will take the place of the name plate. HAB-8200 also indicates that the G-1 Data Report shall be traceable to the serial number of the vessel in which the GCA is installed.

The staff finds HAB-8200 to be acceptable because it does not contain any technical requirements and because the staff agrees that it is not practical to attach a nameplate to a GCA. Furthermore, HAB-8200 does not otherwise impact other requirements.

HAB-8400 Data Reports

HAB-8410 General Requirements

Paragraph HAB-8410 indicates that the appropriate Data Report, as specified in Table HAB-8100-1, shall be filled out by the G or GC Certificate Holder, Graphite Material Organization, or Owner and shall be signed by the G or GC Certificate Holder, Graphite Material Organization, or Owner and the Authorized Nuclear Inspector (Graphite) for each item.

Paragraph HAB-8410 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8140, “General Requirements,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8410 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8410 acceptable.

The staff also finds Table HAB-8100-1 to be acceptable as written because it adequately lists the different types of certificates issued by ASME and the associated scope. Further, this table does not contain any technical requirements and does not otherwise impact other technical requirements.

HAB-8411 Compiling Data Report Records

Paragraph HAB-8411 has three subparagraphs, (a), (b), and (c). These three subparagraphs describe three different ways in which the Data Reports (G-1, G-2, and G-4), which are the basis for approval of the final G-1 Data Report, may be compiled.

Paragraph HAB-8411 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8411, “Compiling Data Report Records,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8411 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8411 acceptable.

HAB-8412 Availability of Data Reports

Paragraph HAB-8412 indicates that all Data Reports and referenced supporting material shall be available to the Authorized Nuclear Inspector (Graphite) and the enforcement authority having jurisdiction at the location of the nuclear power plant site.

Paragraph HAB-8412 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8412, “Availability of Data Reports,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8412 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8412 acceptable.

HAB-8420 Owner’s Data Report

Paragraph HAB-8420 indicates that the Owner shall be responsible for completing one or more Form N-3s, and it shall certify, by signing the form, that each GC Certificate Holder or Graphite Material Organization was the holder of the appropriate certificate and that components and installation comply with the applicable provisions of this Section. HAB-8420 also indicates that the Authorized Nuclear Inspector (Graphite) has the authority to review the completed Owner’s Data Report Form N-3, including attached Data Reports for all components and installation, as necessary, to verify ASME Code compliance, and to sign the Owner’s Data Report.

Paragraph HAB-8420 serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-8420, “Owner’s Data Report,” which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, Paragraph HAB-8420 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds Paragraph HAB-8420 acceptable.

3.2.8 Article HAB-9000 Glossary

HAB-9100 Introduction

HAB-9100 indicates that the Article provides the definitions used in HAB and Subsection HH, Subpart A. It also explains that, if any conflicts exist with definitions found elsewhere, the definitions in this Article shall prevail. HAB-9100 states that if there are terms not defined in this Article, the definitions of Article NCA-9000 shall apply.

The staff finds HAB-9100 to be acceptable because it serves the same purpose as the corresponding provision for metallic components in ASME Code III-1, Paragraph NCA-9100, "Introduction," which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HAB-9100 does not contain any technical requirements and does not otherwise impact other requirements.

HAB-9200 Definitions

HAB-9200 defines several technical terms used throughout the Article.

The NRC staff determined that the definitions in HAB -9200 are clear and will ensure consistent understanding and application of the Division 5 provisions. Accordingly, HAB-9200 is acceptable.

3.3 Mandatory Appendix HAB-I Certificate Holder's Data Report Forms, Instructions, and Application Forms for Certificates of Authorization

ASME has deleted this appendix from the 2017 Edition of the ASME Code, Section III, Division 5. The rest of the 2017 Edition of ASME Code III-5 remains valid without this appendix.

3.4 Subsection HA General Requirements, Subpart C Composite Materials (HAC)

3.4.1 Article HAC-1000 Introduction

HAC-1100 General

HAC-1110 Scope

The staff is unable to make a finding on the acceptability of Article HAC-1000 at this time because this Appendix is in the course of preparation. The rest of the 2017 Edition of ASME Code III-5 remains valid without this subsection.

3.5 Subsection HB Class A Metallic Pressure Boundary Components, Subpart A Low Temperature Service (HBA)

3.5.1 Article HBA-1000 Introduction

HBA-1100 General

HBA-1110 Scope

HBA-1110 states that the rules of Subsection HB, Subpart A (HBA) constitute the requirements associated with Class A metallic components used in the construction of high-temperature reactor systems and their supporting systems when subjected to low-temperature service.

HBA-1110 has minor subparagraphs (a) through (e).

HBA-1110 (a), (c), (d), and (e) clarify the scope, terminology, and procedural provisions of HBA-1100. The staff has determined that these provisions are adequate to clearly define the scope, terminology, and procedural provisions of Subsection HBA.

HBA-1110(b) states, in part, that the rules of Subsection HB, Subpart A, are contained in ASME Code III-1-NB, except for those paragraphs or subparagraphs (with numbered headers) replaced by corresponding numbered HBA paragraphs or subparagraphs in this Subpart.

Subsection HB, Subpart A, is for Class A metallic pressure boundary components in low -temperature service. Low-temperature service is defined in HAA-9200 as service where the component(s), support(s), or core support structure(s), during normal, upset, emergency, or faulted operating conditions, do not experience temperatures that exceed those indicated in Table HAA-1130-1 for the material under consideration. These temperatures are either 370 degrees C (700 degrees F) or 425 degrees C (800 degrees F), depending on the material type. The maximum temperatures for the corresponding material types, as defined in ASME Code, Section III, Division 1, NB-1120, are either less than or equal to the temperature limits in ASME Code III-5. In addition, Class A components, as defined in ASME Code III-5, are analogous to Class 1 components in ASME Code III-1, the requirements for which are covered in ASME Code III-1-NB. The 2017 and 2019 Editions of ASME Code III-1, which include Subsection NB, are incorporated by reference in 10 CFR 50.55a; therefore, the NRC has approved the provisions of Subsection NB for use with metallic components in low-temperature service. Since components within the scope of Subsection HB, Subpart A, will be exposed to the same temperature range and have analogous component classification as components within the scope of Subsection NB, the staff finds use of the rules of Subsection NB, as referenced in HBA-1110(b), to be acceptable for components within the scope of Subsection HB, Subpart A.

Based on the above, the staff finds the provisions of HBA-1000 to be acceptable for Class A metallic components in low-temperature service.

3.5.2 Article HBA-8000 Nameplates, Stamping with the Certification Mark, and Reports

HBA-8100 Requirements

HBA-8100 indicates that the provisions in Article HAA-8000 also apply to Class A metallic pressure boundary components. HAA-8110 indicates that the rules for certificates, nameplates, the Certification Mark, and Data Reports for metallic components, metallic supports, and metallic core support structures under ASME Code III-5 shall be the same as those established for ASME Code III-1.

HBA-8100 serves the same purpose and is substantively equivalent to the corresponding provision in ASME Code, Section III, Division 1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HBA-8100 does not contain any technical requirements and does not otherwise impact other requirements. Therefore, the staff finds HBA-8100 acceptable.

3.6 Subsection HB Class A Metallic Pressure Boundary Components, Subpart B Elevated Temperature Service (HBB)

3.6.1 Article HBB-1000 Introduction

HBB-1100 General

HBB-1110 Scope

Subsubarticle HBB-1110 mainly describes the scope of the 2017 Edition of the ASME Code III-5, Subsection HB, Subpart B. Specifically, HBB-1110 states that "the rules of this Subsection HB, Subpart B constitute the requirements associated with Class A metallic components used in the construction of high temperature reactor system-s and their supporting systems when subjected to elevated temperature service." HBB-1110 also specifies when the rules of ASME Code III-1-NB may be used, specifically for Class A metallic components for which creep and relaxation effects are negligible. HBB-1110 also lists the failure modes that the design procedures of the subpart protect against, namely:

- ductile rupture from short-term loadings
- creep rupture from long-term loadings
- creep-fatigue failure
- gross distortion due to incremental collapse and ratcheting

Subsubarticle HBB-1110 serves the same purpose and is substantively equivalent to Subsubarticle -1110 of Code Case 1592. HBB-1110 simply describes the scope of Subpart B and does not contain specific technical provisions but rather references provisions elsewhere in the 2017 Edition of the ASME Code III-5 or III-1. The staff has determined that these provisions are adequate to clearly define the scope, terminology, and procedural provisions of Subsection HBB. Accordingly, the staff finds HBB-1110 acceptable.

HBB-1120 Temperature and Service Life Limits

HBB-1120 states that the rules of Subsection HB, Subpart B, shall not be used for structural parts that will be subjected either to metal temperatures or to times greater than those values associated with the allowable values for the general primary membrane stress intensity (S_{mt}) data for the specified material (see Mandatory Appendix HBB-I-14). The staff finds this acceptable, as modified by the exceptions and limitations related to additional temperature restrictions the staff identified in its review of Mandatory Appendix HBB-I-14. Section 3.7 of this NUREG documents the staff's review of Mandatory Appendix HBB-I-14 and lists these exceptions and limitations.

3.6.2 Article HBB-2000 Material

HBB-2120 Pressure Retaining Materials

HBB-2121 Permitted Material Specifications

HBB-2121(a) states that *a*ll materials shall comply with the rules of ASME Code III-1, Article NB-2000, except for those paragraphs replaced by correspondingly numbered paragraphs of Subsection HB, Subpart B.

HBB-2121(b) describes the permitted material specifications for pressure-retaining materials as those conforming to the materials specifications for base and weld material listed in Tables HBB-I-14.1(a) and HBB-I-14(b). HBB-2121(b) also states that the allowable stress intensities in Tables HBB-I-14.3A through HBB-I-14.3E, and Figures HBB-I-14.3A through HBB-I-14.3C, shall be considered extensions of Section II, Part D, Subpart 1, Tables 2A, 2B, and 4.

HBB-2121(d) also lists items that are not associated with the pressure-retaining function of a component required to comply with the permitted materials specifications, such as shafts, stems, and valve seats.

HBB-2121(c) essentially calls for pressure-retaining materials to meet one of the materials specifications listed in the tables in ASME Code, Section II, Part D (Section II-D), Subpart 1, for design stress intensity values, which is consistent with HBB-2121(b), which states that the high-temperature allowable stress intensities in the HBB-I-14 tables are an extension of the Section II-D, Subpart 1, allowable stress intensities.

HBB-2121(e), (f), and (h) essentially list types of components that are exempt from the provisions for material in HBB-2121(c). HBB-2121(g) states that welding material used in the manufacture of items shall comply with Table HBB-I-14.1(b) and the ASME special filler (SFA) specifications in Section II, Part C, and shall also comply with the applicable requirements of this Article. It further states that the requirements of this Article do not apply to material used as backing rings or backing strips in welded joints. Therefore, HBB-2121(g) is consistent with HBB-2121(b), and the provision for weld specification to meet Section II, Part C, is analogous to the base material provisions in HBB-2121(c).

HBB-2121(a), (b), and (d) serve the same purpose and are technically equivalent to paragraphs -2121(a), (b), and (c) of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraphs -2121(a), (b), and (c) of Code Case 1592 remain conservative and acceptable. HBB-2121(b), (e), (f), (g), and (h) do not specify detailed standards but provide a procedural statement referring to tables, rules, and provisions that the NRC reviewed separately in this NUREG and that are beyond the scope of the review of the present paragraph. The procedural reference is acceptable. Therefore, the staff finds HBB-2121 acceptable.

HBB-2123 Design Stress Intensity Values

HBB-2123 states that design stress intensity values for material are listed in ASME Code II-D, Subpart 1, Tables 2A, 2B, and 4, as extended in coverage by the rules of HBB-2121(b). HBB-2123 also states that with the exception of attachment material covered by HBB-2121(h), no material shall be used at metal and design temperatures above those for which values are given.

HBB-2121(b) refers to the allowable stress intensities in various tables and figures in Nonmandatory Appendix HBB-I-14, which the staff reviewed and finds acceptable as documented in Section 3.7 of this NUREG. Therefore, the staff finds HBB-2123 acceptable because it does not specify detailed requirements but provides a procedural statement referring to tables, rules, and provisions that the NRC reviewed separately in this NUREG and that are beyond the review scope for the present paragraph.

HBB-2160 Deterioration of Materials in Service

HBB-2160(a) essentially states that consideration of deterioration in service is outside the scope of Subsection HBB and that selection of suitable material for the conditions is the responsibility of the owner. HBB-2160(b) addresses special chemistry considerations for reactor vessel beltline materials and indicates that such considerations shall be specified in the Design Specification. HBB-2160(c) states that the combination of fabrication-induced cold working and subsequent elevated temperature service may affect time-dependent material properties, but it does not include any specific provisions directed to that issue.

In the 2017 Edition of the ASME Code III-5, HBB-2160(d), states that “long-time, elevated temperature, service may result in the reduction of the subsequent yield and ultimate tensile strengths.” It also provides a procedure for reducing the allowable stresses (S_{mt} and S_m) in Tables HBB-I-14.3A–E to account for the reduction in yield and tensile strength. HBB-2160(d) refers to Table HBB-3225-2 for these tensile and yield strength reduction factors.
Table HBB-3225-2, in turn, refers to Tables HBB-3225-3A and 3B for the yield and tensile strength reduction factors for 2-1/4 Cr-1 Mo, and Table HBB-3225-4 for the tensile strength reduction factor for 9Cr-1Mo-V.

Table HBB-3225-1 gives tensile strength at temperature values. Section 3.6.3 includes the staff’s review of these factors.

An independent analysis of the yield and tensile strength reduction factors, documented in ORNL, 2020, used recent data based on a literature search. The independent analysis found the yield and tensile strength reduction factors for 304 SS and 316 SS in Table HBB-3225-2 are conservative. The NRC staff reviewed the ORNL analysis and adopts it except as described below.

For 2-1/4 Cr-1 Mo, the independent analysis in ORNL, 2020 found that some of the yield and tensile strength reduction factors were lower than the values in the 2017 Edition of the ASME Code III-5. The maximum difference in the calculated factors is around 10 percent. However, a comparison in ANL, 2021, of the yield strength and tensile strength reduction factors from the measured data by Klueh (Klueh, 1977) to the values in Table HBB-3225-3A for 2-1/4Cr-1 Mo shows that the ASME Code values are generally conservative compared to the measured data. ANL, 2021 indicates that ORNL, 2020 factors were based on the ratio of the aged strength to the unaged strength, which is a different method than was used to determine the code values (average ratio of measured yield or tensile strength to code minimum yield or tensile strength).

The same method should be used for any confirmatory analysis, including the independent analysis, as was used to determine the values in the 2017 Edition of the ASME Code III-5. Although the measured data for 510 degrees C (950 degrees F) and 566 degrees C (1,050 degrees F) for the tensile strength reduction factors were more conservative than the 2017 Edition values, ANL, 2021 concludes that overall, the yield and tensile strength aging factors in the 2017 Edition of the ASME Code III-5 reflects the average thermal aging effect and, therefore the current factors provide a reasonable margin for deterioration in service. Therefore, the staff finds the yield and tensile strength reduction factors in the 2017 Edition of the ASME Code III-5, acceptable for 2-1/4 Cr-1 Mo.

For 9Cr-1Mo-V material, ANL, 2021 notes that the yield and tensile strength reduction factors were reevaluated under ASME Code Record 19-411 (Messner, 2013), whose primary purpose was to extend the current factors from 300,000 hours to 500,000 hours. As of November 2020, Record 19-411 had not yet been approved and incorporated into the ASME Code. Messner, 2013 also evaluated the reduction factors based on the ratio of the measured yield and tensile strength values to the code minimum values. The analysis showed the yield strength reduction factors for 9Cr-1Mo-V in Table HBB-3225-3A are conservative. The proposed values for the tensile strength reduction factors in Record 19-411 are slightly smaller (more conservative) than the values in the 2017 Edition of the ASME Code III-5, for certain times and temperatures (mainly at longer times and higher temperatures). However, the differences are relatively minor, and the staff finds that the values for the yield and tensile strength reduction factors in the 2017 Edition of the ASME Code III-5, are acceptable.

For Alloy 800H, ORNL, 2020 recommends that no tensile or yield strength reduction factors are needed below 732 degrees C (1,350 degrees F). ORNL, 2020 cites limited data for ex-service Alloy 800H material, indicating that the tensile and yield strength reduction factors in the 2017 Edition of the ASME Code III-5 may be nonconservative for temperatures at or above 732 degrees C (1,350 degrees F). The staff notes that the maximum temperature for allowable stress values for Alloy 800H in the Nonmandatory Appendix HBB-I-14 tables is 760 degrees C (1,400 degrees F). ANL, 2021 indicates that some of the ex-service data cited in ORNL, 2020 were for material that had previous service temperatures greater than 760 degrees C (1,400 degrees F), so these data are not applicable to determine the strength reduction factors. Further, the amount of ex-service data is very limited. ANL, 2021 also presents data from an Electric Power Research Institute (EPRI) report that confirms the current 2017 Edition strength reduction factors for Alloy 800H up to 760 degrees C (1,400 degrees F). In view of the inapplicability of the data cited by ORNL showing nonconservatism in the factors, along with the EPRI data cited by ANL, 2021, the staff finds the strength reduction factors in the 2017 Edition of the ASME Code III-5, acceptable for Alloy 800H.

Based on the above, the staff finds the yield and tensile strength reduction factors for long-term aging in Tables HBB-3225-2, -3A, -3B, and -4 of the 2017 Edition of the ASME Code III-5, to be acceptable.

HBB-2430

HBB-2433 Delta Ferrite Determination

HBB-2433 addresses the methods and acceptance criteria for delta ferrite determination for austenitic SS weld filler materials used with Type 304 and Type 316 SS. It is desirable for welds made with austenitic SS weld filler metal to contain a certain minimum amount of delta ferrite to minimize the tendency for hot cracking or microfissuring in the completed weld. Therefore, the ASME Code and NRC guidance in RG 1.31, "Control of Ferrite Content in Stainless Steel Weld Metal," Revision 4, issued October 2013 (NRC, RG 1.31 R4), specify ranges of delta ferrite in austenitic SS welds. It is also desirable to limit the maximum amount of delta ferrite because excessive amounts can contribute to degradation of the weld mechanical properties over time due to thermal aging, particularly at higher service temperatures. HBB-2433.1 allows the amount of delta ferrite to be determined by using the magnetic method but also allows the chemical analysis method to be used for such determinations in accordance with NB-2432 in the 2017 Edition of the ASME Code III-5. With respect to acceptance standards, HBB-2433.2 specifies a minimum delta ferrite content of 5 FN (ferrite number) for design temperatures up to and including 425 degrees C (800 degrees F). HBB-2433.2 states that for design temperatures exceeding 425 degrees C (800 degrees F), the delta ferrite shall be limited to the range 3 FN to 10 FN.

ORNL, 2020 recommends that HBB-2400, including the referenced Table HBB-I-14.1(b), be accepted with the condition that the alternative delta ferrite determination by chemical analysis in HBB-2433.1 be limited to filler metals used with gas tungsten arc welding (GTAW) and plasma arc welding (PAW). This is consistent with the guidance in NRC RG 1.31, Revision 4.

The explanation for the proposed limitation is that welding deposits performed by GTAW and PAW methods generally have low base metal dilution of the filler metal while many other approved welding processes can have widely varying amounts of base metal dilution, depending on weld joint design and weld procedure heat input. The concern is, therefore, that dilution of the weld deposit by the base metal could change the chemical composition of the weld deposit, which could result in an inaccurate ferrite determination.

However, the staff notes that normal industry practice is to use the chemical analysis method to determine delta ferrite content for processes that use solid weld wire, such as GTAW and gas metal arc welding, while for processes such as shielded metal arc welding, the magnetic method is typically used. Further, HBB-2433.1 states that, alternatively, the delta ferrite determinations for welding materials may be performed by chemical analysis in Division 1, NB-2432, in conjunction with Figure NB-2433.1-1. The chemical analysis in accordance with Division 1, NB-2432, is conducted on undiluted weld deposits. Therefore, the possibility of dilution mentioned in ORNL, 2020 does not seem to be an issue. In addition, although RG 1.31 does not approve the chemical analysis method for delta ferrite determination for processes other than the GTAW and PAW processes, the NRC did not include any conditions in 10 CFR 50.55a on the use of the chemical analysis method for delta ferrite determination in NB-2433. There is no reason that delta ferrite determination for use in Section III, Division 5 Class A components would need to be done differently than for Section III, Division 1 components. Accordingly, the staff has not identified a reason to withhold endorsement of the use of the chemical analysis method to which Figure HBB-2433.1-1 refers.

Therefore, the staff finds HBB-2433 to be acceptable as written, and it is not necessary to include a condition restricting the chemical analysis method to certain weld processes based on (1) the provision to test chemistry on undiluted weld deposits, and (2) the lack of a similar condition on NB-2433.

With respect to the acceptance criteria for delta ferrite, the staff finds the acceptance criteria of a minimum delta FN of 5 for materials with design temperatures up to 425 degrees C (800 degrees F) to be acceptable because this value is consistent with the acceptance criteria of NB-2433 for materials used at lower temperatures The staff finds the limitation on delta ferrite for materials with design temperatures greater than 425 degrees C (800 degrees F) of an FN greater than or equal to 3 and less than 10 to be acceptable, because the maximum FN of 10 will limit the material property degradation that can be caused by delta ferrite at higher temperatures. ORNL, 2020 includes additional technical details on the degradation that can result from ferrite. ORNL, 2020 also notes that a minimum FN in the range of 3–5 is generally sufficient to prevent hot cracking, so the minimum FN of 3 for the higher temperature range is acceptable. Further, with regard to austenitic SS weld filler metal, the American Society of Metals Handbook, Volume 1A, "Properties and Selection: Irons, Steels, and High-Performance Alloys," (ASM, 1990), states that at least 3 to 4 FN delta ferrite is needed in the as-deposited weld metal for effective suppression of hot cracking.

HBB-2500

HBB-2530

HBB-2539 Repair by Welding

This section describes the provisions for repair by welding of materials. HBB-2539 refers to the provisions of the analogous sections of the 2017 Edition of the ASME Code III-1, NB-2539 and NB-2160, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. With regard to the weld material used, HBB-2539 refers to Table HBB-I-14.1(b), which the staff reviews and accepted for reasons explained in Section 3.7 of this NUREG, and NB-2400, which the staff has also previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, since HBB-2539 references other portions of the ASME Code that the NRC has accepted, or portions of the 2017 Edition of the ASME Code III-5, that the staff accepted as documented elsewhere in this NUREG, the NRC finds HBB-2539 acceptable.

HBB-2800

This section describes an additional fatigue test that can be performed for Type 304 and Type 316 SS if design conditions do not meet the provisions of HBB-T-1324(a) and (b), which are tests for total creep strain using elastic analysis. The additional fatigue tests would theoretically enable the material to meet the creep-fatigue provisions of HBB-T. However, this would still have to be demonstrated in accordance with HBB-T-1400. Therefore, the staff finds HBB-2800 acceptable because it merely provides test data; however, acceptable creep-fatigue life is determined under other ASME Code III-5 provisions.

3.6.3 Article HBB-3000 Design

As stated in the 2017 Edition of the ASME Code III-5, Article HBB-3000 is a self-contained set of design rules for metal structures serving as component pressure-retaining boundaries under temperatures that may, at times, exceed those for which design stress-intensity values S_m are given in Section II, Part D, Subpart 1. Portions of the component, part, or appurtenance that are at all times experiencing temperatures within the range covered by ASME Code II-D, Subpart 1, Tables 2A, 2B, and 4, may be designed in compliance with Article HBB-3000, or alternatively, in compliance with ASME Code III-1-NB, Article NB-3000.

Article HBB-3000 includes passages from code cases that were approved for use through NRC RG 1.87, Rev. 1. Therefore, the staff, in its review of Article HBB-3000, referred to RG 1.87, Rev. 1, where appropriate, and also used recommendations in PNNL, 2020, where appropriate. The staff’s review of HBB-3000 follows.

HBB-3100 General Requirements for Design

HBB-3110 Scope, Acceptability, and Loadings

HBB-3111 Scope

HBB-3111.1 Acceptability

HBB-3111 and subparagraph HBB-3111.1 serve the same purpose as paragraph -3111 and subparagraph -3111.1 of Code Case 1592, endorsed in RG 1.87, Rev. 1. Paragraph -3111 and subparagraph -3111.1 of Code Case 1592 remain conservative and acceptable, and the description of the scope and criteria for acceptability for the design of high-temperature components in HBB-3111 and HBB-3111.1 is technically equivalent to the corresponding provisions in Code Case 1592. Therefore, the staff finds HBB-3111 and HBB-3111.1 acceptable.

HBB-3111.2 Loadings

HBB-3111.2 serves the same purpose as subparagraph -3111.2 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subparagraph -3111.2 of Code Case 1592 remains conservative and acceptable, and HBB-3111.2 is technically equivalent to -3111.2 except for subsubparagraph HBB-3111.2(g). Subsubparagraph HBB-3111.2(g) adds conservatism by calling for consideration of impact forces caused by either external or internal events. Therefore, the staff finds HBB-3111.2 acceptable.

HBB-3112 Design Parameters

HBB-3112 serves the same purpose as paragraph -3112 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3112 of Code Case 1592 remains conservative and acceptable, and HBB-3112 is technically equivalent to paragraph -3112 of Code Case 1592. Therefore, the staff finds HBB-3112 acceptable.

HBB-3113 Loading Categories

HBB-3113 serves the same purpose as paragraph -3113 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3113 of Code Case 1592 remains conservative and acceptable, and HBB-3113 is technically equivalent to paragraph -3113 of Code Case 1592. Therefore, the staff finds HBB-3113 acceptable.

HBB-3114 Load Histogram

HBB-3114 serves the same purpose as paragraph -3114 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3114 of Code Case 1592 remains conservative and acceptable, and HBB-3114 is technically equivalent to paragraph -3114 of Code Case 1592. Therefore, the staff finds HBB-3114 acceptable.

HBB-3120 Special Considerations

HBB-3121 Corrosion

Paragraph HBB-3121 calls for the applicant to consider the effects of material thinning due to corrosion effects when determining acceptable material thickness in the design or specified life of the component. This provision is not included in Code Case 1592; therefore, its inclusion in HBB is conservative.

HBB-3121 serves the same purpose and is technically equivalent to NB-3121, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3121 acceptable.

HBB-3122 Cladding

HBB-3122 simply refers to HBB-3227.8 for cladding provisions. The staff finds HBB-3122 acceptable, based on the acceptance of HBB-3227.8, which documented in Section 3.6.3 of this NUREG.

HBB-3123 Welding

HBB-3123.1 Dissimilar Welds

Subparagraph HBB-3123.1 calls for the applicant to exercise caution in the design and construction of welds involving dissimilar metals having different coefficients of thermal expansion. HBB-3123.1 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, NB-3123.1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3123.1 acceptable.

HBB-3123.2 Fillet Welded Attachments

HBB-3123.2 simply refers to HBB-3356.2 acceptability. The staff finds HBB-3123.2 acceptable, based on the acceptance of HBB-3356.2, as documented in Section 3.6.3 of this NUREG.

HBB-3124 Environmental Effects

HBB-3124 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, NB-3124, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3124 acceptable.

HBB-3125 Configuration

Paragraph HBB-3125 provides that applicants and licensees provide accessibility in the design of the component to permit the inservice examinations specified by ASME Code, Section XI. HBB-3125 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3125 acceptable.

HBB-3130 General Design Rules

Subarticle HBB-3130 provides design rules generally applicable to all components.

HBB-3131 Scope

Paragraph HBB-3131 serves the same purpose as paragraph -3131 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3131 of Code Case 1592 remains conservative and acceptable, and HBB-3131 is technically equivalent to paragraph -3131 of Code Case 1592. Therefore, the staff finds HBB-3131 acceptable.

HBB-3132 Dimensional Standards for Standard Production

Paragraph HBB-3132 directs the applicant to use the approved dimensional standard documents from Table NCA-7100-1 and cautions that compliance with these standards does not replace or eliminate the provisions for stress analysis when called for by the design subarticle for a specific component.

The staff finds HBB-3132 acceptable because it serves the same purpose and is technically equivalent to the corresponding provision in ASME Code, Section III, Division 1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3132 acceptable.

HBB-3133 Size Restrictions in Nozzle, Branch, Piping, and Other Connections

Paragraph HBB-3133 points to Table HBB-3133-1 for assistance in understanding where the limits are imposed. Table HBB-3133-1 shows that size restrictions in ASME Code III-5-HBB are either the same as those in Subsection NB of ASME Code III-1, or where different, are more conservative (more restrictive) than those in Subsection NB of ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR Part 50.55a without conditions. Table HBB-3133-1 also lists the applicable HBB sections for each item description. Acceptance evaluation of these HBB sections is separately shown under these sections. Therefore, the staff finds Paragraph HBB-3133 and Table HBB-3133-1 acceptable.

HBB-3134 Leak Tightness

Paragraph HBB-3134 serves the same purpose as paragraph -3134 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3134 of Code Case 1592 remains conservative and acceptable, and HBB-3134 is technically equivalent to paragraph -3134 of Code Case 1592. Therefore, the staff finds HBB-3134 acceptable.

HBB-3135 Attachments

Paragraph HBB-3135 serves the same purpose as paragraph -3135 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3135 of Code Case 1592 remains conservative and acceptable, and HBB-3135 is technically equivalent to paragraph -3135 of Code Case 1592. Therefore, the staff finds HBB-3135 acceptable.

HBB-3136 Reinforcement for Openings

This paragraph points to HBB-3330 and HBB-3643 for the rules that apply to reinforcement of openings. The acceptability of HBB-3330 and HBB-3643 is evaluated in the reviews of these paragraphs in this NUREG.

HBB-3137 Design Considerations Related to Other Articles of the Code

HBB-3137.1 Design Considerations for Static Pressure Testing

Subparagraph HBB-3137.1 serves the same purpose as paragraph -3137.1 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3137.1 of Code Case 1592 remains conservative and acceptable, and HBB-3137.1 is technically equivalent to paragraph -3137.1 of Code Case 1592. Therefore, the staff finds HBB-3137.1 acceptable.

HBB-3137.2 Design Considerations for Overpressure Protection of the System

Subparagraph HBB-3137.2 serves the same purpose as paragraph -3137.2 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3137.2 of Code Case 1592 remains conservative and acceptable, and HBB-3137.2 is technically equivalent to paragraph -3137.2 of Code Case 1592. Therefore, the staff finds HBB-3137.2 acceptable.

HBB-3138 Elastic Follow-Up

Paragraph HBB-3138 serves the same purpose as paragraph -3138 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3138 of Code Case 1592 remains conservative and acceptable, and HBB-3138 is technically equivalent to paragraph -3138 of Code Case 1592. Therefore, the staff finds HBB-3138 acceptable.

HBB-3139 Welding

HBB-3139.1 Abrupt Changes in Mechanical Properties at Weld and Compression Contact Junctions

Subparagraph HBB-3139.1 serves the same purpose as paragraph -3139 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3139 of Code Case 1592 remains conservative and acceptable, and HBB-3139.1 is technically equivalent to paragraph -3139 of Code Case 1592. Therefore, the staff finds HBB-3139.1 acceptable.

HBB-3139.2 Weld Design

Subparagraph HBB-3139.2 includes the general provisions for weld designs, stating that welds shall comply with the rules of Division 1, NB-3350, except as modified in HBB-3400, HBB-3500, or HBB-3600. The NRC has previously approved NB-3350 in ASME Code III-1 through incorporation by reference in 10 CFR 50.55a without conditions. The acceptability of HBB-3400, HBB-3500, and HBB-3600 is evaluated in the reviews of these subarticles in Section 3.6.3 of this NUREG. Therefore, the staff finds subparagraph HBB-3139.2 acceptable.

HBB-3200 Design By Analysis

Subarticle HBB-3200 provides design and acceptance criteria to be followed by Owners and N Certificate Holders with respect to the design by analysis for the elevated temperature construction of Class A metallic pressure boundary components. The substance of this subarticle is evaluated below.

HBB-3210 Design Criteria

HBB-3211 Requirements for Acceptability

Paragraph HBB-3211 provides the standards for acceptability of a design based on analysis. HBB-3211 serves the same purpose as paragraph -3211 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3211 of Code Case 1592 remains conservative and acceptable, and HBB-3211 is technically equivalent to paragraph -3211 of Code Case 1592, except subparagraphs -3211(d) and -3211(e) of Code Case 1592 have been summarized and combined as subparagraph HBB-3211(d) in paragraph HBB-3211. Therefore, the staff finds HBB-3211 acceptable.

HBB-3212 Basis for Determining Stress, Strain, and Deformation Quantities

Subparagraphs HBB-3212(a) and HBB-3212(b) serve the same purpose as subparagraphs -3212(a) and -3212(b) of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subparagraphs -3212(a) and -3212(b) of Code Case 1592 remain conservative and acceptable, and HBB-3212(a) and HBB-3212(b) are technically equivalent to subparagraphs -3212(a) and -3212(b) of Code Case 1592. HBB-3212(c) adds a paragraph that refers to 9Cr-1Mo-V material and discusses unique characteristics of the material that should be considered by the designer. The added paragraph is informational and does not contain any specific requirements, and therefore is acceptable to the staff. 9Cr-1Mo-V is a newer material that is not included in Code Case 1592, but has been added as a permissible material in ASME Code III-5, and is allowed in accordance with the material provisions of Article HBB-2000 and Mandatory Appendix HBB-I. The acceptability of and recommendations for the use of 9Cr-1Mo-V are discussed in the reviews of Article HBB-2000 and Mandatory Appendix HBB-I, which the staff accepted for reasons documented in Sections 3.6.2 and 3.7 in this NUREG, respectively. Therefore, the staff finds HBB-3212 acceptable.

HBB-3213 Terms Relating to Analysis

Paragraph HBB-3213 serves the same purpose as paragraph -3213 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3213 of Code Case 1592 remains conservative and acceptable, and HBB-3213 is technically equivalent to paragraph -3213 of Code Case 1592. Note 11 of HBB-3213 also serves the same purpose and is technically equivalent to Note 2 in paragraph -3213 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Therefore, the staff finds HBB-3213 acceptable.

The subparagraphs of HBB-3213 contain common engineering terms and definitions related to the structural analysis of pressure boundary components. With the exception of HBB-3213.8, HBB-3213.9, HBB-3213.10, HBB-3213.13, HBB-3213.20, HBB-3213.21, HBB-3213.22, HBB-3213.23, HBB-3213.24, HBB-3213.25, HBB-3213.26, HBB-3213.27, HBB-3213.30, HBB-3213.31, and HBB-3213.32, which are reviewed below, the terms and definitions found in HBB-3213.1 through HBB-3213.39 serve the same purpose and are technically equivalent to the terms and definitions found in the subparagraphs of paragraph -3213 of Code Case 1592 endorsed in RG 1.87, Rev. 1.

Based on the above, the staff finds the terms and definitions found in HBB-3213.1 through HBB-3213.32 acceptable as written, with the exception of HBB-3213.8, HBB-3213.9, HBB-3213.10, HBB-3213.13, HBB-3213.20, HBB-3213.21, HBB-3213.22, HBB-3213.23, HBB-3213.24, HBB-3213.25, HBB-3213.26, HBB-3213.27, HBB-3213.30, HBB-3213.31, and HBB-3213.32, which are reviewed below.

The staff notes that the exact order and placement of subparagraphs within HBB-3213 may not be the same as in paragraph -3213 of Code Case 1592. For instance, HBB-3213.18 is identical to -3213.19, HBB-3213.28 is identical to the first and last sentence of subparagraph -3213.21, HBB-3213.29 is identical to subparagraph -3213.22, HBB-3213.33 is identical to -3213.23, HBB-3213.34 is identical to -3213.18, HBB-3213.35 is identical to -3213.24, HBB-3213.36 is identical to -3213.25, HBB-3213.37 is identical to -3213.26, HBB-3213.38 is identical to -3213.27, and HBB-3213.39 is identical to -3213.28.

HBB-3213.8 Primary Stress

Subparagraph HBB-3213.8 provides the definition of primary stress. HBB-3213.8 serves the same purpose as subparagraph -3213.8 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subparagraph -3213.8 of Code Case 1592 remains conservative and acceptable, and HBB-3213.8 is technically equivalent to subparagraph -3213.8 of Code Case 1592 with the exception that HBB-3213.8 includes an additional sentence and an additional reference. The added sentence cautions that "[p]rimary stresses that considerably exceed the yield strength will result in failure or, at least in gross distortion," and is identical to a sentence in the 2017 Edition of the ASME Code III, Mandatory Appendix XIII, XIII-1300(y). The added reference in subparagraph HBB-3213.8 simply directs the applicant to examples of primary stress found in Table HBB-3217-1 of the 2017 Edition of the ASME Code. This added reference serves the same purpose as the reference made in ASME Code III, Mandatory Appendix XIII-1300(y) to examples of primary stress found in Table XIII-2600-1 of the 2017 Edition of the ASME Code III-1. Therefore, the staff finds HBB-3213.8 acceptable.

HBB-3213.9 Secondary Stress

Subparagraph HBB-3213.9 serves the same purpose as paragraph -3213.9 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3213.9 of Code Case 1592 remains conservative and acceptable, and HBB-3213.9 is technically equivalent to paragraph -3213.9 of Code Case 1592.

HBB-3213.9(a) directs the applicant to subparagraph HBB-3213.13 for the definition of thermal stresses in relation to secondary stresses. HBB-3213.9(b) is identical to -3213.9(a) of Code Case 1592. While HBB-3213.9 omits provisions corresponding to -3213.9(e) and -3213.9(f) of Code Case 1592, these provisions have been moved to subsubparagraphs HBB-3213.13(a)(1) and HBB-3213.13(a)(2), respectively. HBB-3213.9 also omits provisions corresponding to -3213.9(b) through -3213.9(d) of Code Case 1592 but the staff determined that these omissions from subparagraph HBB-3213.9 do not detract from the meaning of secondary stress and were only given as an aid in defining secondary stress. The added reference at the bottom of subparagraph HBB-3213.9 simply directs the applicant to examples of secondary stress found in Table HBB-3217-1 of the 2017 Edition of the ASME Code. ASME Code III-XIII-1300(ab), makes a similar reference directing the applicant to examples of secondary stress found in Table XIII-2600-1 of the 2017 Edition of the ASME Code. Based on the above, the staff finds HBB-3213.9 acceptable.

HBB-3213.10 Local Primary Membrane Stress

Subparagraph HBB-3213.10 serves the same purpose as subparagraph -3213.10 of Code Case 1592 endorsed in RG 1.87, Rev. 1, with the exception that the definition has been expanded. The expansion of the local primary membrane stress definition from -3213.10 of Code Case 1592 to HBB-3213.10 is technically equivalent to the definition in ASME Code, Section III, Mandatory Appendix XIII, XIII-1300(n), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3213.10 acceptable.

HBB-3213.13 Thermal Stress

Subparagraph HBB-3213.13 serves the same purpose as subparagraph -3213.9 of Code Case 1592 endorsed in RG 1.87 Rev. 1, with the exception that the definition has been expanded. The expansion of the definition of thermal stress from -3213.10 of Code Case 1592 to HBB-3213.10 is technically equivalent to the definition in ASME Code, Section III, Mandatory Appendix XIII, XIII-1300(aj), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. For further guidance on classification, subparagraph HBB-3213.13 refers to subparagraph HBB-T-1331(d). The acceptability of HBB-T-1331(d) is evaluated in the reviews of HBB-T-1331(d) found in Section 3.9.3 of this NUREG. Therefore, the staff finds HBB-3213.13 acceptable.

HBB-3213.20 Deformation

Subparagraph HBB-3213.20 defines a common engineering term (deformation), and the definition is technically equivalent to that in the 2017 Edition of the ASME Code III-XIII, XIII-1300(d), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3213.20 acceptable.

HBB-3213.21 Inelasticity

Subparagraph HBB-3213.21 defines a common engineering term (inelasticity), and the definition is technically equivalent to that in the 2017 Edition of the ASME Code, Section III, Mandatory Appendix XIII, XIII-1300(j), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3213.21 acceptable.

HBB-3213.22 Creep

Subparagraph HBB-3213.22 defines a common engineering term (creep), and the definition is technically equivalent to that in the 2017 Edition of the ASME Code, Section III, Mandatory Appendix XIII, XIII-1300(c), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3213.22 acceptable.

HBB-3213.23 Plasticity

Subparagraph HBB-3213.23 defines a common engineering term (plasticity), and the definition is technically equivalent to that in the 2017 Edition of the ASME Code III-XIII, XIII-1300(x), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a with one exception. Specifically, the last sentence in HBB-3213.23 states that for 9Cr-1Mo-V, time-independent plasticity at higher temperatures occurs only in limiting cases where strain rates are high relative to creep rates. The information on 9Cr-1Mo-V contains no specific requirements, and is similar to information in HBB-3212, which has been accepted by the staff in Section 3.6.3 of this NUREG. Therefore, the staff finds HBB-3213.23 acceptable.

HBB-3213.24 Plastic Analysis

Subparagraph HBB-3213.24 defines a common engineering analysis method (plastic analysis), and the definition is technically equivalent to that in the 2017 Edition of the ASME Code III-XIII, XIII-1300(t), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a with one exception. Specifically, the last sentence in HBB-3213.24 states that, for 9Cr-1Mo-V, a plastic analysis must generally account for rate dependence and creep effects. A plastic analysis thus implies a full inelastic analysis. The information on 9Cr-1Mo-V contains no specific requirements, and is similar to information in HBB-3212, which has been accepted by the staff in Section 3.6.3 of this NUREG. Therefore, the staff finds HBB-3213.24 acceptable.

HBB-3213.25 Plastic Analysis—Collapse Load

Subparagraph HBB-3213.25 defines a common engineering analysis (plastic analysis—collapse load), and the definition is technically equivalent to an updated revision of -3213.25 in Code Case 1592 (N-47-29). In addition, subparagraph HBB-3213.25 is technically equivalent to that in the 2017 Edition of the ASME Code III-XIII, XIII-1300(u), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3213.25 acceptable.

HBB-3213.26 Plastic Instability Load

Subparagraph HBB-3213.26 defines a common engineering term (plastic instability load), and the definition is technically equivalent to that in the 2017 Edition of the ASME Code III-XIII, XIII-1300(w), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds subparagraph HBB-3213.26 acceptable.

HBB-3213.27 Limit Analysis

Subparagraph HBB-3213.27 defines a common engineering term (limit analysis), and the definition is technically equivalent to that in the 2017 Edition of the ASME Code III-XIII, XIII-1300(k), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds subparagraph HBB-3213.27 acceptable.

HBB-3213.30 Plastic Hinge

Subparagraph HBB-3213.30 defines a common engineering term (plastic hinge), and the definition is technically equivalent to that in the 2017 Edition of the ASME Code III-XIII,

XIII-1300(v), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds subparagraph HBB-3213.30 acceptable.

HBB-3213.31 Strain Limiting Load

Subparagraph HBB-3213.31 defines a common engineering term (strain limiting load), and the definition is technically equivalent to that in the 2017 Edition of the ASME Code III-XIII, XIII-1300(af), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds subparagraph HBB-3213.31 acceptable.

HBB-3213.32 Test Collapse Load

Subparagraph HBB-3213.32 defines a common engineering term (test collapse load), and the definition is technically equivalent to that in the 2017 Edition of the ASME Code III-XIII, XIII-1300(ai), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds subparagraph HBB-3213.32 acceptable.

HBB-3214 Stress Analysis

Paragraph HBB-3214 serves the same purpose as paragraph -3214 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3214 of Code Case 1592 remains conservative and acceptable, and HBB-3214 is technically equivalent to paragraph -3214 of Code Case 1592. Therefore, the staff finds HBB-3214 acceptable.

HBB-3214.1 Elastic Analysis

Subparagraph HBB-3214.1 serves the same purpose as subparagraph -3214.1 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subparagraph -3214.1 of Code Case 1592 remains conservative and acceptable, and HBB-3214.1 is technically equivalent to subparagraph -3214.1 of Code Case 1592. Therefore, the staff finds HBB-3214.1 acceptable.

HBB-3214.2 Inelastic Analysis

Subparagraph HBB-3214.2 indicates that inelastic analysis may be necessary when significant creep stress, strains, or deformation exist. Subparagraph HBB-3214.2 serves the same purpose as subparagraph -3214.2 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subparagraph -3214.2 of Code Case 1592 remains conservative and acceptable, with the exception that it does not contain instructions (it is silent) on how to perform an inelastic analysis, either as to analytical methods or mathematical behavior, and indicates that justification of the selected methods and relations shall be included in the Design Report. Subparagraph HBB-3214.2 explicitly states that inelastic analysis may be necessary, does not contain any methods or instructions on how to perform an inelastic analysis, and states that the basis for choosing the selected methods and relations used should be included in the Design Report. Therefore, the staff finds subparagraph HBB-3214.2 acceptable.

HBB-3214.3 Mechanical and Physical Properties

Subparagraph HBB-3214.3 serves the same purpose as subparagraph -3214.3 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subparagraph -3214.3 of Code Case 1592 remains conservative and acceptable, and HBB-3214.3 is technically equivalent to subparagraph -3214.3 of Code Case 1592. Therefore, the staff finds HBB-3214.3 acceptable.

HBB-3215 Derivation of Stress Intensities

HBB-3215 serves the same purpose as paragraph -3215 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3215 of Code Case 1592 remains conservative and acceptable, and HBB-3215 is technically equivalent to paragraph -3215 of Code Case 1592. Therefore, the staff finds HBB-3215 acceptable.

HBB-3216 Derivation of Stress Differences and Strain Differences

HBB-3216 serves the same purpose as paragraph -3216 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3216 of Code Case 1592 remains conservative and acceptable, and HBB-3216 is technically equivalent to paragraph -3216 of Code Case 1592. Therefore, the staff finds HBB-3216 acceptable.

HBB-3217 Classification of Stresses

HBB-3217 serves the same purpose as paragraph -3217 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3217 of Code Case 1592 remains conservative and acceptable, and HBB-3217 is technically equivalent to paragraph -3217 of Code Case 1592. Therefore, the staff finds HBB-3217 acceptable.

HBB-3220 Design Rules and Limits for Load-Controlled Stresses in Structures Other than Bolts

HBB-3221 General Requirements

Paragraph HBB-3221 states the general provisions for load-controlled stresses. HBB-3221 serves the same purpose as paragraph -3221 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3221 of Code Case 1592 remains conservative and acceptable, and HBB-3221 is technically equivalent to paragraph -3221 of Code Case 1592, except for the additional information discussed below.

Subparagraph HBB-3221(a) includes information on where to locate the allowable stress intensity values that is not in -3221(a) of Code Case 1592. Except for the additional information in HBB-3221(a), it serves the same purpose and is technically equivalent to -3221(a) of Code Case 1592 endorsed in RG 1.87, Rev. 1. As for the additional information, HBB-3221 states that the allowable stress intensity values used in HBB-3220 are listed in Section II, Part D (Section II-D), Subpart 1, Tables 2A and 2B and Tables HBB-I-14.1(a) through HBB-I-14.13(c). The allowable stresses in Tables HBB-I-14.3A through HBB-I-14.3E, and Figures HBB-I-14.13A through HBB-I-14.13C are considered extensions of the Section II-D, Subpart 1, Tables 2A and 2B values as discussed in HBB-2121 (Section 3.6.2). Although not specifically stated in HBB-3221, the allowable stresses in Tables HBB-I-14.1(a) through HBB-I-14.13(c) cover temperatures above the continuous operating temperature defined for the ASME Code III-1. The allowable stress intensity values found in the 2017 Edition of the ASME Code, Section II, Part D (II-D), Subpart 1, Tables 2A and 2B, at or below the continuous operating temperature defined for ASME Code III-1 are acceptable because these tables from II-D are approved for use by reference in ASME Code III-1, Subsection NB (III-1-NB), of the 2017 Edition of the ASME Code incorporated by reference in 10 CFR 50.55a. The review of Mandatory Appendix HBB-I-14 in Section 3.7 of this NUREG evaluates the allowable stress intensity values found in Tables HBB-I-14.1(a) through HBB-I-14.13C and their acceptability.

Subparagraph HBB-3221(b) serves the same purpose and is technically equivalent to -3221(a) of Code Case 1592 endorsed in RG 1.87, Rev. 1, except subparagraph HBB-3221(b) makes a distinction between base metal and weldments, evaluated below.

Paragraph -3221 of Code Case 1592 remains conservative and acceptable, and HBB-3221 is technically equivalent to paragraph -3221 of Code Case 1592, except as noted above and evaluated below.

HBB-3221(b)(1) Base Metal

Subsubparagraph HBB-3221(b)(1) – S_m, serves the same purpose as subsubparagraph -3221(b) of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subsubparagraph -3221(b) of Code Case 1592 remains conservative and acceptable, and HBB-3221 is technically equivalent to paragraph -3221 of Code Case 1592, except for the language on the use of HBB-2160(d). The acceptability for the use of S_m values extended beyond the ASME Code III-1 continuous use temperature is evaluated in the review of Tables HBB-I-14.3A-E in Section 3.7.5 of this NUREG, and the acceptability of the factors to adjust S_m for long time service at elevated temperature is evaluated in Section 3.6.2 of this NUREG.

Subsubparagraph HBB-3221(b)(1) – S_{mt}, serves the same purpose as subsubparagraph -3221(b) of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subsubparagraph -3221(b) of Code Case 1592 remains conservative and acceptable, and HBB-3221 is technically equivalent to paragraph -3221 of Code Case 1592, except for the language on the use of HBB-2160(d). The acceptability of the allowable values for the general primary membrane stress intensity, S_{mt}, found from Figures HBB-I-14.3A through HBB-I-14.3E and in Tables HBB-I-14.3A through HBB-I-14.3E, and the adjustment to account for long-time service at elevated temperature, as described in HBB-2160(d), is evaluated in the review of Mandatory Appendix HBB-I-14, in Section 3.7 of this NUREG.

Subsubparagraph HBB-3221(b)(1) – S_o, serves the same purpose as subsubparagraph -3221(b) of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subsubparagraph -3221(b) of Code Case 1592 remains conservative and acceptable, and HBB-3221 is technically equivalent to paragraph -3221 of Code Case 1592, except for the additional language in the last two sentences of HBB-3221, which is discussed in the next paragraph of this NUREG. HBB-3221(b)(1) states in part that the values (of S_0) correspond to the S values given in Section II, Part D, Subpart 1, Table 1A, except for a few cases at lower temperatures where values of S_{mt} (defined below and given in Tables HBB-I-14.3A through HBB-I-14.3E) at 300,000 hours exceed the S values. In those limited cases, S_o is equal to S_{mt} at 300,000 hours rather than S. Section II-D, Subpart 1, Table 1A, contains the maximum allowable stress values, S, for ferrous materials for Section I; Section III, Classes 2 and 3, Section VIII, Division 1, and Section XII. Therefore, for both Code Case 1592 and HBB-3221(b)(1), the S_0 values are the same as the S values allowed for ASME III-1, Divisions 2 and 3, which are approved for use by reference in the 2017 Edition of ASME Code III-1, Subsections NC (III-1-NC) and ND (III-1-ND), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a.

The additional language in HBB-3221(b)(1) states that the S_0 values are based on the higher of the Section II-D, Subpart 1, Table 1A S values and the S_{mt} values at 300,000 hours. ANL, 2021, notes that the design loading (S_0) allowable stress intensity values were intended to provide assurance to the original ASME Code Main Committee that the then-new (in the mid-1970's) elevated temperature design rules with time-dependent allowable stress criteria for operating conditions with durations less than 100,000 hours would not result in component thicknesses less than would be achieved under the design rules and allowable stress criteria for Section VIII, Division 1, based on extrapolated 100,000-hour properties. ANL, 2021, further notes that it was later recognized that, at lower temperatures, there was a limited regime where the Section II-D, Tables 1A and 1B, allowable stress values based on time-independent tensile properties could be lower than the S_{mt} intensities at 300,000 hours, leading to a thickness greater than that governed by the S_{mt} intensities at 300,000 hours for Service Level conditions. This was considered to be contrary to the purpose of the criteria for Design Loadings addressing the shorter lifetimes, and, thus, the current allowable stresses for Design Loadings, S_0, are based on the higher of the S value in Section II-D or the value of S_{mt} at 300,000 hours in HBB. The staff therefore finds that an appropriate rationale exists for basing the S_o values on the higher of the Section II-D, Subpart 1, Table 1A S values and the S_{mt} values at 300,000 hours.

Based on the above, the staff finds the definition of S_0 acceptable because it is technically equivalent to that in Code Case 1592, with the exception of the last two sentences of HBB-3221. With respect to these two sentences, an appropriate justification has been provided above, and the ASME Code Section II-D, Subpart 1, Table 1A S values that S_0 values are based on are used in conjunction with the ASME Code III-1, which is approved through incorporation by reference in 10 CFR 50.55a.

The acceptability of the allowable stress values, S_o, given in Table HBB-I-14.2 is evaluated in the review of Mandatory Appendix HBB-I-14 found in this NUREG.

Subsubparagraph HBB-3221(b)(1) – S_t, serves the same purpose as subsubparagraph -3221(b) of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subsubparagraph -3221(b) of Code Case 1592 remains conservative and acceptable, and HBB-3221 is technically equivalent to paragraph -3221 of Code Case 1592, except for the additional limit reduction HBB-3221 sets for the testing parameters used to determine the temperature and time-dependent stress intensity limit. The additional sentence that states the lesser value from (a), (b), and (c) should be used is conservative when compared to the language in Code Case 1592, which only states that (a), (b), and (c) must be considered. Also, the limits indicated in HBB-3221(a) through (c) for S_t are either technically equivalent or conservative compared to those imposed in Code Case 1592, as detailed below:

a) For HBB-3221(b)(1) S_t(a), the updated language of "100% of the average stress required to obtain a total (elastic, plastic, primary, and secondary creep) strain of 1%" is technically equivalent to -3221(b) S_t(a) of Code Case 1592, which states that "the stress required to obtain a total (elastic, plastic, primary, and secondary creep) strain of 1%." This requirement remains conservative and acceptable. Therefore, the staff finds this provision of HBB-3221(b)(1) acceptable, and no further investigation is required.

b) For HBB-3221(b)(1) S_t(b), the updated language of "80% of the minimum stress to cause initiation of tertiary creep" is more conservative than -3221(b) S_t(b) of Code Case 1592, which states "the stress to cause initiation of tertiary creep." HBB-3221 call for the use of the "minimum stress" instead of simply stating "stress" and imposes an additional factor of safety by lowering the stress value from 100% to 80%. Therefore, the staff finds this provision of HBB-3221(b)(1) acceptable because it is more conservative than the requirement of Code Case 1592.

c) For HBB-3221(b)(1) S_t(c), the updated language of “67% of the minimum stress to cause rupture” is more conservative than -3221(b) S_t(c) of Code Case 1592, which states “the stress to cause rupture.” HBB-3221 calls for the use of the “minimum stress” instead of simply stating “stress” and imposes an additional factor of safety by lowering the stress value from 100% to 67%. Therefore, the staff finds this provision of HBB-3221(b)(1) acceptable because it is more conservative the requirement of Code Case 1592.

Subsubparagraph HBB-3221(b)(1) – S_y serves the same purpose as subsubparagraph -3221(b) of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subsubparagraph -3221(b) of Code Case 1592 remains conservative and acceptable, and HBB-3221 is technically equivalent to paragraph -3221 of Code Case 1592, except that it specifies that the yield strength of a material at a given temperature is to be taken from Table HBB-I-14.5. The acceptability of Table HBB-I-14.5 is evaluated in the review of Mandatory Appendix HBB-I-14 found in Section 3.7 of this NUREG.

HBB-3221(b)(2) Weldments

HBB-3221(b)(2) is an added subsubparagraph in the 2017 Edition of the ASME Code III-5, which was not included in Code Case 1592. It indicates that the value for allowable limits of S_{mt} and S_t on the weldments are the lower values taken from Tables HBB-I-14.3A through HBB-I-14.3E and Tables HBB-I-14.4A through HBB-I-14.4E, respectively, or 80 percent of the minimum stress to rupture, S_r, from Tables HBB-I-14.6A through HBB-I-14.6F, scaled by the weld metal to base metal creep rupture strength ratio from Tables HBB-I-14.10A-1 through HBB-I-14.10E-1. This provision places lower allowable limits on the weldment when compared to Code Case 1592, which used the base material allowable limits for the weldments. The staff finds this to be a conservative addition and, therefore, is acceptable.

This subsubparagraph also states that, as described in HBB-2160(d), it may be necessary to adjust the values of S_{mt} to account for the effects of longtime service at elevated temperature, which is the same as is provided by HBB-3221(b)(1) for S_m and S_{mt} for the base metal. The acceptability of these tables and the adjustment to account for long-time service at elevated temperature described in HBB-2160(d) is evaluated in the reviews of Article HBB-2000 and Mandatory Appendix HBB-I-14 found in Section 3.7 of this NUREG.

Based on the above, the staff finds paragraph HBB-3221 acceptable.

Figure HBB-3221-1 Flow Diagram for Elevated Temperature Analysis

The flow diagram of Figure HBB-3221-1 illustrates the rules for design against failure from load-controlled stresses and is divided into two columns: the “Load-Controlled Stress Limits” column and the “Strain and Deformation Limits” column.

<u>“Load-Controlled Stress Limits” Column</u>

The “Design Limits” entry is technically equivalent to this entry in Figure 3220-1 of Code Case 1592 endorsed in RG 1.87, Rev. 1.

The entries for "Levels A and B Service Limits" and the "Level C Limits" are technically equivalent to the entry in Figure 3220-1 of Code Case 1592 endorsed in RG 1.87, Rev. 1. It is noted that the combined primary membrane and bending limits shown in Figure 3220-1 of Code Case 1592 have been split into separate limit entries for readability and usability in Figure HBB-3221-1.

Other than the changes discussed below, the "Level D Service Limits" entry is technically equivalent to this entry in Figure 3220-1 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Changes to the "Level D Service Limits" entry are as follows.

- The changes to the Level D service limits portion of the figure in HBB-3221 are acceptable because the changes are consistent with the changes in HBB-3225 relative to -3225 of the Code Case, which the staff finds acceptable. See the staff's review of Level D service limits in HBB-3225 in Section 3.6.3 of this NUREG.

- The two entries of Code Case 1592 for Collapse Load, C_L, and the Plastic Instability Load have been changed in Figure HBB-3221-1 of HBB-3221 to Nonmandatory Appendix F. The staff finds this acceptable because the 2015 Edition of the ASME Code, Section III, Subsection NB, NB-3225, directs the user to Nonmandatory Appendix F for Level D service limits. It is noted that the 2017 Edition of the ASME Code replaced Nonmandatory Appendix F with Mandatory Appendix XXVII, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions.

<u>"Strain and Deformation Limits" Column</u>

With regard to the "Design Limits" entry, Figure 3220-1 of Code Case 1592 does not impose strain and deformation limits for the design condition. Figure HBB-3221-1 provides that time-independent buckling be checked for the design condition and refers to "Division 1, NB-3133 or HBB-T-1500." ASME Code III-1, NB-3133, has been approved through incorporation by reference in 10 CFR 50.55a without conditions. Adding the provision to investigate buckling is conservative, bolsters the safety of the design, and, therefore, is acceptable. The acceptability of HBB-T-1500 is evaluated in the reviews of Appendix HBB-T found in Section 3.9 of this NUREG.

The entry for Levels A, B, and C Limits is technically equivalent to this entry in Figure 3220-1 of Code Case 1592 endorsed in RG 1.87, Rev. 1, except for the changes to the entry for Levels A, B, and C Limits described below.

The "computed quantity" of Elastic Analysis and Test in Figure HBB-3221-1 replaces the equation shown in Figure 3220-1 of Code Case 1592. The equation is listed as guideline (b) in paragraph HBB-T-1321 from ASME Code III-5 and paragraph T-1321 from Code Case 1592 for satisfying the strain limits using an elastic analysis. The simplification in Figure HBB-3221-1 encompasses the entire subsubarticle HBB-T-1320 on satisfaction of strain limits using elastic analysis, which gives greater detail on how to determine this limit. Therefore, the staff finds this acceptable.

The "controlled quantity for inelastic analysis" variable "D" in Figure HBB-3221-1 replaces the quantity of "1.0" shown in Figure 3220-1 of Code Case 1592. Variable "D" is defined as the total creep-fatigue damage in paragraph HBB-T-1411 from ASME Code III-5 and paragraph T-1411 of Code Case 1592. In both Figure HBB-T-1420-2 of ASME Code III-5 and Figure T-1420-2 of

Code Case 1592, the range of variable “D” goes from 0.0 to 1.0. Therefore, it is acceptable to replace the maximum possible value of “1.0” with the more general form of variable “D” in ASME Code III-5, which allows for a lower creep-fatigue damage envelope. This approach is acceptable because it accounts for some materials that have lower creep-fatigue damage limits. The staff determined the creep-fatigue damage envelope (creep-fatigue interaction diagram) for the Section III-5 Class A materials acceptable as documented in its evaluation of HBB-T-1433 in Section 3.9.4 of this NUREG.

The entry for Level D Limits is technically equivalent to this entry in Figure 3220-1 of Code Case 1592 endorsed in RG 1.87, Rev. 1.

Based on the above, the staff finds Figure HBB-3221-1 acceptable.

HBB-3222 Design and Service Limits

HBB-3222.1 Design Limits

Subparagraph HBB-3222.1 serves the same purpose and is technically equivalent to subparagraph -3222.1 of Code Case 1592 endorsed in RG 1.87, Rev. 1, except for the addition of HBB-3222.1(c). The additional provision of HBB-3222.1(c) accounts for adequate buckling strength and is conservative because Code Case 1592 did not account for this. HBB-3222.1(c) uses the approved rules of the ASME Code III-1, NB-3133, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds subparagraph HBB-3222.1 acceptable.

HBB-3222.2 Level A Service Limits

HBB-3222.2 serves the same purpose and is technically equivalent to the corresponding paragraph in Code Case 1592 endorsed in RG 1.87, Rev. 1. Subparagraph -3222.2 of Code Case 1592 remains conservative and acceptable. Therefore, the staff finds HBB-3222.2 acceptable.

HBB-3223 Level A and B Service Limits

HBB-3223 serves the same purpose as the corresponding paragraph in Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3223 of Code Case 1592 remains conservative and acceptable, and HBB-3223 is technically equivalent to paragraph -3223 of Code Case 1592 except for HBB-3223(g). The additional provision of subparagraph HBB-3223(g) to account for buckling under the provisions of HBB-3250 is conservative because Code Case 1592 does not account for buckling. Therefore, the staff finds HBB-3223 acceptable.

HBB-3224 Level C Service Limits

HBB-3224 serves the same purpose as the corresponding paragraph in Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3224 of Code Case 1592 remains conservative and acceptable, and HBB-3224 is technically equivalent to paragraph –3224 of Code Case 1592. Therefore, the staff finds HBB-3224 acceptable.

HBB-3225 Level D Service Limits

HBB-3225 serves the same purpose as the corresponding paragraph in Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3225 of Code Case 1592 remains conservative and acceptable, and HBB-3225 is technically equivalent, or conservative related to, paragraph -3225 of Code Case 1592. The staff notes that HBB-3225(b) has replaced the Level D service limit of $1.2S_t$ found in -3225 of the Code Case with the lower of 0.67Sr and 0.8*R*Sr, where R is the stress rupture factor (see staff's review of HBB-3221(b)(2) in Section 3.6.3 of this NUREG). Use of $0.67S_r$ is conservative compared to $1.2S_t$ since S_t cannot be greater than $0.67S_r$ (therefore, $0.67S_r$ is less than or equal to $1.0S_t$ (see staff's review of HBB-3221(b)(1) in Section 3.6.3 of this NUREG for a description of how S_t is determined), and using the lower of 0.67Sr and 0.8*R*Sr ensures the Level D allowable stress will not exceed the weldment allowable stress from HBB-3221(b)(2). In doing so, the scale factor of 1.2 has been eliminated, thus lowering the allowables used for the general primary membrane stress intensity. Therefore, the staff finds that the elimination of the factor 1.2 and the use of the reduced minimum stress-to-rupture (see discussion on HBB3221(b)) is conservative relative to the code case, and thus constitutes an acceptable approach for determining the allowable stress intensity values.

Figures HBB-3224-1 and HBB-3224-2

The staff finds Figures HBB-3224-1 and HBB-3224-2 acceptable because these figures summarize the use-fraction information from the acceptable paragraphs (see above) HBB-3224 and HBB-3225 for membrane and membrane plus bending onto Figures HBB-3224-1 and HBB-3224-2, respectively.

HBB-3226 Pressure Testing Limitations

HBB-3226 serves the same purpose as paragraph -3226 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3226 of Code Case 1592 remains conservative and acceptable, and HBB-3226 is technically equivalent to paragraph -3226 of Code Case 1592. Therefore, the staff finds HBB-3226 acceptable.

HBB-3227 Special Stress Limits

HBB-3227 serves the same purpose as paragraph -3227 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3227 of Code Case 1592 remains conservative and acceptable, and HBB-3227 is technically equivalent to paragraph -3227 of Code Case 1592. Therefore, the staff finds HBB-3227 acceptable.

HBB-3227.1 Bearing Loads

Subparagraph HBB-3227.1 serves the same purpose as subparagraph -3227.1 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subparagraph -3227.1 of Code Case 1592 remains conservative and acceptable, and HBB-3227.1 is technically equivalent to -3227.1 except for the additional information provided in HBB-3227.1(a). The additional information in part (1) of HBB-3227.1(a) on the bearing stress limit for levels A, B, and C is similar to and more conservative than that found in Section III, Mandatory Appendix XIII, XIII-3710, for Division 1. The additional information in part (2) of HBB-3227.1(a) in the use of S_y at temperatures above the ASME Code III-1, maximum temperature limits is found in Mandatory Appendix HBB-I-14.

The acceptability of Appendix HBB-I-14 is evaluated in the review of Mandatory Appendix HBB-I-14 found in Section 3.7 of this NUREG. Therefore, the staff finds subparagraph HBB-3227.1 acceptable.

HBB-3227.2 through HBB-3227.7

Subparagraphs HBB-3227.2 through HBB-3227.7 serve the same purpose as subparagraphs -3227.2 through -3227.7 of Code Case 1592, respectively, endorsed in RG 1.87, Rev. 1. Subparagraphs -3227.2 through -3227.7 remain conservative and acceptable, and Subparagraphs HBB-3227.2 through HBB-3227.7 are technically equivalent to -3227.2 through -3227.7, respectively. Therefore, the staff finds HBB-3227.2 through HBB-3227.7 acceptable.

HBB-3227.8 Cladding

Subparagraph HBB-3227.8 serves the same purpose as subparagraph -3227.8 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subparagraph -3227.8 remains conservative and acceptable, and Subparagraph HBB-3227.8 is technically equivalent to -3227.8 of Code Case 1592. Therefore, the staff finds HBB-3227.8 acceptable.

HBB-3230 Stress Limits for Load-Controlled Stresses on Bolts

HBB-3230 serves the same purpose as subarticle -3230 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subarticle -3230 of Code Case 1592 remains conservative and acceptable, and HBB-3230 is technically equivalent to subarticle -3230 of Code Case 1592. Therefore, the staff finds HBB-3230 acceptable.

HBB-3240 Special Requirements for Elevated Temperature Components

HBB-3240 serves the same purpose as subarticle -3240 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subarticle -3240 of Code Case 1592 remains conservative and acceptable, and HBB-3230 is technically equivalent to subarticle -3240 of Code Case 1592. Therefore, the staff finds HBB-3240 acceptable.

HBB-3250 Limits on Deformation-Controlled Quantities

HBB-3250 serves the same purpose as subarticle -3250 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subarticle -3250 of Code Case 1592 remains conservative and acceptable, and HBB-3250 is technically equivalent to subarticle -3250 of Code Case 1592. Therefore, the staff finds HBB-3250 acceptable.

The staff notes that HBB-3252 states that the acceptability criteria and material properties contained in Nonmandatory Appendix HBB-T may be used (with regard to evaluation of buckling, strain, deformation and fatigue limits in the Design Specifications), but that alternative criteria may also be applied by the Manufacturer subject to approval by the Owner. The staff's review of Nonmandatory Appendix HBB-T is in Section 3.9 of this NUREG.

HBB-3300 Vessel Designs

HBB-3310 General Requirements

HBB-3311 Acceptability

HBB-3311 serves the same purpose as paragraph -3311 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3311 of Code Case 1592 remains conservative and acceptable, and HBB-3311 is technically equivalent to paragraph -3311 of Code Case 1592. Therefore, the staff finds HBB-3311 acceptable.

HBB-3330 Openings and Reinforcement

The paragraphs and subparagraphs under subsubarticle HBB-3330 serve the same purpose as those paragraphs and subparagraphs under subsubarticle -3330 of Code Case 1592 endorsed in RG 1.87, Rev. 1. The paragraphs and subparagraphs under subsubarticle -3330 of Code Case 1592 remain conservative and acceptable, and the paragraphs and subparagraphs under subsubarticle HBB-3330 are technically equivalent to the paragraphs and subparagraphs under subsubarticle -3330 of Code Case 1592, with the exception of paragraphs HBB-3331, HBB-3338, and HBB-3339, which are reviewed below. Therefore, the staff finds the paragraphs and subparagraphs under subsubarticle HBB-3330 acceptable.

HBB-3331 General Requirements for Openings

Paragraph HBB-3331 serves the same purpose as paragraph -3331 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3331 of Code Case 1592 remains conservative and acceptable, and HBB-3331 is technically equivalent to paragraph -3331 of Code Case 1592, except subparagraph HBB-3331(b). The added subparagraph HBB-3331(b) conservatively places the limit of 4 inches (100 mm) maximum on the nominal diameter of openings using deposited weld metal as reinforcement shown in Division 1, Figure NB-4244(c)-1, while III-1-NB has no upper limit. Therefore, the staff finds paragraph HBB-3331 acceptable.

HBB-3338 Evaluation of Strain and Creep-Fatigue Limits in Openings

HBB-3338.1 General

Paragraph HBB-3338.1 serves the same purpose as paragraph -3338 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3338 of Code Case 1592 remains conservative and acceptable and HBB-3338.1 is technically equivalent to it. In addition, HBB-3338.1 provides two common engineering methods for determining deformation-controlled stresses. Both these methods are technically equivalent to methods included in NB-3338.1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Paragraph -3338 of Code Case 1592 states that the rules of NB-3338 apply when creep phenomena are insignificant and subsubarticle -3250 applies when creep effects are significant. Subsubarticle -3250 is technically equivalent to HBB-3250. Therefore, creep effects are accounted for under the provisions of HBB-3250. In addition, the staff also notes that although NB-3338.1 addresses design of openings in low-temperature vessels, the general provisions for vessel design in HBB-3311 refer to the general provisions for design of Class A components in HBB-3111, which address high temperature effects such as creep and creep-fatigue. Therefore, the staff finds subparagraph HBB-3338.1 acceptable.

HBB-3338.2 Stress Index Method

For stress indices and rules to determine stress components due to pressure in satisfying strain and creep-fatigue limits using elastic and simplified inelastic analyses, subparagraph HBB-3338.2 points to ASME Code III-1, NB-3338, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3338.2 acceptable.

HBB-3339 Alternative Rules for Nozzle Design

HBB-3339 expands the provisions of paragraph -3339 of Code Case 1592 by calling for the wall thickness, t_r, to be defined by ASME Code III-5, Subsection HBB, instead of allowing it to be defined by Division 1, Subsection NB. Additionally, HBB-3339 aligns itself with NB-3339 as an acceptable alternative to the rules of HBB-3332 through HBB-3336 and HBB-3338, which is technically equivalent to what is stated in NB-3339 for an alternative to the rules of NB-3332 through NB-3336 and NB-3338. The NRC has previously approved NB-3339 through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds paragraph HBB-3339 acceptable.

HBB-3339.1 Stress Indices

Subparagraph HBB-3339.1 indicates that the stress indices and rules of NB-3339.7 may be used to determine stress components due to pressure in satisfying strain and creep-fatigue limits using elastic and simplified inelastic analyses. HBB-3339.1 serves the same purpose and is technically equivalent to ASME Code III-1, NB-3339.7, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-3339.1 acceptable.

HBB-3350 Design of Welded Construction

Paragraphs and subparagraphs under subsubarticle HBB-3350 with Figures HBB-3351-1 and HBB-3352-1 serve the same purpose as those paragraphs and subparagraphs under subsubarticle -3350 of Code Case 1592 endorsed in RG 1.87, Rev. 1. The paragraphs and subparagraphs under subsubarticle -3350 of Code Case 1592 remain conservative and acceptable, and the paragraphs and subparagraphs under subsubarticle HBB-3350 are technically equivalent to the paragraphs and subparagraphs under subsubarticle -3350 of Code Case 1592, with the exception of HBB-3352, HBB-3354, HBB-3356.2, and HBB-3356.2, which are reviewed below. Therefore, the staff finds the paragraphs and subparagraphs under subsubarticle HBB-3350 acceptable.

HBB-3352 Permissible Types of Welded Joints

Subparagraphs HBB-3352(a) through HBB-3352(g) are technically equivalent to subparagraphs -3352(a) through -3352(g), respectively, of Code Case 1592 endorsed in RG 1.87, Rev. 1, with the exception of an added subparagraph, HBB-3352(h), for full-penetration corner welds (as shown in III-1-NB, Figures NB-4243-1 and NB-4244(b)-1, and defined as Category C and D vessel welds, or as similar welds for piping, pumps, and valves). HBB-3352(h) conservatively limits the nominal diameter for full-penetration corner welds to 4 inches (100 mm) or less, while III-1-NB does not have an upper limit. Therefore, the staff finds paragraph HBB-3352 acceptable.

HBB-3354 Structural Attachment Welds

Paragraph HBB-3354 serves the same purpose as paragraph -3354 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3354 of Code Case 1592 remains conservative and acceptable, and HBB-3354 is technically equivalent to paragraph -3354 of Code Case 1592, except for the additional information described below. The additional weld provision of NB-4240 referenced in subparagraph HBB-3354(a) dictates the types of acceptable welds according to category instead of leaving the weld type to the discretion of the applicant. The additional provisions in subparagraph HBB-3354(b) for attachments using the exemption of HBB-2121(h) call for the structural attachment welds to be on a rib outside the limits of reinforcement, as defined in NB-3334, and to comply with the rules of Class A pressure boundary welds. In this regard, HBB-3354(b) is technically equivalent to NB-3354, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55 without conditions. In addition, HBB-3354 provides that the loads on the pressure boundary imposed by all permanent attachments be considered in the Design Report. As shown above, the additional information in paragraph HBB-3354 is an improvement over paragraph -3354 of Code Case 1592. The acceptability of HBB-2121(h) is evaluated in the review of Article HBB-2000 found in this NUREG. Therefore, the staff finds paragraph HBB-3354 acceptable.

HBB-3356 Fillet Welds

HBB-3356.2 At Structural Attachment Joints

Subparagraph HBB-3356.2 applies to fillet welds at structural attachment joints. HBB-3356 serves the same purpose as paragraph -3356 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraph -3356 of Code Case 1592 remains conservative and acceptable, and HBB-3356 is technically equivalent to paragraph -3356 of Code Case 1592, except for the added subsubparagraph HBB-3356.2(c). Subsubparagraph HBB-3356.2(c) calls for the applicant to consider the temperature differences between the component and the attachment and of expansion (or contraction) of the component due to pressure and also to use a fatigue reduction factor of four. This approach is consistent with evaluating fatigue strength in the ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, and which also applies to components operating in high-temperature applications. Therefore, the staff finds subparagraph HBB-3356.2 acceptable.

HBB-3360 Special Vessel Requirements

The paragraphs under HBB-3360 serve the same purpose as the paragraphs under -3360 of Code Case 1592 endorsed in RG 1.87, Rev. 1. The paragraphs under -3360 of Code Case 1592 remain conservative and acceptable, and the paragraphs under HBB-3360 are technically equivalent to the paragraphs under -3360 of Code Case 1592. Therefore, the staff finds HBB-3360 and the paragraphs under HBB-3360 acceptable.

HBB-3400 Design of Class A Pumps

HBB-3410 General Requirements

The general provisions for the design of Class A pumps presented in subsubarticle HBB-3410, with its paragraphs and subparagraphs, including Figures HBB-3410.2-1 and HBB-3410.2-2, serve the same purpose as the paragraphs, subparagraphs, and figures found in subsubarticle -3410 of Code Case 1592 endorsed in RG 1.87, Rev. 1. These provisions of

Code Case 1592 remain conservative and acceptable, and the provisions in HBB-3410 are technically equivalent to the provisions in -3410 of Code Case 1592. Therefore, the staff finds subsubarticle HBB-3410, with its paragraphs and subparagraphs, including Figures HBB-3410.2-1 and HBB-3410.2-2 acceptable.

HBB-3420 Design Considerations

HBB-3421 Design Requirements

The provisions for the design of Class A pumps presented in the subparagraphs of paragraph HBB-3421 serve the same purpose as subparagraphs under paragraph -3421 of Code Case 1592 endorsed in RG 1.87, Rev. 1. These provisions of Code Case 1592 remain conservative and acceptable, and the provisions in HBB-3421 are technically equivalent to the provisions in -3421 of Code Case 1592, except subparagraph HBB-3421.19, which the staff has accepted for the reasons set forth below. Therefore, the staff finds the subparagraphs of paragraph HBB-3421 acceptable.

HBB-3421.19 Cutwater Tip Stresses

Subparagraph HBB-3421.19 serves the same purpose as subparagraph -3421.19 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subparagraph -3421.19 of Code Case 1592 remains conservative and acceptable, and HBB-3421.19 is technically equivalent to subparagraph -3421.19 of Code Case 1592, except subsubparagraph HBB-3421.19(a), as explained in the next paragraph. In addition, some differences exist when referring to Subsection NB. These are editorial changes made between Subsection NB of the 1971 Edition of the ASME Code, which was in effect when Code Case 1592 was introduced, and Subsection NB of the 2017 Edition of the ASME Code. These editorial changes do not affect the substance of HBB-3421.19.

Subsubparagraph HBB-3421.19(a) explicitly states that sufficient area at the cutwater tip of volute casings must be present to meet the stress limits of HBB-3220 through the evaluation of load-controlled stresses. The addition of this subsubparagraph is conservative because it mandates that the applicant evaluate the design of the cutwater tip against the Design and Service Limits, which Code Case 1592 did not specify. Therefore, the staff finds subparagraph HBB-3421.19 acceptable.

HBB-3430 Pump Types

Paragraph HBB-3430 states that design requirements for specific pump types are listed in Division 1, NB-3430 but does not specify that these design requirements are for regions where creep is negligible. As stated in HBB-1110, Scope, stress limits and design rules of Division 1, Subsection NB are applicable only to service conditions where creep and relaxation effects are negligible. Based on the above, the staff finds HBB-3430 acceptable with the following exception:

- The NRC staff does not endorse HBB-3430 as written. Instead, the applicant or licensee should use the following: Descriptions and definitions of common pump types are listed in NB-3440.

The basis for this exception is that it is equivalent to paragraph -3430 of Code Case 1592, which has been approved for use through NRC RG 1.87.

HBB-3500 Design of Class A Valves

HBB-3510 Design Requirements

The paragraphs in subsubarticle HBB-3510, HBB-3511, and HBB-3512 serve the same purpose as paragraphs -3511 and -3512 in subsubarticle -3510 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Paragraphs -3511 and -3512 in subsubarticle -3510 of Code Case 1592 remain conservative and acceptable, and the paragraphs in subsubarticle HBB-3510, HBB-3511, and HBB-3512 are technically equivalent to the provisions of Code Case 1592, except paragraph -3513 and accompanying Table -3513-1 are deleted. The omission of Code Case 1592 paragraph -3513 and accompanying Table -3513-1 from subsubarticle HBB-3510 is acceptable because this general requirement is inherently part of HBB-3512, which sends the applicant to III-1 NB-3500. Therefore, the staff finds subsubarticle HBB-3510 acceptable.

HBB-3520

HBB-3524 Earthquake Design Analysis

Paragraph HBB-3524 serves the same purpose as the corresponding paragraph in -3520 of Code Case 1592 endorsed in RG 1.87, Rev. 1. The provision of Code Case 1592 remains conservative and acceptable, and HBB-3524 is technically equivalent to it. Therefore, the staff finds HBB-3524 acceptable.

HBB-3526 Level C Service Limits

Paragraph HBB-3526 serves the same purpose as the corresponding paragraph in -3520 of Code Case 1592 endorsed in RG 1.87, Rev. 1. The provision of Code Case 1592 remains conservative and acceptable, and HBB-3526 is technically equivalent to it. Therefore, the staff finds HBB-3526 acceptable.

HBB-3540

HBB-3544 Body Shape Rules

Paragraph HBB-3544 serves the same purpose as the corresponding paragraph in -3540 of Code Case 1592 endorsed in RG 1.87, Rev. 1. The provision of Code Case 1592 remains conservative and acceptable, and HBB-3544 is technically equivalent to it. Therefore, the staff finds HBB-3544 acceptable.

HBB-3546 Other Valve Parts

Paragraph HBB-3546 serves the same purpose as the corresponding paragraph in -3540 of Code Case 1592 endorsed in RG 1.87, Rev. 1. The provision of Code Case 1592 remains conservative and acceptable, and HBB-3546 is technically equivalent to it. Therefore, the staff finds HBB-3546 acceptable.

HBB-3550 Cyclic Loading Requirements

Subsubarticle HBB-3550 serves the same purpose as subsubarticle -3550 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subsubarticle -3550 of Code Case 1592 remains conservative and acceptable, and HBB-3550 is technically equivalent to subsubarticle -3550 of Code Case 1592. Therefore, the staff finds HBB-3550 acceptable.

HBB-3600 Piping Design

Subarticle HBB-3600 provides the provisions and design criteria for the acceptability of Class A piping systems. HBB-3600 serves the same purpose as subarticle -3600 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subarticle -3600 of Code Case 1592 remains conservative and acceptable, and HBB-3600 is technically equivalent to subarticle -3600 of Code Case 1592, except for paragraphs HBB-3651 and HBB-3660, which the staff determined are acceptable as described below. However, Subparagraph HBB-3643.2, Branch Connections, shows that one the methods for branch connections in piping may use socket welded connections, which are subject to a condition in 10 CFR 50.55a applicable to ASME III-1. This is a longstanding condition in 10 CFR 50.55a that was included to address concerns related to the structural integrity of socket welds if the weld leg length was less than the pipe wall thickness that arose after ASME modified the Section III, Division 1 requirements to allow a leg length as small as 0.75 times the wall thickness ($0.75t_n$), which the NRC determined was not supported by test data. The staff has determined this condition to be equally applicable to socket welds in high temperature applications because the same concerns related to the structural integrity of socket welds exist if the weld leg length is less than 1.09 times the nominal pipe wall thickness. Therefore, the staff finds HBB-3600 acceptable with the following exception:

- The staff does not endorse the use of Section III provisions in accordance with HBB-3600, HBB-3660, HCB-3150, and HCB-4000 for socket welded fittings used in pressure-retaining joints and referenced in HBB-3000, HCB-3000 and HCB-4000, for welds with leg size less than 1.09* t_n, where t_n is the nominal pipe thickness.

HBB-3651 General Requirements

The general provisions for the analysis of Class A piping systems presented in paragraph HBB-3651 serve the same purpose and are technically equivalent to those in paragraph -3651 of Code Case 1592 endorsed in RG 1.87, Rev. 1, except the addition of HBB-3651(c) and the expansion in HBB-3651(b). The added subparagraph HBB-3651(c) indicates that computerized finite element analysis may be used, which is acceptable since the advancement of finite element analysis since the endorsement of Code Case 1592 has allowed for realistic detailed stress distributions. The expansion in HBB-3651(b) does the following. Its first sentence adds more detail to the limits on load-controlled stresses by stating primary and secondary stress indices (B and C) instead of just stress indices as written in -3651(b) of Code Case 1592. This is acceptable based on the definition of load-controlled stresses in HBB-3213(a). It also points to HBB-T-1320, which uses primary and secondary stress in the elastic analysis to satisfy the strain limits of HBB-T-1310. The second sentence of HBB-3651(b) is technically equivalent to that in the remainder of -3651(b) of Code Case 1592 and provides the actual location in NB-3600 to determine the stress indices to be used in satisfying strain and creep-fatigue limits using elastic and simplified inelastic analyses outlined in HBB-T-1320, HBB-T-1330, and HBB-T-1430.

The staff has determined that the use of HBB-T-1320, HBB-T-1330 and HBB-T-1430 is acceptable for the reasons set forth in the review of Appendix HBB-T found in Section 3.9 of this NUREG.

HBB-3660 Design of Welds

Subsubarticle HBB-3660 serves the same purpose as subsubarticle -3660 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subsubarticle -3660 of Code Case 1592 remains conservative and acceptable, and HBB-3660 is technically equivalent to subsubarticle -3660 of Code Case 1592, except the last sentence in subparagraph HBB-3660(b). The last sentence in subparagraph HBB-3660(b) conservatively limits the size for socket-welded joints and seal-welded threaded joints, where allowed, to 25 millimeters (1 inch) and smaller, while III-1-NB has an upper limit of no more than 50 millimeters (2 inches) on socket-welded joints and no upper limit on seal-welded threaded joints. However, and as has been stated above (under HBB-3600), 10 CFR 50.55a conditions the use of socket welds for ASME Section III applications to address concerns related to the structural integrity of socket welds if the weld leg length was less than the pipe wall thickness. Therefore, the staff finds Subsubarticle HBB-3660 acceptable with the following exception:

- The staff does not endorse the use of Section III provisions in accordance with HBB-3600, HBB-3660, HCB-3150, and HCB-4000 for socket welded fittings used in pressure-retaining joints and referenced in HBB-3000, HCB-3000 and HCB-4000, for welds with leg size less than 1.09* t_n, where t_n is the nominal pipe thickness.

3.6.4 Article HBB-4000 Fabrication and Installation

ASME Code III-5, Article HBB-4000, allows those portions of the component that do not experience elevated temperature service (as defined by the rules of Article HBB-3000) to use Division 1, Article NB-4000, rules as applicable. HBB-4000 provides that those portions of the component that do not meet these conditions shall comply with the provisions of Subsection HBB-4000 in addition to the rules of Division 1, Article NB-4000. HBB-4000 also provides that those portions of the component to which either of the two options described above apply shall be identified during all phases of manufacture and installation.

HBB-4000 includes some provisions from Code Case 1593, which were approved for use through RG 1.87, Rev. 1, and new added sections. NB-4000 has been modified since the publication of Code Case 1593 and now includes more detailed and updated provisions. The provisions of HBB-4000 apply in addition to the rules of NB-4000, as applicable. In some instances, the rules of HBB-4000 supplement those in NB-4000. In other cases, the rules in HBB-4000 replace the rules in corresponding paragraphs in NB-4000. In its review of Article HBB-4000, the staff referred to RG 1.87, Rev. 1, where appropriate, and used PNNL, 2020. The staff’s review of HBB-4000 appears below.

HBB-4100 General Requirements

HBB-4110 Introduction

Paragraph HBB-4110 serves the same purpose as the Reply paragraph of Code Case 1593 endorsed in RG 1.87, Rev. 1. The Reply paragraph remains conservative and acceptable, and HBB-4110 is technically equivalent to the Reply paragraph. Therefore, the staff finds HBB-4110 acceptable. Note that the Reply paragraph of Code Case 1593 erroneously references Section III “NB-400” instead of “NB-4000.” This has been corrected in HBB-4110.

HBB-4200

HBB-4210

HBB-4212 Effects of Forming and Bending Processes

HBB-4212 includes provisions in addition to those in NB-4212 and NB-4213 and these additional provisions are more detailed than those listed in Code Case 1593.

HBB-4212 calls for a post-fabrication heat treatment, or a written justification for not performing a heat treatment, when local strains exceed 5 percent. HBB-4212 provides limits on the use of a written justification, in lieu of performing a post-fabrication heat treatment, for cold-worked 304 SS, 316 SS, and Alloy 800H, as discussed below.

When HBB-4212 calls for post-fabrication heat treatment of ferritic materials, HBB-4212(b)(1) specifies that the heat treatment conform to the provisions of ASME III-1, Table NB-4622.1-1. Table NB-4622.1-1 provides the time and temperature for postweld heat treatments (PWHTs). The staff finds this acceptable because the specified time and temperature for PWHT of ferritic welds are also adequate to relieve stress after forming or bending operations. Alternatively, ferritic base material and welds may be reheat treated and recertified with the applicable material specification and the provisions of Division 1, NB-2400, which is acceptable because reheat treatment and recertification, after forming and bending operations, in accordance with the original material specification will restore the material to its original prefabrication condition. For austenitic materials, except Alloy 800H, HBB-4212 indicates that post-fabrication heat treatment, when called for, shall consist of heat treatment in accordance with the base material specification. The staff finds this acceptable because the heat treatment specified in the original material specification will restore the material to the solution annealed condition. For Alloy 800H, HBB-4212 states the appropriate heat treatment provisions and the resulting grain size necessary to ensure optimal performance at higher temperatures.

HBB-4212 includes Figure HBB-4212-1, “Permissible Time/Temperature Conditions for Material Which Has Been Cold Worked >5% and <20% and Subjected to Short-Time High Temperature Transients.” Subsequent to ASME Code approval of Code Case 1593, the DOE sponsored a substantial multiyear research effort on the use of cold-worked 304 and 316 SS, as well as nickel-iron chromium Alloy 800H, in high-temperature environments. The purpose of this research was to provide a database for subsequent use by individuals or groups within the ASME Code committees. Cold work lowers the recrystallization temperature of these materials, when compared to materials in the annealed condition, and as a result, degrades creep properties. Figure HBB-4212-1 provides acceptable limits for cold work for 304, 316, and 800H between 5 percent and 20 percent, as a function of operating time and temperature, where significant recrystallization does not occur. The staff located and reviewed two papers (Lai, 1977 and Moen, 1978) that summarize DOE-funded research data on the recrystallization behavior of 304, 316, and 800H. The staff determined that Figure HBB-4212-1 was developed based on this data and is therefore acceptable.

HBB-4240 Special Joints and Fittings—Added Rules for Division 1, NB-4240

The staff finds paragraph HBB-4240 acceptable as written. HBB-4240 calls for the evaluation of socket welds to determine whether an axial gap is needed at the bottom of the socket to prevent the pipe from bottoming out during service due to thermal expansion. If a gap is determined necessary, then it should be verified by radiographic examination or by following special written procedures. While radiography is the most conservative method to measure the bottom clearance in a socket weld, verifying bottoming clearance by following special written procedures during fabrication is the most commonly used method to verify an axial gap at the pipe end/socket bottom interface and the NRC staff experience with this method is that it is effective in verifying the clearance. Accordingly, the staff has determined this method is acceptable for verifying adequate clearance.

HBB-4400

HBB-4420

HBB-4424 Surfaces of Welds

The staff finds paragraph HBB-4424 acceptable as written. HBB-4424 states that as-welded surface geometry is permitted, provided that the surface geometry is considered in the stress analysis in accordance with the rules for the design of Class A elevated temperature components. Including the surface geometry in the stress analysis will ensure that the impact of as-welded surfaces will be appropriately accounted for by using the proper stress indices when performing the analysis in accordance with HBB-3600.

3.6.5 Article HBB-5000 Examination

ASME Code III-5, Article HBB-5000, allows those portions of the component that do not experience elevated temperature service (as defined by the rules of Article HBB-3000) to use Division 1, Article NB-5000 rules unchanged by Article HBB-5000. HBB-5000 indicates that those portions of the component that operate at elevated temperature shall comply with the provisions of Subsection HBB-5000 in addition to the rules of Division 1, Article NB-5000. HBB-5000 also indicates that those portions of the component to which either of the two options described above apply shall be identified during all steps of examination.

HBB-5000 includes some provisions from Code Case 1594, which was approved for use through NRC RG 1.87, Rev. 1, and new added sections. NB-5000 has been modified since the publication of Code Case 1594 and now includes more detailed and updated requirements than it did previously. The provisions of HBB-5000 should be followed in addition to the rules of NB-5000, as applicable. In some instances, the rules of HBB-5000 supplement those in NB-5000. In other cases, the rules in HBB-5000 replace the rules in corresponding paragraphs in NB-5000. In its review of Article HBB-5000, the staff referred to RG 1.87, Rev. 1, where appropriate, and used PNNL, 2020. The staff’s review of HBB-5000 appears below.

HBB-5100 General Requirements for Examination

HBB-5110 General Requirements

HBB-5110 serves the same purpose as the Reply paragraph of Code Case 1594 endorsed in RG 1.87, Rev. 1. The Reply paragraph of Code Case 1594 remains conservative and acceptable, and HBB-5110 is technically equivalent to the Reply paragraph of Code Case 1594. Therefore, the staff finds HBB-5110 acceptable.

HBB-5130 Examination of Weld Edge Preparation Surfaces

HBB-5130 conservatively calls for an additional level of component examination with acceptable NDE methods for weld thickness greater than 25 millimeters (1 inch) compared to NB-5130. Accordingly, HBB-5130 is more conservative than NB-5130, and is acceptable.

HBB-5200 Required Examination of Welds

HBB-5210 Category A Vessel Welded Joints and Longitudinal Welded Joints in Other Components

HBB-5210 serves the same purpose as paragraph 1.0 of Code Case 1594, previously endorsed in RG 1.87, Rev. 1. Paragraph 1.0 of Code Case 1594 remains conservative and acceptable except Code Case 1594 was subsequently revised to provide for the use of additional inspection methodologies while eliminating a statement on radiography that was not relevant. HBB-5210 is technically equivalent to Section 1.0 of Code Case 1594 except it includes the subsequent revisions. The provision in subparagraph 1.0(b)(2) of Code Case 1594 to conduct radiography at orientations at least 30 degrees but not more than 150 degrees apart is not relevant. Because radiography views through the object, radiographic examinations taken 180 degrees apart show the same material, just from the opposite side. Thus, angles greater than 150 degrees would be less than the original 30 degrees from the vertical initially specified. Therefore, the staff finds HBB-5210 acceptable because it provides examination requirements that are better defined and more specific than those endorsed in RG 1.87, Rev. 1, in accordance with accepted NDE methods and examination volumes.

HBB-5220 Category B Vessel Welded Joints and Circumferential Welded Joints in Other Components

HBB-5220 incorporates paragraph 2.0 of Code Case 1594, Revision 0, which has been approved for use through NRC RG 1.87. Paragraph HBB-5220 also includes clarifications given in Code Case 1594, Revision 1, which was prepared by ASME in 1975. The NRC did not subsequently revise RG 1.87, issued in 1975, to incorporate the clarified inspection information.

The staff finds HBB-5220 acceptable because it states examination provisions that are better defined and more specific than those in Code Case 1594, in accordance with accepted NDE methods and examination volumes.

HBB-5230 Category C Vessel Welded Joints and Similar Welded Joints in Other Components

The NDE methods and examination volumes identified are proven based on applicability to similar type welds. HBB-3351.3 describes Category C welds as comprising welds connecting flanges, tube sheets, or flat heads to main shells and formed heads to transitions in diameter, nozzles, or communicating chambers; effectively, any weld joint connecting one side plate to another side plate of a flat-sided vessel. HBB-5230 provides expanded information on the provisions for proper NDE of welds made under this paragraph over the information provided in NB-5230 (NB-5231) and states NDE methods for configurations that would be difficult to properly inspect by some methods. Therefore, the staff finds HBB-5230 acceptable.

HBB-5240 Category D Vessel Welded Joints and Branch and Piping Connections in Other Components

HBB-5240 substitutes the rules in HBB-5240 for the rules in NB-5240.

HBB-5242 Butt-Welded Nozzles and Branch and Piping Connections

The NDE methods and examination volumes identified are proven based on applicability to similar type welds. These types of welds involve full-penetration joining of metal in the installation or fabrication of flanges, nozzles, and piping connections. This paragraph provides expanded direction on inspection compared to previously endorsed Code Case 1594, paragraph 3.0, resulting in better guidance on the evaluation of welds, depending on sizes and configurations. Therefore, the staff finds HBB-5242 acceptable.

HBB-5243 Full Penetration Corner-Welded Nozzles and Branch and Piping Connections

The NDE methods and examination volumes identified are proven based on applicability to similar type welds. These types of welds involve full-penetration joining of metal in the installation or fabrication of flanges, nozzles, and piping connections. This paragraph provides expanded guidance on inspection compared to previously endorsed Code Case 1594, paragraph 3.0, resulting in better direction on the evaluation of welds, depending on sizes and configurations. Therefore, the staff finds HBB-5243 acceptable.

HBB-5244 Deposited Weld Metal as Reinforcement for Openings and Attachment of Nozzles, Branch, and Piping Connections

The NDE methods and examination volumes identified are proven based on applicability to similar type welds. These types of welds involve full-penetration joining of metal in the installation or fabrication of flanges, nozzles, and piping connections. This paragraph provides expanded guidance on inspection compared to previously endorsed Code Case 1594, paragraph 3.0, resulting in better direction on the evaluation of welds, depending on sizes and configurations. Therefore, the staff finds HBB-5244 acceptable.

HBB-5245 Partial Penetration Welds

The NDE methods and examination volumes identified are proven based on applicability to similar type welds. These types of welds involve partial-penetration joining of metal in the installation or fabrication of flanges, nozzles, and piping connections. These types of welds include fillet welds on small-diameter applications. This paragraph provides expanded guidance on inspection compared to previously endorsed Code Case 1594, paragraph 3.0, resulting in better direction on the evaluation of welds, depending on sizes and configurations. Therefore, the staff finds HBB-5245 acceptable.

HBB-5246 Full Penetration Category D Welds at Oblique Connections

While the 1973 Code Case 1594, paragraph 3.0, did not permit the examinations defined in this paragraph, the NDE methods identified in HBB-5246 provide surface and volumetric coverage and call for the removal of backing rings and preparation of the bore surface to be compatible with the NDE method used. HBB-5246 provides expanded direction on the inspection compared to previously endorsed Code Case 1594, paragraph 3.0, resulting in better guidance on the evaluation of welds, depending on sizes and configurations. Therefore, the staff finds HBB-5246 acceptable.

HBB-5260 Fillet, Socket, and Attachment Welds

HBB-5261 Fillet and Socket Welds

The NDE methods and examination volumes identified in paragraph HBB-5261 are proven based on applicability to similar type welds. HBB-5261 reiterates that HBB-3000 restricts the use of fillet and socket welds to small-diameter joints It further includes provisions for enhanced inspection to ensure that planned clearances exist after welding, which is not called for by NB-5261. The limit on fillet and socket weld size and the enhanced inspection to verify the axial gap at the base of the socket weld mitigates fatigue due to thermal and mechanical stresses at high temperature. Therefore, the staff finds HBB-5261 acceptable.

HBB-5262 Permanent Structural Attachment Welds

HBB-5262 incorporates paragraph 4.0 of Code Case 1594, which has been approved for use through NRC RG 1.87, with examination provisions that are better defined and more specific than Code Case 1594 with accepted NDE methods and examination volumes. Therefore, the staff finds HBB-5262 acceptable.

HBB-5263 Nonstructural and Temporary Attachments

HBB-5263 serves the same purpose as paragraph 4.2 of Code Case 1594 endorsed in RG 1.87, Rev. 1. Paragraph 4.2 of Code Case 1594 remains conservative and acceptable, and HBB-5262 is technically equivalent to paragraph 4.2 of Code Case 1594. Therefore, the staff finds HBB-5262 acceptable.

3.6.6 Article HBB-6000 Testing

HBB-6100 General Requirements

HBB-6100 states that testing of ASME Code III-5, Class A components when metal temperatures exceed those for which allowable stress values are given in Section II, Part D, Subpart 1, shall be in accordance with Subsection HB.

HBB-6110 Scope of Testing

HBB-6111 General Hydrostatic and Pneumatic Test Media

HBB-6111 serves the same purpose as paragraph -6111 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph-6111 of Code Case 1595 remains conservative and acceptable, and HBB-6111 is technically equivalent to paragraph-6111 of Code Case 1595. Therefore, the staff finds HBB-6111 acceptable.

HBB-6112 Pressure Testing of Components and Appurtenances

HBB-6112 serves the same purpose as paragraph-6112 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6112 of Code Case 1595 remains conservative and acceptable, and HBB-6112 is technically equivalent to paragraph -6112 of Code Case 1595, except for subparagraphs HBB-6112(f)–(g). HBB-6112(f) allows the components or appurtenance pressure-testing conducted in accordance with HBB-6221 (Hydrostatic) or HBB-6321 (Pneumatic) to be applicable as a pressure test of part and piping subassemblies. This is technically equivalent to Code Case 1595, subparagraph 6114(a), except for the use of the pneumatic pressure test. The addition of this option for those components needing a pneumatic pressure test provides flexibility and has no impact on safety. HBB-6112(g) states that components and appurtenances subjected to external pressure loads in service may be pressure tested following the provisions of HBB-6112(a) on the basis of an internal pressure test and that additional tests may be needed to demonstrate structural integrity under external pressure loads. This approach is acceptable because it makes clear that the Design Specification may call for further tests, other than an internal pressure test, to demonstrate structural integrity under external pressure loading.

Therefore, the staff finds HBB-6112 acceptable.

HBB-6113 Pressure Testing of Systems

HBB-6113 serves the same purpose as paragraph -6113 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6113 of Code Case 1595 remains conservative and acceptable, and HBB-6113 is technically equivalent to paragraph -6113 of Code Case 1595. Therefore, the staff finds HBB-6113 acceptable.

HBB-6115 Time of Pressure Test and Stamping of Components and Appurtenances

HBB-6115(a) appropriately references HBB-6112(a), which was incorrectly referenced as paragraph -6111 in Code Case 1595. Paragraph 6112 was the correct reference to provisions for pressure testing of components and appurtenances. HBB-6115(a) also points to the hydrostatic and pneumatic pressure-testing sections (HBB-6221(a) and HBB-6321(a)), which provide the appropriate provisions for pressure testing components and appurtenances, and are, therefore, acceptable. HBB-6221(a) and HBB-6321(a) are acceptable for the reasons discussed below.

Subparagraph HBB-6115(b) permits pressure tests of components and appurtenances called for by HBB-6112(a) to be performed after installation if the system pressure test is used under the provisions of HBB-6221(c) or HBB-6321(c). The staff finds this acceptable as described below in the staff’s evaluation of subparagraphs HBB-6221(c) or HBB-6321(c).

Subparagraph HBB-6115(c) serves the same purpose as the second written sentence of paragraph -6115 of Code Case 1595 endorsed in RG 1.87, Rev. 1. This sentence in Code Case 1595 remains conservative and acceptable, and HBB-6115(c) is technically equivalent to the second written sentence of paragraph -6115 of Code Case 1595. Therefore, the staff finds subparagraph HBB-6115(c) acceptable.

Subparagraph HBB-6115(d) states that specially designed seal welds that are identified on the Data Report Form as being welded by the Installer under the rules of HBB-6118 need not be tested before the stamping of the component. The staff finds this acceptable, as described below in the staff’s evaluation of paragraph HBB-6118.

HBB-6115(e) serves the same purpose as the last written sentence of paragraph -6115 of Code Case 1595 endorsed in RG 1.87, Rev. 1. This sentence in Code Case 1595 remains conservative and acceptable, and HBB-6115(e) is technically equivalent to the last written sentence of paragraph -6115 of Code Case 1595, except for the added portion that calls for pressure testing of pumps not designed by detailed analysis before installation in the piping system. The staff finds that it is acceptable to exempt pumps designed by detailed analysis from preinstallation pressure testing because a detailed analysis provides added assurance of the structural integrity of a component. This does not eliminate the need to pressure test the system in accordance with paragraph HBB-6121. Therefore, the staff finds HBB-6115(e) acceptable.

HBB-6116 Machining of Local Areas After Static Pressure Testing

Subparagraphs HBB-6116(a) and HBB-6116(b) serve the same purpose and are technically equivalent to the approach given in III-1 NB-6115 for Class 1 (Class A for III-5 use) components, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds subparagraphs HBB-6116(a) and HBB-6116(b) acceptable.

Subparagraph HBB-6116(c) provides that the final wall thickness, after machining to critical dimensions and tolerances, comply with the minimum wall thickness defined in the rules for the design of Class A components for elevated temperature service. The staff finds subparagraph HBB-6116(c) acceptable because the provision will ensure that components are verified to meet minimum wall thicknesses after final machining is complete.

HBB-6117 Alternative Tests of Closure Welds and Access Hatches

Paragraph HBB-6117 serves the same purpose as subparagraphs -6116(a) and -6116(b) of Code Case 1595 endorsed in RG 1.87, Rev. 1. Subparagraphs -6116(a) and -6116(b) of Code Case 1595 remain conservative and acceptable, and HBB-6117 is technically equivalent to them. Therefore, the staff finds subparagraph HBB-6117 acceptable.

HBB-6118 Alternative Tests at Specially Designed Welded Seals

Paragraph HBB-6118 serves the same purpose as paragraph -6127 and subparagraph -6116(c) of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6127 and subparagraph -6116(c) of Code Case 1595 remain conservative and acceptable, and HBB-6118 is technically equivalent to them. Therefore, the staff finds subparagraph HBB-6118 acceptable.

HBB-6120 Preparation for Testing

HBB-6121 Exposure of Joints

Paragraph HBB-6121 serves the same purpose as paragraph -6121 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6121 of Code Case 1595 remains conservative and acceptable, and HBB-6121 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6121 acceptable.

HBB-6122 Addition of Temporary Supports

Paragraph HBB-6122 serves the same purpose as paragraph -6122 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6122 of Code Case 1595 remains conservative and acceptable, and HBB-6122 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6122 acceptable.

HBB-6123 Restraint or Isolation of Expansion Joints

Paragraph HBB-6123 serves the same purpose as paragraph -6123 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6123 of Code Case 1595 remains conservative and acceptable, and HBB-6123 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6123 acceptable.

HBB-6124 Isolation of Equipment Not Subjected to Pressure Test

Paragraph HBB-6124 serves the same purpose as paragraph -6124 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6124 of Code Case 1595 remains conservative and acceptable, and HBB-6124 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6124 acceptable.

HBB-6125 Treatment of Flanged Joints Containing Blinds

Paragraph HBB-6125 serves the same purpose as paragraph -6125 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6125 of Code Case 1595 remains conservative and acceptable, and HBB-6125 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6125 acceptable.

HBB-6126 Precautions Against Test Medium Expansion

Paragraph HBB-6126 serves the same purpose as paragraph -6126 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6126 of Code Case 1595 remains conservative and acceptable, and HBB-6126 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6126 acceptable.

HBB-6200 Hydrostatic Tests

HBB-6210 Hydrostatic Testing Procedure

HBB-6211 Provision of Air Vents at High Points

Paragraph HBB-6211 serves the same purpose as paragraph -6211 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6211 of Code Case 1595 remains conservative and acceptable, and HBB-6211 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6211 acceptable.

HBB-6212 Test Medium and Test Temperature

Paragraph HBB-6212 serves the same purpose as paragraph -6212 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6212 of Code Case 1595 remains conservative and acceptable, with limitations stated in RG 1.87, Rev. 1, and HBB-6212 is technically equivalent to it Code Case 1595. Therefore, the staff finds subparagraph HBB-6212 acceptable with the following limitations based on RG 1.87, Rev. 1, which remain applicable:

- When using HBB-6212(a), the “nonhazardous liquid” should be (a) nonhazardous relative to possible reactions between residual test liquid and the normal coolant fluid and (b) nonhazardous with respect to deleterious effects to the component (material) (such as through corrosion by either the test liquid or a fluid created by reaction of test liquid and coolant).

- An applicant or licensee may justify a liquid as nonhazardous even if the liquid does not fall within one of the criteria above by employing post-test procedures that ensure proper draining and drying. When a test liquid is considered "nonhazardous" as a result of such prescribed post-test procedures, the posttest procedures should be documented and included as part of the appropriate Data Report Form specified by NCA-8400, as incorporated into Division 5 by HAA-1110(a).

HBB-6213 Check of Test Equipment Before Applying Pressure

Paragraph HBB-6213 serves the same purpose as paragraph -6213 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6213 of Code Case 1595 remains conservative and acceptable, and HBB-6213 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6213 acceptable.

HBB-6215 Examination for Leakage After Application of Pressure

Paragraph HBB-6215 serves the same purpose as paragraph -6215 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6215 of Code Case 1595 remains conservative and acceptable, and HBB-6215 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6215 acceptable.

HBB-6220 Hydrostatic Test Pressure Requirements

HBB-6221 Minimum Required System Hydrostatic Test Pressure

Paragraph HBB-6221 serves the same purpose as paragraph -6221 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6221 of Code Case 1595 remains conservative and acceptable, and HBB-6221 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6221 acceptable.

HBB-6222 Maximum Permissible Hydrostatic Test Pressure

Paragraph HBB-6222 serves the same purpose as paragraph -6222 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6222 of Code Case 1595 remains conservative and acceptable, and HBB-6222 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6222 acceptable.

HBB-6223 Hydrostatic Test Pressure for Valves, Pumps, and for Components and Appurtenances Containing Brazed Joints

Subparagraph HBB-6223(a) serves the same purpose as paragraph -6223 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6223 of Code Case 1595 remains conservative and acceptable, and HBB-6223 is technically equivalent to it, except that it permits pumps designed by detailed stress analysis to forgo hydrostatic testing before installation. The staff notes that any such components would still be subject to a system pressure test. The staff finds this acceptable because a detailed stress analysis provides added assurance of the structural integrity of a component, making a pre-installation hydrostatic test at 1.5 times the system design pressure unnecessary. Subparagraph HBB-6223(b) calls for the inlet portion of safety and safety relief valves to be tested at 1.5 times the set pressure and 1.5 times the design secondary pressure for the outlet side of valves in closed systems. The staff finds this acceptable as this approach will produce testing pressures that are typically higher than the system design pressure.

HBB-6224 Hydrostatic Test Pressure Holding Time

Paragraph HBB-6224 serves the same purpose as paragraph -6224 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6224 of Code Case 1595 remains conservative and acceptable, and HBB-6224 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6224 acceptable.

HBB-6300 Pneumatic Tests

HBB-6310 Pneumatic Testing Procedures

HBB-6311 General Requirements

Paragraph HBB-6311 serves the same purpose as paragraph -6311 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6311 of Code Case 1595 remains conservative and acceptable, and HBB-6311 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6311 acceptable.

HBB-6312 Test Medium and Test Temperature

Paragraph HBB-6312 serves the same purpose as paragraph -6312 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6312 of Code Case 1595 remains conservative and acceptable, and HBB-6312 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6312 acceptable.

HBB-6313 Check of Test Equipment Before Applying Pressure

Paragraph HBB-6313 serves the same purpose as paragraph -6313 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6313 of Code Case 1595 remains conservative and acceptable, and HBB-6313 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6313 acceptable.

HBB-6314 Procedure for Applying Pressure

Paragraph HBB-6314 serves the same purpose as paragraph -6314 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6314 of Code Case 1595 remains conservative and acceptable, and HBB-6314 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6314 acceptable.

HBB-6315 Examination for Leakage After Application of Pressure

Paragraph HBB-6315 serves the same purpose as paragraph -6315 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6315 of Code Case 1595 remains conservative and acceptable, and HBB-6315 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6315 acceptable.

HBB-6320 Pneumatic Test Pressure Requirements

HBB-6321 Minimum Required System Pneumatic Test Pressure

Paragraph HBB-6321 serves the same purpose as paragraph -6321 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6321 of Code Case 1595 remains conservative and acceptable, and HBB-6321 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6321 acceptable.

HBB-6322 Maximum Permissible Pneumatic Test Pressure

Paragraph HBB-6322 serves the same purpose as paragraph -6322 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6322 of Code Case 1595 remains conservative and acceptable, and HBB-6322 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6322 acceptable.

HBB-6323 Pneumatic Test Pressure for Valves, Pumps, and for Components and Appurtenances Containing Brazed Joints

Subparagraph HBB-6323(a) serves the same purpose as paragraph -6323 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6323 of Code Case 1595 remains conservative and acceptable, and HBB-6323 is technically equivalent to it, except that it permits pumps designed by detailed stress analysis to forgo pneumatic testing before installation. The staff notes that such pumps would be subject to a system pressure test. The staff finds this acceptable because a detailed stress analysis provides added assurance of the structural integrity of a component.

Subparagraph HBB-6323(b) calls for the inlet portion of safety and safety relief valves to be tested at 1.5 times the set pressure and 1.5 times the design secondary pressure for the outlet side of valves in closed systems. The staff finds this acceptable, as this approach will produce testing pressures that are typically higher than the system design pressure.

HBB-6324 Pneumatic Test Pressure Holding Time

Paragraph HBB-6324 serves the same purpose as paragraph -6324 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Paragraph -6324 of Code Case 1595 remains conservative and acceptable, and HBB-6324 is technically equivalent to it. Therefore, the staff finds subparagraph HBB-6324 acceptable.

HBB-6400 Pressure Test Gages

Subarticle HBB-6400 serves the same purpose as subarticle -6400 of Code Case 1595 endorsed in RG 1.87, Rev. 1. Subarticle -6400 of Code Case 1595 remains conservative and acceptable, and HBB-6400 is technically equivalent to it. Therefore, the staff finds subarticle HBB-6400 acceptable.

3.6.7 Article HBB-7000 Overpressure Protection

HBB-7100 General Requirements

Article HBB-7100 serves the same purpose as the corresponding provision in ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. The staff finds HBB-7100 acceptable for overpressure protection for ASME Code III-5, Class A components. The staff reached this finding based on the regulatory and technical assessment below.

HBB-7110 Scope

Subarticle HBB-7110 serves the same purpose as the corresponding provision in ASME Code III-1, NB-7110 which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Subarticle HBB-7110 is technically equivalent to the provisions of subarticle -7110 delineated in ASME Code Case 1596 endorsed in RG 1.87, Rev.-1. These provisions in Code Case 1596 remain conservative and acceptable. Therefore, the staff finds HBB-7110 acceptable.

HBB-7130 Verification of the Operation of Pressure Relief Devices

Subarticle HBB-7130 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, NB-7130 which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Since the precision and accuracy of pressure relief devices can be affected by environmental conditions, the staff finds the capability to test for potential impairment necessary. HBB-7130 is equivalent to NB-7130 in calling for this test capability. Therefore, the staff finds HBB-7130 acceptable.

HBB-7170 Permitted Use of Pressure Relief Devices

Subarticle HBB-7170 serves the same purpose as the corresponding provision in Code Case 1596 endorsed in RG 1.87, Rev. 1. This provision in Code Case 1596 remains conservative and acceptable, and HBB-7170 is technically equivalent to it but add that rupture disk devices may be used in air, gas, or liquid metal service. The staff agrees that non-reclosing devices, such as rupture disks, can suffice as pressure relief devices for elevated temperature service. Therefore, the staff finds HBB-7170 acceptable.

HBB-7200 Content of Overpressure Protection Report

Article HBB-7200 serves the same purpose as the corresponding provision in Code Case 1596 endorsed in RG 1.87, Rev. 1. This provision in Code Case 1596 remains conservative and acceptable, and HBB-7200 is technically equivalent to it. Therefore, the staff finds Article HBB-7200 acceptable.

HBB-7300 Relieving Capacity

Article HBB-7300 serves the same purpose as ASME Code III-1, NB-7321(c), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. The staff finds HBB-7300 acceptable because the total rated relieving capacity should be available to preclude an SSC from exceeding its design criteria for Service Limit C, as is provided in NB-7321(c). Therefore, the staff finds Article HBB-7300 acceptable.

HBB-7600 Nonreclosing Pressure Relief Devices

HBB-7610 Use of Rupture Disk Devices

Subarticle HBB-7610 serves the same purpose as the corresponding provision in Code Case 1596 endorsed in RG 1.87, Rev. 1. This provision of Code Case 1596 remains conservative and acceptable, and subarticle HBB-7610 is technically equivalent to it. Accordingly, the staff finds HBB-7610 acceptable. Moreover, non-reclosing devices, such as rupture disks, can suffice as pressure relief devices for elevated temperature service.

HBB-7620

HBB-7621 Provisions for Venting or Draining Near Rupture Disks

HBB-7621 serves the same purpose as paragraph -7714 of Code Case 1596 endorsed in RG 1.87, Rev. 1. Paragraph -7714 of Code Case 1596 remains conservative and acceptable, and HBB-7621 is technically equivalent to paragraph -7714 of Code Case 1596. HBB-7621 provides that for non-reclosing devices such as rupture disks, the space between the rupture disk and any associated pressure relief valve shall be connected to a controlled disposal system as provided for the associated pressure relief valve. HBB-7621 also provides that this space, if it exists, shall be provided with means to monitor its internal pressure during service periods. HBB-7621 is technically equivalent to -7714, therefore HBB-7621 is adequate.

3.6.8 Article HBB-8000 Nameplates, Stamping with the Certification Mark, and Reports

HBB-8100 Requirements

HBB-8100 indicates that the provisions in Article HAA-8000 also apply to Class A metallic pressure boundary components.

HBB-8100 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1 (NB-8100), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HBB-8100 acceptable. Further, HBB-8100 does not contain any technical requirements and does not otherwise impact other requirements.

3.7 Mandatory Appendix HBB-I-14 Tables and Figures

Mandatory Appendix HBB-I-14 contains numerous tables and figures containing information used in design calculations performed in accordance with HBB-3000 and in the procedures of Nonmandatory Appendix HBB-T. This information includes a list of allowable specifications for base materials and weld materials and both time-dependent and time-independent allowable stresses. The allowable stresses include S_0, the maximum allowable stress intensity for design condition calculations, S_{mt}, the allowable stress intensity, which is the lower of the time-dependent allowable stress S_t, and the time-independent allowable stress S_m, and the stress rupture strength S_r. Separate tables of allowable stresses are provided for bolting materials. Other tables include weld strength reduction factors, which are applied to account for the lower strength of weld material relative to base material of similar composition. The HBB-I-14 tables also include the minimum yield strength (S_y) as a function of temperature. The minimum ultimate tensile strength (S_u) as a function of temperature is contained in Table HBB-3225-1, but it is also reviewed in this section.

In making the determinations documented in Section 3.7 of this NUREG, the staff considered of the technical input in ORNL, 2020. The staff reviewed and agreed with the recommendations of the portions of the ORNL, 2020 technical input upon which the staff relied in this NUREG; the staff reasons for not accepting certain ORNL conclusions that ASME Code-III-5 appears to lack conservatism are set forth below. Additional information on historical background and perspective on the allowable stresses in ASME Code III-5 appears in ANL, 2021.

The staff notes that ORNL, 2020 identified numerous instances where independent analysis by ORNL determined lower values of the allowable stresses and other material properties. In ORNL, 2020, in the various tables showing its analysis results[5] compared to the values in ASME Code III-5, ORNL highlighted the Section III-5 value in orange if its independent analysis determined values that are less than the Section III-5 values by more than 10 percent. ORNL, 2020 also highlighted the Section III-5 value in yellow if its independent analysis determined values that are between 5 percent and 10 percent less than the Section III-5 values. In some cases, ORNL, 2020 recommends further review of allowable stresses and properties for certain materials. The staff considered the recommendations of ORNL's independent analysis holistically, considering how the properties are used, inherent conservatisms in the Section III-5 design rules, and inherent conservatisms in the method of determination of the materials' allowable stresses and properties.

ANL, 2021, Section 2.1.1, contains a discussion and examples of some of the conservatisms in the Section III-5 design rules compared to other ASME Code sections for high-temperature nonnuclear components (Section I and Section VIII, which use allowable stresses from Section II, Part D, Tables 1A and 1B). One example in ANL, 2021 is for an ASME Code III-5 component with a long service life (longer than 100,000 hours). In this case, the allowable stress in Section II, Part D, Tables 1A and 1B, based on creep rupture properties is the lower of 0.67 times the average or 0.80 times the minimum creep rupture strength in 100,000 hours. By contrast, for a Class A component in Section III-5, the corresponding criterion is 0.67 times the minimum creep rupture strength for the specified service life. Thus, as would be expected, for most Class A and similarly specified components, the minimum wall thickness for a specified life of 300,000 hours is greater than that for a Section I or VIII, Division 1, component operating at the same conditions.

ANL, 2021 provides another example of the conservatism of comparing the Section III, Division 5 design rules to those in Section III, Division 1. In Section III, Division 1, Subsection NB, for Service Level B, the primary stress allowable from Appendix XIII, Table 3110-1, is $1.2\,S_m$. This means that the allowable primary membrane stress from a seismic event categorized as Service Level B is 1.2 times the value of S_m as given by the criteria in Section II, conceptually the lesser of $\frac{2}{3}S_y$ or $\frac{1}{3}S_u$. In the HBB rules, the corresponding allowable stress for a time-independent Service Level B event is S_m without the 1.2 factor increase but with a reduction in S_y and S_u to account for the detrimental effects of thermal aging. For Service Level C, the allowable primary membrane stress in Subsection NB is the higher of $1.2\,S_m$ or S_y and, in HBB, it is just $1.2\,S_m$

5 For example, Table R.14.4-1A of Reference X compares the S_t values for Type 304 SS from the 2017 and 2019 Editions of the ASME Code, Section III, Division 5, Table HBB-I-14.4B, with the results of ORNL's independent analysis of S_t for Type 304 SS.

without the increase in allowable stress for work hardening material like austenitic SS. Thus, ANL, 2021 concludes that the allowable stress in Section III-5, HBB, for a time-independent B or C event is generally more conservative than the equivalent event in Subsection NB.

Another example of conservatism in the HBB primary stress rules of HBB-3222 discussed in ANL, 2021 is the use of a section factor, K_t, conservatively based on a power law creep exponent in the range of 2 to 3 instead of the nominally higher creep rate exponent of 5 for many materials. The resultant value of K_t is 1.25 vs. a factor of 1.5 for a perfectly plastic redistribution. With respect to the Level A and B service limits, K_t is used in the HBB-3223(c), Equation (5) for combined primary membrane plus bending stresses:

$$P_L + {}^{P_b}/_{K_t} \leq S_t$$

Where P_L is the local membrane stress intensity, P_b is the bending stress, and S_t is the temperature and time-dependent allowable stress value as defined in HBB-3221. See Section (3.7.5). As used in the equation above, K_t is a divisor on bending stress and thus reduces the combined membrane plus bending stress. Smaller K_t values are thus more conservative.

In addition, Equation (4) in HBB-3223 (c) is $P_b + P_L \leq KS_m$.
Equation (6) in HBB-3223 is $K_t = (K+1)/2$. Rearranging this, $K = 2K_t - 1$

In Equation (4), K is a multiplier on the time-independent allowable stress S_m. Therefore, a smaller K_t in the rearranged Equation (6) results in a smaller K and thus a smaller multiplier on the allowable stress. Smaller K_t values are therefore conservative.

ANL, 2021 also indicates that the strain limits and creep-fatigue design checks in Nonmandatory Appendix HBB-T represent redundant protection against component failure that is inherent in the Section III-5 design process. Although HBB-T is a nonmandatory appendix, the staff anticipates most if not all designers of high-temperature reactors to use it. The staff's review of the time-dependent allowable stress (S_t) values in Section 4.5.5 will discuss these conservatisms and redundancies in more detail.

The allowable stresses for design loadings (S_0) were included as a check to ensure component wall thicknesses determined under the HBB rules would not be less than would be determined for Section I and VIII, Division 1, components in the creep regime.

The staff generally considered values from the independent analysis that are equal to or greater than the Section III-5 values, or within 10 percent less than the Section III-5 values, to support a finding of adequacy of the Section III-5 values. In addition to the conservatisms and redundant protection against failure inherent in the Section III-5 design rules and procedures discussed above, the staff determined values that are lower than the Section III-5 values by up to 10 percent to be acceptable for several reasons:

- Many of these parameters that are both time and temperature dependent are determined using logarithmic polynomial fits to the data to determine the Larson-Miller Parameter (LMP). There is considerable variability in how such a curve may be fit to the available data.

- Consistent with ASME's practice when it originally determined the allowable stress values, the allowable stresses in the ORNL, 2020 independent analysis are essentially

90-percent lower bounding values. The discussion of the determination of S_t in Section 3.7.5 of this NUREG includes more details.

- There are inherent margins in how some of the Section III-5 allowable stresses are determined, particularly the time-dependent allowable stress S_t. Section 4.5.5 provides details.
- Both the S_{mt} and S_t values are determined, in part, by 80 percent of the minimum stress to cause initiation of tertiary creep. Determining the onset of tertiary creep is known to be problematic, and the ASME Code committees are considering eliminating this criterion. Section 3.7.5 provides additional details on this issue.

The staff has determined that the permissible material specifications for base materials and weld materials, material allowable stresses and properties, and weld stress rupture factors in the Mandatory Appendix HBB-I-14 tables and figures to be acceptable, subject to the following exceptions and limitations:

(1) The NRC staff is not endorsing Mandatory Appendix HBB-I-14 for:

(a) Type 304 stainless steel (Type 304 SS) values of S_{mt}, S_t, and S_r for the following time/temperature combinations[6] (these are also shown graphically in Table 3-1):

a. US Customary Units

i. Times greater than 30,000 hours at 1350 degrees F.

ii. Times greater than 3000 hours at 1400 degrees F.

iii. Times greater than 1000 hours at 1450 degrees F.

iv. Times greater than 100 hours at 1500 degrees F.

b. SI Units

i. Times greater than 30,000 hours at 725 degrees C.

ii. Times greater than 3000 hours at 750 degrees C.

iii. Times greater than 1000 hours at 775 degrees C.

iv. Times greater than 300 hours at 800 degrees C.

(b) Type 316 stainless steel (Type 316 SS) S_r values for the following time/temperature combinations (these are also shown graphically in Table 3-3):

a. US Customary Units

i. Times greater than 300 hours at 1400 degrees F.

ii. Times greater than 30 hours at 1450 degrees F.

[6] For all the S_{mt}, S_t, and S_r values not endorsed in Section 3.7 of this NUREG, the temperature values are not exact conversions from US Customary to SI units for the same times. This is because Section III-5 provides separate tables of allowable stresses (S_{mt}, S_t, and S_r) for US Customary and SI units in Appendix HBB-I-14, which are provided in increments of 50 °F for US Customary units, and 25 °C for SI units. The temperatures at which S_{mt}, S_t, and S_r were not endorsed were evaluated separately for the US Customary and SI tables. Use of either set of limitations is acceptable because any differences in allowable stresses resulting from conversion of temperatures and interpolation of allowable stresses are minor.

iii. Times greater than 10 hours at 1500 degrees F.

b. SI Units

i. Times greater than 300 hours at 750 degrees C.

ii. Times greater than 30 hours at 775 degrees C.

iii. Times greater than 30 hours at 800 degrees C.

(c) 2-1/4Cr-1Mo material S_{mt}, S_t, and S_r values for the following time/temperature combinations (these are also shown graphically in Table 3-2)

a. US Customary Units

i. Times greater than 100,000 hours at temperatures of 1000 degrees F and 1050 degrees F.

ii. Temperature greater than or equal to 1100 degrees F, for all times.

b. SI Units

i. Times greater than 100,000 hours at temperatures of 525 degrees C and 550 degrees C.

ii. Temperature greater than or equal to 575 degrees C, for all times.

(d) 9Cr-1Mo-V S_0, S_{mt}, S_t, and S_r values

(e) 9Cr-1Mo-V R-factors in Table HBB-I-14.10E for temperatures greater than 525 °C (977 °F).[7]

(f) The R-factors in Tables HBB-I-14.10A-3 and HBB-I-14.10B-3 for Type 304 or Type 316 SS base metal welded with Type 316 SS filler using processes other than gas tungsten arc welding.[8]

(2) For 9Cr-1Mo-V, the NRC staff is endorsing the use of certain values in the 2019 Edition of Section II, Part D and Mandatory Appendix HBB-I-14 of the 2019 edition of ASME Code Section III, Division 5:

(a) S_0 values should be based on the larger of the S values in Section II, Part D (2019 Edition) and the S_{mt} values at 300,000 hours in Section III-5 Table HBB-I-14.3E (2019 edition).

(b) S_{mt} values should be based on the values in Table HBB-I-14.3E from the 2019 Edition of Section III-5.

(c) S_t values should be based on the values in Table HBB-I-14.4E from the 2019 Edition of Section III-5.

(d) S_r values should be based on the values in Table HBB-I-14.6F from the 2019 Edition of Section III-5.

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7 Unless ASME approves and the NRC endorses the proposed R-factors in ASME Code Record 17-2817, the NRC will evaluate applications to use them on a case-by-case basis with appropriate justification.

8 Applicants wishing to use these base metal/weld metal combinations for welds made with processes other than gas tungsten arc welding may be able to demonstrate the adequacy of these R-factors by submitting additional data.

Subsections 3.7.1 through 3.7.11 include the details of the staff's review and the justification for the above exceptions and limitations.

3.7.1 Table HBB-I-14.1(a) Permissible Base Materials for Structures Other than Bolting

Table HBB-I-14(a) lists the allowable material specifications for each of the base materials that are permitted in Section III-5. For nonbolting components, Section III-5 allows only five different alloys: Type 304 SS, Type 316 SS, Alloy 800H, 2-1/4 Cr-1 Mo, and 9Cr-1Mo-V. Each alloy has a number of different product forms and specifications listed in Table HBB-I-14(a). Under the "Types, Grades and Classes" column in Table HBB-I-14.1(a), for base material Type 304 SS and Type 316 SS, the table lists both "H" and non-"H" grades; for example, for SA-182, Grades F 304 and F 304H, and F 316 and F 316H are listed. The "H" grades are distinguished from the non-H grades by having a minimum carbon content of 0.04 weight percent, and a maximum carbon content of 0.10 weight percent, while non-H grades have no minimum carbon content and a maximum carbon content of 0.08 weight percent. However, Note 1 to Table HBB-I-14.1(a), pertaining to base material Type 304 SS and Type 316 SS, states that these materials shall have a minimum specified room temperature yield strength of 207 megapascals (MPa) (30,000 pounds-force per square inch (psi)) and a minimum specified carbon content of 0.04 percent. The minimum specified carbon content of 0.04 weight percent effectively ensures that all the Type 304 SS and Type 316 SS materials permissible under Table HBB-I-14.1(a) meet the chemistry standards for "H" grades.

Note (2) to Table HBB-I-14.1(a), which pertains to Type 304 SS and Type 316 SS, and Type 304 H and Type 316 H, states "For use at temperatures above 1,000°F (540°C), these materials may be used only if the material is heat treated by heating to a minimum temperature of 1,900°F (1040°C) and quenching in water or rapidly cooling by other means." Most of the material specifications for these grades allow direct quenching after hot working to be substituted for a separate solution annealing heat treatment. However, ORNL, 2020 notes that such in-process heat treatment can adversely impact the elevated temperature properties of the material and is specifically prohibited for the H grades but permitted for the non-H grades in several specifications (SA-182, SA-213, SA-376, SA-403), while other specifications are silent (SA-249, SA-240, SA-479). Only SA-965 prohibits in-process heat treatment for all grades. Therefore, the staff will recommend a limitation to Table HBB-I-14.1(a) to modify Note 2 to prohibit substitution of such in-process heat treatment for a separate solution-annealing heat treatment.

One specification listed in the table, SA-430, does not exist. ASTM A312 superseded ASTM A430 (last edition A430-1991) in 1995. The staff will recommend a clarification to update the table to remove ASTM A430.

With respect to 2-1/4 Cr-1 Mo material, Note (6) states the following:

> The material allowed under SA-234 shall correspond to one of:
>
> a) SA-335, Grade P 22
> b) SA-387, Grade 22, Class 1
> c) SA-182, Grade F 22, Class 1 in compliance with Note (4).

ORNL, 2020 states that the reference to Note (4) under clause (c) of Note 6 is an obvious error, possibly a carryover from a previous edition, and should refer to Note (5). Note (5) pertains to the specified tensile properties for 2-1/4 Cr-1 Mo, while Note (4) pertains to the heat treatment of Alloy 800H. The staff will therefore recommend a limitation that under Note (6) clause (c), “Note (4)” is changed to “Note (5).”

Next to SA-234, the table lists WP22 and WP22W under “Types, Grades and Classes.” ORNL, 2020 notes that WP22, by itself, is not a listed material because it excludes specified grade or class and the “W” identifier (after WP22W) is only for marking purposes. The staff will therefore recommend a limitation that, in the line for SA-234, “WP22, WP22W” should be replaced with “WP22 CL1, CL3.”

The staff also notes that under specification SA-403, Grades WP 304W, WP 304HW, WP 316W, and WP 316HW listed in Table HBB-I-14.1(a) do not exist. The staff will recommend removal of these grades from Table HBB-I-14.1(a) as a limitation.

Also related to 2-1/4 Cr-1 Mo, ORNL, 2020 notes that only SA-182 for forgings specifies a minimum anneal temperature and a normalizing temperature of 900 degrees C (1,650 degrees F). ORNL, 2020 further states that, while the strength standards typically force an appropriate anneal or normalization plus tempering, the addition of a heat treatment temperature minimum note is recommended to ensure properties. However, the staff does not consider this issue to merit a limitation because proper heat treatment is ensured through the mechanical properties standards of the materials specifications. In addition, ANL, 2021 indicates that Section III-5 only allows 2-1/4 Cr-1Mo in the annealed condition.

The staff finds that, in general, subject to the limitations identified below, the material types and grades and specification listed in Table HBB-I-14.1(a) are acceptable because these materials have been adequately characterized for high-temperature service with respect to allowable stresses and other properties given in the other tables in Mandatory Appendix HBB-I-14. In addition, with the exception of 9Cr-1Mo-V, the alloys approved for use in Table HBB-I-14.1(a) are the same as those listed in Table I-14.1, “Permissible Materials for Structures other than Bolting,” in NRC-approved ASME Code Case 1592.

The staff recommends endorsing Table HBB-I-14.1(a) with the following limitations:

1. Note (2) to the table should be modified to add the following words: “The heat treatment is to be separately performed, and in-process heat treatment such as by direct quenching from hot forming is not permitted.”

2. Under Note (6) clause (c), “Note (4)” should be changed to “Note (5).”

3. In the line for SA-234, “WP22, WP22W” should be replaced with “WP22 CL1, CL3.”

4. For base material Type 304 SS and Type 316 SS, for Specification SA-403, Grades WP 304W, WP 304HW, WP 316W, and WP 316HW should be removed from the list of grades.

The staff recommends the cognizant ASME Code committee(s) should make these changes in a future revision to Section III-5.

3.7.2 Table HBB-I-14.1(b) Permissible Weld Materials

Table HBB-I-14(b) lists the permissible weld materials allowed in conjunction with the five alloy types listed in Table HBB-I-14.1(a). These consist of those weld materials that are compatible with the base materials listed in Table HBB-I-14.1(a). The staff finds these weld materials acceptable because they are generally compatible with the corresponding base materials, and the material properties have been adequately characterized. The weld material properties are accounted for through the weld stress rupture factors included in Nonmandatory Tables HBB-I-14.10A-1 through E-1, discussed in Section 4.5.8. Section 4.5.8 of this report gives the staff's evaluation of the weld stress rupture factors in Tables HBB-I-14.10A-1 through E-1.

3.7.3 Table HBB-I-14.2 S_σ—Maximum Allowable Stress Intensity, ksi (MPa), for Design Condition Calculations

HBB-3221 defines S_o values as the maximum allowable value of general primary membrane stress intensity to be used as a reference for stress calculations under Design Loadings. HBB-3221 further states that the values correspond to the S values given in ASME Code, Section II, Part D (Section II-D), Subpart 1, Table 1A, except for a few cases at lower temperatures where values of S_{mt} at 300,000 hours exceed the S values. In those limited cases, S_o is equal to S_{mt} at 300,000 hours rather than S.

The S values of Section II-D, Subpart 1, Table 1A, are based on the lowest of several quantities defined in Mandatory Appendix 1 to Section II-D. These quantities include fractions of the ultimate tensile and yield strengths at given temperatures. In the temperature range where creep is active, one of the quantities is 80 percent of the stress rupture strength, $S_{r,}$ at 100,000 hours.

ORNL, 2020 documents an independent analysis of the S_0 values. The analysis considered stress rupture data compiled from a comprehensive literature search (p. 115). The determination of S_r followed the same methodology used to determine S_r that is described in Section 4.5.5.

The independent analysis of the S_0 values by ORNL generally determined higher or equivalent values of S_0 to those in Table HBB-I-14.2, except for some higher temperatures. In some cases, the values calculated in the independent analysis are lower that the Section III-5 values by more than 10 percent. The lower values calculated in the independent analysis were related to lower S_r values determined by the regression analysis. Lower S_0 values were determined for all five materials over a given temperature range.

ANL, 2021 notes that the design loading (S_0) allowable stress intensity values were intended to provide assurance to the original ASME Code Main Committee that the then-new elevated temperature design rules (to be published in Code Case 1592) with time-dependent allowable stress criteria for operating conditions with durations less than 100,000 hours would not result in component thicknesses less than would be achieved under the design rules and allowable stress criteria for Section VIII, Division 1, based on extrapolated 100,000-hour properties. ANL, 2021 further notes that it was later recognized that, at lower temperatures, there was a limited regime where the Section II-D, Tables 1A and 1B, allowable stress values based on time-independent tensile properties could be lower than the S_{mt} intensities at 300,000 hours, leading to a thickness greater than that governed by the S_{mt} intensities at 300,000 hours for Service Level conditions. This was considered to be contrary to the purpose of the criteria for Design

Loadings addressing the shorter lifetimes, and, thus, the current allowable stresses for Design Loadings, S_0, are based on the higher of the S value in Section II-D or the value of S_{mt} at 300,000 hours in HBB.

ANL, 2021 notes that the S_0 intensities for Design Loadings are determined from tabulated values in Section II-D and HBB, and that as such, the tabulation of the S_0 values in Table HBB-I-14.2 is somewhat redundant. ANL, 2021 further notes that sometimes, there is a lag or a failure in coordination when the values in Section II-D or HBB are modified and the S_0 values in Table HBB-I-14.2 are not updated simultaneously, creating inconsistency.

There is considerable conservatism in the method of determining the S values given in Section II-D, Subpart 1, Table 1A. The S values are based on the lowest of several quantities, including 2/3 the yield strength (both at room temperature and above room temperature), the room temperature tensile strength divided by 3.5, the tensile strength above room temperature times 1.1 divided by 3.5, 0.8 times the minimum rupture stress at 100,000 hours, and the average rupture stress at 100,000 times a factor of 0.67 or less. Further, ANL, 2021 notes that experience suggests that the Service Loadings, rather than the Design Loadings, control the primary load design.

For each material, ANL, 2021 calculated the S_0 values based on the larger of the S value from Section II-D, Tables 1A and IB, and the Section III-5 S_{mt} value at 300,000 hours, and compared the calculated value with the tabulated S_0 value from Section III-5. The comparison determined no discrepancy between the calculated and tabulated S_0 values except for 9Cr-1Mo-V.

For 9Cr-1Mo-V steel, ANL, 2021 notes that the values of S and the S_{mt} stress intensities were revised in the 2019 Edition of the ASME Code II-D, and ASME Code III-5, respectively. These two actions were carried out independently. However, the S_0 values for 9Cr-1Mo-V were not revised. The comparison of the values of S, S_{mt} at 300,000 hours, and S_0 for 9Cr-1Mo-V found some of the values calculated based on the 2019 Editions S values are lower than the tabulated S_0 values in the 2017 Edition of Section III-5. As discussed in Sections 4.5.4, 4.5.5, and 4.5.8 of this document, the staff recommends conditions that the values of S_{mt}, S_t, and S_r, for 9Cr-1Mo-V from the 2019 Edition of HBB should be used. Similarly, ANL, 2021 recommends that the S_0 values for 9Cr-1Mo-V should be based the larger of the S values in Section II-D, and the S_{mt} values at 300,000 hours in HBB, both from the 2019 Edition of the ASME Code.

For the materials other than 9Cr-1Mo-V, since ANL determined the S_0 values are consistent with the S values from Section II-D, Tables 1A and IB, or the Section III-5 S_{mt} values at 300,000 hours, whichever is larger, the staff finds the S_0 values have been determined consistently with the criteria for S_0 from HBB-3221. By doing so, the S_0 values achieve the purpose of preventing component thicknesses less than would be achieved under the design rules and allowable stress criteria for Section VIII, Division 1. Therefore, the staff finds the S_0 values in Table HBB-I-14.2 acceptable, except for 9Cr-1Mo-V.

For 9Cr-1Mo-V, the NRC staff is not endorsing the S_0 values for 9Cr-1Mo-V in the 2017 Edition of Section III, Division 5, Table HBB-I-14.2. For 9Cr-1Mo-V, the staff is endorsing the use of S_0 values based on the larger of the S values in Section II, Part D (2019 Edition) and the S_{mt} values at 300,000 hours in Section III-5 Table HBB-I-14.3E (2019 edition). The foregoing resolves the concern that some S_0 values for higher temperatures in Table HBB-I-14.2 appear nonconservative.

3.7.4 Figures and Tables HBB-I-14.3A–E, S_{mt}—Allowable Stress Intensity Values

S_{mt} is the allowable limit of general primary membrane stress intensity to be used as a reference for stress calculations for the actual service life and under the Level A and B Service Loadings; values are the lower of the time-dependent allowable stress S_t and the time-independent allowable stress S_m. HBB-3221 describes the method of determining the S_t values and S_m values.

The determination of S_{mt} values is conservative because these values are based on the lower of S_t and S_m, which ensures that the lowest value is used whether determined by time-dependent or time-independent properties. Conservatisms in determining S_t are described in Section 3.7.6 of this NUREG. S_m is also determined conservatively because it is based on the lowest of several quantities, including 2/3 S_y, 1/3 S_u, etc.

S_{mt} Values

With respect to the S_{mt} values tabulated for the five materials in Section III-5, the independent analysis in ORNL, 2020 calculates lower values than the Section III-5 values for a portion of the times and temperatures, particularly at longer times and higher temperatures. For 9Cr-1Mo-V material, ORNL, 2020 indicates that the values in the 2019 Edition of Section III-5 are not significantly different from the values determined by to the independent analysis. ORNL, 2020 notes that a major portion of the time-temperature range over which it determined the Section III-5 S_{mt} values to be nonconservative relative to ORNL's independent analysis is the range over which the S_{mt} values are controlled by the (time-dependent) stress to initiate tertiary creep. This means the S_{mt} values in these cases are determined by S_t, and that the S_t value is controlled by the time to tertiary creep. The staff notes that the S_t and S_{mt} values determined by ORNL to be controlled by the stress to initiate tertiary creep were typically for longer times and higher temperatures. Section 3.7.6 discusses the issues associated with the tertiary creep criterion in determining S_t.

Based on the conservatisms inherent in the methodology of determining S_{mt}, the staff has determined that values of S_{mt} determined by the independent analysis that are within 10 percent of the Section III-5 values support a finding of adequacy of the Section III-5 values. For cases in which ORNL's analysis found values of S_{mt} lower than the Section III-5 values by more than 10 percent, Section 3.7.6 provides details of some alternative analyses and assessments of the S_t values documented in ANL, 2021 that mitigate some of the findings of potential nonconservatism in ORNL's analysis of the S_t values.

Type 304 SS and Type 316 SS

The S_{mt} values at longer times and higher temperatures for both Type 304 SS and Type 316 SS were controlled by the S_t values. (ORNL, 2020, Sengupta and Nestell, 2013) Based on an alternate analysis of the S_t values for Type 304 SS, which handled tertiary creep in a different way (see Section 3.7.6), some of the staff's independent analysis values of S_t were less than the Section III-5 values of S_t by more than 10 percent at temperatures greater than 700 degrees C (SI Units) and 1300 degrees C (US Customary Units). For Type 304 SS, the Sr values (Section 3.7.8) from the staff's independent analysis also were less than the corresponding Section III-5 values for certain times and temperatures at temperatures greater than 700 degrees C (SI units) and 1300 degrees C (US Customary Units). The time-temperature combinations at which the staff identified this potential nonconservatism were slightly different for S_r versus the S_t and S_{mt} values. Therefore, the staff is not endorsing the S_{mt}, S_t, and S_r values for Type 304 SS for the time-temperature combinations depicted by shaded cells in Table 3-1, which are based on the time-temperature combinations at which one or more of the three allowable stresses, S_{mt}, S_t or S_r are less than the corresponding Section III-5 value by greater than 10%.

Based on the alternate analysis of the S_t values for Type 316 SS described in Section 3.7.6, the S_{mt} values were reevaluated and determined to be acceptable for Type 316 SS for all times and temperatures.

<u>Alloy 800H</u>

For Alloy 800H, the S_{mt} values for which the ORNL analysis calculated lower values than Section III-5 were mainly controlled by the lower S_t values determined by ORNL's analysis. In accordance with Section 3.7.6, based on an assessment of the S_t values for Alloy 800H that used recently updated Section III-5 S_r values, the staff determined the S_t values for Alloy 800H are acceptable.

<u>2-1/4Cr-1Mo</u>

For 2-1/4Cr-1Mo, the S_{mt} values for which the ORNL analysis determined lower values than Section III-5 were controlled by lower S_t values determined by ORNL's analysis. Therefore, a similar limitation is applicable to the S_{mt} as for the S_t values. Consistent with the limitations on the S_t values described in Section 3.7.6, the staff determined the S_{mt} values for 2-1/4Cr-1Mo are acceptable for temperatures up to 500 degrees C (950 degrees F) for all times, and the same condition is applied to the S_{mt} values. Accordingly, the staff is endorsing the Section III-5 S_{mt} values at 525-550 degrees C and 1000-1050 degrees F for times up to and including 300,000 hours. At 575 degrees C and 1100 degrees F and above, the staff is not endorsing the Section III-5 S_{mt} values. Table 3-2 shows the staff's limitations on the S_{mt}, S_t, and S_r values graphically.

<u>9Cr-1Mo-V</u>

For 9Cr-1Mo-V material, ORNL, 2020 notes that the S_{mt} values have been updated in the 2019 Edition of Section III-5 and that the updated values match closely with the values from ORNL's independent analysis. The 2019 Section III-5 values also have been extended to a time of 500,000 hours. ORNL's independent analysis of the S_{mt} values showed the 2017 Section III-5 values are nonconservative by 10 percent or more but only for temperatures and times greater than 595 degrees C (1,100 degrees F) and 100,000 hours, and 540 degrees C (1,000 degrees F) and 300,000 hours. However, since updated values endorsed by the ASME Code are available and ORNL's independent analysis determined these values to be conservative, the staff is not endorsing the 2017 Section III-5 S_{mt} values but is endorsing the use of the 2019 Section III-5 S_{mt} values in lieu of the 2017 Section III-5 S_{mt} values for 9Cr-1Mo-V.

Summary – S_{mt} Values

Based on the above, the staff is not endorsing the Section III-5 S_{mt} values for:

- Type 304 SS for the following time/temperature combinations (these are also shown graphically in Table 3-1):

- US Customary Units
  - Times greater than 30,000 hours at 1350 degrees F.
  - Times greater than 3000 hours at 1400 degrees F.
  - Times greater than 1000 hours at 1450 degrees F.
  - Times greater than 100 hours at 1500 degrees F.
- SI Units
  - Times greater than 30,000 hours at 725 degrees C.
  - Times greater than 3000 hours at 750 degrees C.
  - Times greater than 1000 hours at 775 degrees C.
  - Times greater than 300 hours at 800 degrees C.

- 2-1/4Cr-1Mo for the following time/temperature combinations (these are also shown graphically in Table 3-2)
  - US Customary Units
    - Times greater than 100,000 hours at temperatures of 1000 degrees F and 1050 degrees F.
    - Temperature greater than or equal to 1100 degrees F, for all times.
  - SI Units
    - Times greater than 100,000 hours at temperatures of 525 degrees C and 550 degrees C.
    - Temperature greater than or equal to 575 degrees C, for all times.

- 9Cr-1Mo-V at all times and temperatures.

In addition, for 9Cr-1Mo-V material, the staff is endorsing the use of the 2019 Section III-5 S_{mt} values in lieu of the 2017 Section III-5 S_{mt} values for 9Cr-1Mo-V.

3.7.5 Figures and Tables HBB-I-14.4A–E, S_t—Allowable Stress Intensity Values

S_t is the temperature and time-dependent allowable stress value as defined in HBB-3221, which is determined based on the lowest of three quantities:

(1) 100 percent of the average stress to obtain a total (elastic, plastic, primary, and secondary creep) strain of 1 percent

(2) 80 percent of the minimum stress to cause initiation of tertiary creep

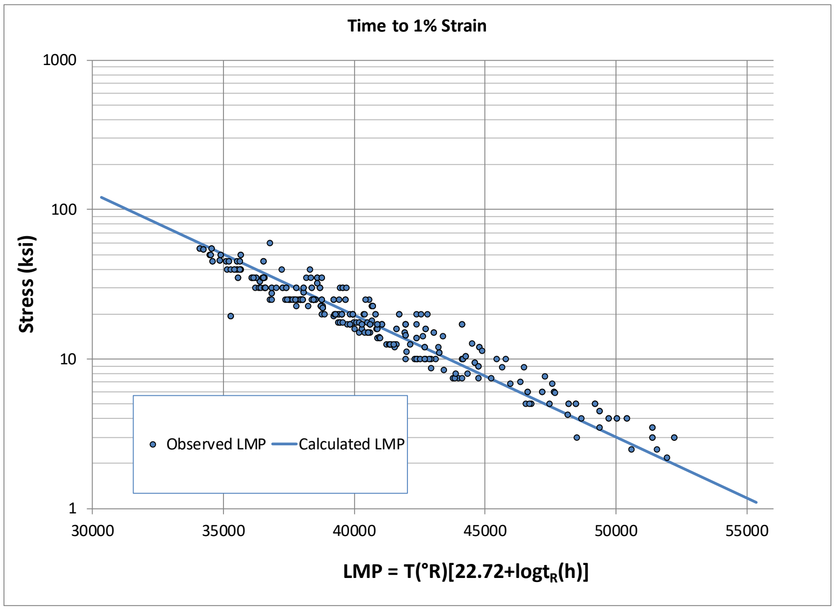
(3) 67 percent of the minimum stress to cause rupture

Section 4.2 of ORNL, 2020 documents an independent analysis of S_t by ORNL, based on current data gathered based on a literature search. The three different stresses are all determined from the data using the LMP logarithmic stress polynomial function.

$$LMP = T(C + logt) = a_0 + a_1 \log(S) + a_2 (logS)^2 + a_3 (logS)^3$$

$$where\ t = time\ to\ 1\%\ strain, time\ to\ initiate\ tertiary\ creep, or\ rupture\ time\ in\ hours$$

Figures 3-1, 3-2, and 3-3 show examples of typical LMP plots for 1-percent strain, stress to initiate tertiary creep, and rupture stress for Type 304 SS from ORNL, 2020.

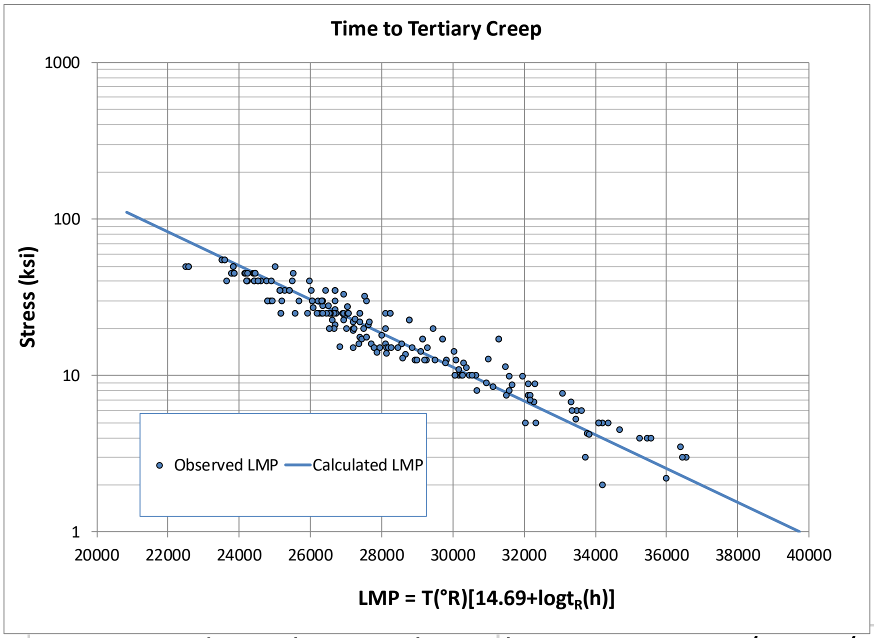


CLP=	22.72198
a0 =	55846.75
a1 =	-12272
SEE=	0.675307
R^2=	0.811152

S is stress in ksi, T is temperature in °R and t1 is time in hours to 1% strain

LMP-1st order polynomial -	logt1 = -CLP + a0/T + a1/T*logS

Figure 3-1 LMP Plot for 1-percent Strain, for Type 304 SS from ORNL, 2020, Figure R14.4-2A

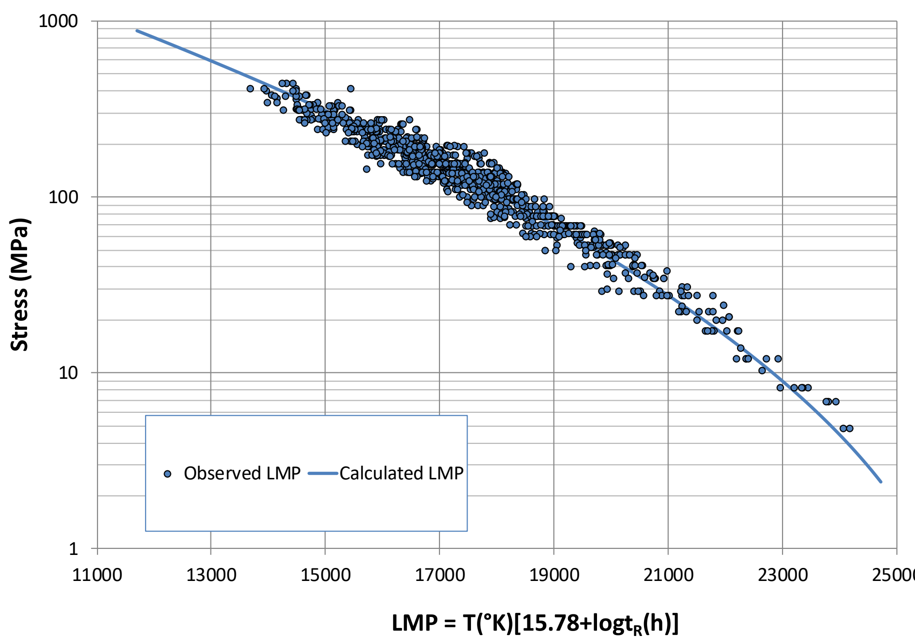


CLP=	14.68774
a 0=	39735.05
a 1=	-9260.06
a 2=	0
SEE=	0.510928
R^2=	0.808216

LMP-1st order polynomial - logt3 = -CLP + a0/T + a1/T*logS

S is stress in ksi, T is temperature in °R and t3 is time in hours to tertiary creep onset

Figure 3-2 Larson-Miller Plot of Stress to Initiate Tertiary Creep for Type 304 SS from ORNL, 2020, Figure R14.4-2A



C_{LP}=	15.77887
a_0 =	25483.48
a_1 =	-1611.22
a_2 =	-1040.6
SEE=	0.464138
R^2	0.67

S is stress in MPa, T is temperature in °K and t_R is rupture time in hours

LMP-2nd order polynomial - $\log t_R = -C_{LP} + a_0/T + a_1/T*\log S + a_2/T*(\log S)^2$

Figure 3-3 LMP Plot for Stress Rupture for Type 304 SS from ORNL, 2020, Figure R14.4-2A

The minimum stresses for initiation of tertiary creep and stress rupture are computed using a lower bound on log(t) of 1.65 x SEE, where SEE is the standard error of the estimate on log t. In other words, the minimum life is defined to be 1.65 SEE short of the average life predicted by the model. Although not statistically rigorous, the staff's interpretation is that this results in essentially a 90-percent lower bound on the stresses. A second order fit was used in all cases, except for the time to 1-percent strain and time to tertiary for Type 304 SS, and the time to tertiary for Type 316 SS. ORNL, 2020 (p. 77) contains additional details. In addition, this method is consistent with the historical practice used by the ASME Code to determine the allowable stresses.

For all five materials, ORNL's analysis resulted in lower S_t values than the values in the 2017 Edition Section III-5 values at certain time-temperature combinations, particularly those with longer times and higher temperatures. For 9Cr-1Mo-V, ORNL, 2020 notes that the S_t values have been updated in the 2019 Edition of Section III-5, and that ORNL's independent analysis found no nonconservatism in the updated 2019 values.

However, the staff notes that there are several conservatisms in the Section III-5 design rules that provide redundant protection against component failure by creep rupture, which the criteria for determining S_t are intended to prevent. ANL, 2021 describes some of these conservatisms. ANL, 2021 notes that, of these three criteria, the 1-percent strain and rupture criteria represent actual design limits; however, the tertiary creep criterion was originally intended to guard against leakage failure in biaxially stressed tubes. ANL, 2021 further notes that the Appendix HBB-T deformation-controlled design limits on strain accumulation and creep-fatigue provide redundant protection against all three of the S_t criteria. Even if the allowable stress S_t in the ASME Code does not match the actual material data, these redundant checks would still adequately guard against these three design limits, provided the ASME Code minimum stress-to-rupture data are reasonably accurate.

According to ANL, 2021, Section 2.1.3, the deformation limits given in Appendix HBB-T provide a redundant check on the 1-percent strain criteria in S_t. The stated limits in HBB-T-1310 are that the maximum accumulated inelastic strain shall not exceed the following:

(1) 1 percent, averaged through the thickness
(2) 2 percent, linearized through a section
(3) 5 percent, at any point

The first two criteria (1 percent averaged through the thickness and 2 percent linearized) provide redundant protection against the first of the S_t criteria. The primary load, S_t allowable stress check, considers only the primary membrane and primary membrane plus bending stresses. The membrane and bending components are analogous to the 1-percent averaged and 2-percent linearized strain criteria. The Appendix HBB-T deformation limits include the effect of both primary and secondary stress and so are generally more conservative than the allowable primary stress check, as the stresses under consideration are greater than just the primary membrane and bending stresses. Appendix HBB-T provides several alternatives for meeting the deformation limits, up to and including a full inelastic analysis. ANL, 2021 thus concludes that these methods provide a conservative, redundant check against the S_t 1-percent criterion. Further, the staff has determined that the methods related to deformation limits cited in ANL, 2021, are acceptable as documented in Section 3.9.3 of this NUREG.

ANL, 2021, Section 2.1.3, indicates that the Appendix HBB-T creep-fatigue design check provides redundant protection against the third S_t criterion: 67 percent of the minimum stress to rupture. Again, Appendix HBB-T provides multiple methods for meeting the creep-fatigue limits, either using elastic or inelastic stress analysis.

ANL, 2021 further notes that the creep-fatigue design approaches (HBB-T-1400) consider the full stress history of the component, not just the primary stresses, as in the allowable stress check. Since realistic analyses of components will include some secondary and peak stress in addition to primary stresses, this means that the total stresses used in the creep-fatigue evaluation are greater than the primary stress used in the allowable stress check. Moreover, the creep-fatigue limits include the detrimental effect of fatigue on creep strength. Applying a higher stress and reducing the creep strength of the material means the Appendix HBB-T creep-fatigue checks provide a conservative redundant check on the S_t rupture criterion. ANL, 2021 also includes an example showing that, even for a hypothetical component with primary stresses only, HBB-T would provide a conservative check on creep-fatigue.

ANL, 2021 notes that most realistic analyses of components would include bending and peak stresses. In this case, the ASME Code creep-fatigue criterion is even more conservative. In the case of nonuniform stresses across a section, the creep-fatigue criterion limits the design life to the time at which the first point exceeds the creep-fatigue limit. Conceptually, this represents the initiation of a creep crack at the most stressed location. In service, the creep crack would then need to propagate through the component section before net section rupture or leakage could occur. The creep-fatigue design rules conservatively do not credit the design with the time to propagate the initial flaw, which can be substantial for actual inservice components.

Based on the above considerations, ANL, 2021 concluded that the HBB-T methods are adequate to prevent the initiation of creep-fatigue failure, which includes steady-state rupture as a limiting case (specifically, the limiting case where the fatigue damage is zero). Further, the staff has determined that the methods related to creep-fatigue cited in ANL, 2021, are acceptable as documented in Section 3.9.4 of this NUREG. ANL, 2021 indicates that the creep-fatigue rules also provide a redundant protection against the tertiary creep criterion in the definition of S_t. The Appendix HBB-T creep-fatigue rules provide protection against multiaxial rupture, which was the purpose of the tertiary creep criterion in the definition of S_t. For the design by elastic analysis rules, this protection takes the form of a correction to the uniaxial stress relaxation profile to account for multiaxiality (HBB-T-1433, Step 5a) or by applying the very conservative isochronous stress-strain curve (ISSC) relaxation approach (HBB-T-1433, Step 5b). For design by inelastic analysis, this protection is accomplished by using the Huddleston effective stress to account for the effects of stress multiaxiality (HBB-T-1411). Combined with the generally conservative creep-fatigue damage approach discussed previously, the creep-fatigue design rules provide a conservative, redundant protection against the S_t time-to-tertiary criterion.

The staff notes that using a 1.65 x SEE factor on log(t) introduces significant conservatism. The application of the factor of 0.67 to the minimum S_r value, rather than the average S_r value, adds conservatism to the determination of S_t, as does the factor of 0.80 applied to the minimum stress to cause initiation of tertiary creep.

Based on the conservatisms and redundant protections in the design process and other conservatisms in the determination of the S_t values discussed above, the staff considers values of S_t determined in the independent analysis up to 10 percent lower than the Section III-5 S_t values to support a finding of adequacy of the Section III-5 values.

Type 304 SS and Type 316 SS

ORNL, 2020, Appendix TCOC, "Comments on the Tertiary Creep Criterion for S_t (and S_{mt})," describes the issues associated with the implementation of the tertiary creep criterion. Appendix TCOC notes that the amount of time-to-tertiary creep data is relatively small compared to the amount of data for the other two criteria. Also, Appendix TCOC indicates that reliable determination of the time-to-tertiary creep is difficult. Appendix TCOC includes an alternate independent analysis by ORNL for Type 304 SS that determined the S_t values that would result if the time-to-tertiary creep criterion is excluded. Appendix TCOC also includes an alternate analysis for Type 304 SS where time-to-tertiary creep values were determined based on a linear correlation with the minimum stress to cause rupture. Both of these alternate analyses result in higher allowable stress values than the Section III-5 values in general, except for temperatures greater than 760 degrees C (1,400 degrees F) at times of 10,000 hours or greater.

ANL, 2021 indicates that, in support of the effort to extend the design lifetime of Class A materials from 300,000 to 500,000 hours, a task under the DOE/ASME Gen IV Materials Project was initiated to extend the S_r and S_t values of 304H and 316H to 500,000 hours, which led to the results published in the report STP-NU-063 (Sengupta and Nestell, 2013). The STP-NU-063 results would suggest that the S_t values for 304H and 316H may need to be reduced in view of new time-to-tertiary data. The ASME Code committees were informed of the outcome of the report. There have been extensive ongoing discussions about the report, and no formal ASME Code action has been taken. In accordance with ANL, 2021, the reason no ASME Code action has been taken is that it is not clear that the time-to-tertiary criterion should be included in the calculation of the allowable stress to begin with, or that accepting reduced allowable stresses is reasonable, as discussed below.

In accordance with ANL, 2021, when the original criterion for the onset of tertiary creep was selected (in the early 1970's) it was based on thin-walled pressurized capsule tests that leaked before they ruptured. In these biaxial tests, the time to rupture correlated with the onset of tertiary creep in uniaxial tests. The time-to-tertiary criterion was included in the allowable stresses at the time; however, with the limited tertiary creep data then available, the onset of tertiary creep did not control any of the allowable stress values. ANL, 2021 notes that a study more recently provided a historical perspective on the tertiary creep criterion (Jetter et al., 2015). The results reported in STP-NU-063 are substantially different in that the proposed allowable stresses were largely controlled by the time-to-tertiary creep criterion. If the STP-NU-063 results were considered at face value, they would result in significantly lower allowable stress values, which could have an impact on basic component thickness calculations.

Because lowering the allowable stress values by this magnitude would be at odds with operating experience in commercial (non-nuclear) service and other international standards, it was deemed appropriate to reexamine the original time-to-tertiary criterion rather than immediately change the allowable stresses specified in the ASME Code. The goal of this reevaluation was to see if the tertiary creep criterion was more generally applicable to thicker walled components, such as the ORNL nozzle-to-sphere test by Corum and Battiste (Corum and Battiste, 1993). The current status of these assessments is that the original capsule failures were equally if not better explained by multiaxial effects, the data used to establish the onset of tertiary creep were compromised by irregularities in the creep curves, and the nozzle-to-sphere failure data did not correlate with the onset of tertiary creep.

ANL, 2021 notes that ASME Code committee consensus on the role of onset of tertiary creep as one of the criteria for the time-dependent allowable stress S_t, and hence the stress intensity S_{mt} for primary load design check, has yet to be achieved. ANL, 2021 also indicates that the HBB primary load design approach does not rely on exactly capturing the minimum-stress-to-tertiary creep in the values of S_t to maintain safe designs, given the conservatism included in the factors on the individual S_t criteria (i.e., 80 percent of the minimum stress to cause initiation of tertiary creep); the general conservatism of the Section III-5 design-by-elastic analysis procedure; and the redundant protection against the onset of creep rupture provided by the creep-fatigue design provisions.

ANL, 2021 notes that, while the role of onset of tertiary creep remains to be clarified, MPR, 2021 has recently reexamined the treatment of the tertiary creep data for 304H and 316H.

ANL, 2021 refers to a presentation given to the ASME Working Group on Allowable Stress Criteria, which indicates that the tertiary creep criterion was introduced as a refinement of the other allowable stress criteria, and it was not expected to control most of the S_t values in the STP-NU-063 analysis of 304H and 316H data. ANL, 2021 listed the following reasons, expressed in the aforementioned presentation, that the tertiary creep criterion may have controlled the S_t values in STP-NU-063:

(1) Tertiary creep data are sensitive to the shape of the creep curve, and identifying the point of onset of tertiary creep is sometimes difficult.

(2) Carbide precipitation during creep testing can markedly affect the shape of the creep curve.

(3) The actual number of tertiary creep data is very small compared with the rupture data available, causing statistical uncertainties and poor extrapolation of the test data to operating times and temperatures.

An empirical observation, first made by Leyda and Rowe in the 1960s (Leyda and Rowe, 1969) and subsequently by others, indicated that the ratio of the time to the onset of tertiary creep to the time to rupture is relatively constant over a range of temperatures and stress levels. Using the tertiary creep data, MPR, 2021 determined an average tertiary-to-rupture time ratio. They then applied this average Leyda-Rowe correlation to the time-to-rupture regression results to arrive at a time-to-tertiary creep correlation. Since the creep rupture database is much more robust, the adoption of the creep rupture statistics essentially mitigates some of the issues associated with the tertiary creep database discussed above. MPR, 2021 combined this more accurate time-to-tertiary creep correlation with the time-to-1-percent-strain and time-to-rupture correlations established in STP-NU-063 to arrive at new S_t values. These new S_t intensity values are shown in ANL, 2021 for Type 304 SS and Type 316 SS.

The MPR, 2021 S_t values are compared with the corresponding design values from the 2017 Edition of the ASME Code, HBB, using the following measures:

$$D_1 \equiv \frac{(S_t)_{Dabrow-Nestell} - (S_t)_{2017}}{(S_t)_{2017}} \times 100\%$$

Tables 3 and 6 of ANL, 2021 provide the S_t values for Type 304 SS and Type 316 SS determined by MPR, 2021. Table 5 and Table 7 of ANL, 2021 provide the D_1 values for Type 304 SS and Type 316 SS. For Type 304 SS, the MPR, 2021 S_t values are all greater than or no more than 10 percent less than the Section III-5 values, except for temperatures greater than 700 degrees C (1,300 degrees F), where some values are less than the Section III-5 values by more than 10 percent (e.g., some MPR D_1 values were less than -10% of the Division 5 values).

For Type 304 SS, the S_{mt} values (Section 3.7.5) and S_r values (Section 3.7.8) from the staff's independent analysis also were less than the corresponding Section III-5 values for certain times and temperatures at temperatures greater than 700 degrees C (SI units) and 1300 degrees C (US Customary Units). The time-temperature combinations at which the staff identified this potential nonconservatism were slightly different for S_r versus the S_t and S_{mt} values. Accordingly, the staff is not endorsing the S_{mt}, S_t, and S_r values for Type 304 SS for the time-temperature combinations depicted by shaded cells in Table 3-1, which are based on the time-temperature combinations at which one or more of the three allowable stresses, S_{mt}, S_t or S_r are less than the corresponding Section III-5 value by greater than 10%.

Table 3-1 Type 304 SS Allowable Stress Limitations
(Gray shaded cells represent time/temperature combinations for which S_t, S_{mt}, and S_r, are not endorsed.)

US Customary Units											
Temp	Time (hr)										
°F	1	10	30	100	300	1k	3k	10k	30k	100k	300k
800											
850											
900											
950											
1000											
1050											
1100											
1150											
1200											
1250											
1300											
1350											
1400											
1450											
1500											
SI Units											
Temp	Time (hr)										
°C	1	10	30	100	300	1k	3k	10k	30k	100k	300k
425											
450											
475											
500											
525											
550											
575											
600											
625											
650											
675											
700											
725											
750											
775											
800											

For Type 316 SS, all the S_t values determined by MPR, 2021 exceed the corresponding Section III-5 values (positive D_1 values).

Based on the above, for Type 304 SS, the staff finds the Section III-5 S_t values are acceptable for all temperatures at 700 degrees C (1,300 degrees F) or below. For Type 316 SS, the staff therefore finds the Section III-5 S_t values are acceptable for Type 316 SS, since the alternative analysis found the S_t values were greater than the Section III-5 values for all times and temperatures.

Alloy 800H

For Alloy 800H, the independent analysis by ORNL determined S_t values that were more than 10 percent lower than the Section III-5 values for temperatures greater than 500 degrees C or 900 degrees F.

ANL, 2021 notes that, as part of the effort to extend the design lifetime of Class A materials from 300,000 to 500,000 hours, another task under the DOE/ASME Gen IV Materials Project was initiated to extend the S_r and S_t values of Alloy 800H to 500,000 hours. The work led to the results published in the report STP-NU-035 (Swindeman, et.al., 2012). Based on the results in STP-NU-035, the 2013 Edition of the ASME Code revised the S_r values of Alloy 800H to extend to longer times (500,000 hours) and higher temperatures (816 degrees C). However, similar to the S_t values for 304H and 316H found in the STP-NU-063 analysis, the Alloy 800H S_t values in STP-NU-035 were also found to be significantly lower in view of the new time-to-tertiary data. In addition, the S_t values were mostly controlled by the tertiary creep criterion, similar to the STP-NU-063 results for stainless steels. The ORNL independent analysis results for Alloy 800H are very similar to the STP-NU-035 results for the S_t values of Alloy 800H.

ANL, 2021 notes that the approach developed by MPR, 2021 on the use of the Leyda and Rowe correlation in the treatment of the 304H/316H creep data can also be applied to the analysis of the Alloy 800H data in establishing the revised values of S_t. ANL, 2021 includes a preliminary assessment of the potential impact of a future code action to update the S_t values of Alloy 800H in the 2017 Edition of the ASME Code using the MPR 2021 methodology, performed as follows. The S_r values of Alloy 800H from the 2017 Edition of the ASME Code are multiplied by the factor 0.67, and the percent difference from the S_t values of Alloy 800H from the 2017 Edition of the ASME Code is determined using the following equation:

$$D_3 \equiv \frac{0.67 \times (S_r)_{2017} - (S_t)_{2017}}{(S_t)_{2017}} \times 100\%$$

The staff notes that this assessment assumes that the revised tertiary creep stresses would not be controlling for Alloy 800H, and 0.67x S_r would control the new S_t values. The results of this comparison, described in ANL, 2021, show that the D_3 values are negative for some longer times and higher temperatures but by no more than 13 percent, with most values within 10 percent of the ASME Code values. Therefore, the 0.67x S_r values are greater than or within 13 percent less than the 2017 Edition Section III-5 S_t values. ANL, 2021 states that, with other sources of conservatism in the overall HBB design procedure, as discussed in Section 2.1.1, it is judged that the S_t values of Alloy 800H from the 2017 Edition of the ASME Code for temperatures up to 760 degrees C (1400 degrees F) and design lives up to 300,000 hours are adequate for primary load assessment. ANL, 2021 also notes that there is a planned ASME Code action to extend the S_t values of Alloy 800H from 300,000 to 500,000 hours and to temperatures higher than 760 degrees C (1400 degrees F), and that it is anticipated that the

MPR, 2021 approach will be employed in the treatment of the Alloy 800H tertiary creep data. Given the assessment in ANL, 2021, which was based on recently updated S_r values and which found reasonable agreement with the current Section III-5 S_t values, with most differences bounded by 10 percent, and considering the conservatisms in the design process previously noted in this section, the staff finds the Section III-5 values acceptable. The staff notes the S_t values for Alloy 800H are expected to be updated in the next few years, and it would review the use of the updated values on a case-by-case basis unless the NRC generically endorses these values in the future.

<u>2-1/4Cr-1Mo</u>

For 2-1/4Cr-1Mo, the independent analysis by ORNL determined S_t values that were more than 10 percent lower than the Section III-5 values for all temperatures at longer times. All the S_t values from the ORNL analysis that were lower than the Section III-5 values are controlled by the 80 percent of the minimum stress to initiate the tertiary creep criterion.

ANL, 2021 also notes that ORNL's database for its independent analysis consists of both solution-annealed and normalized and tempered (N&T) 2-1/4Cr-1Mo materials. By contrast, Section III-5 only allows the use of solution-annealed 2-1/4Cr-1Mo. ANL, 2021 states that it is generally known that the N&T condition gives higher tensile strength but weaker creep strength at longer times and higher temperatures, and thus, it is not appropriate to combine these two material conditions into a single database for analysis.

ANL, 2021 notes that the issue of potential lack of conservatism in the long-term, high-temperature, allowable stress values for 2-1/4Cr-1Mo has been recognized for many years. ANL, 2021 summarizes previous studies of the allowable stress values for 2-1/4Cr-1Mo.

ANL, 2021 indicates that, in the assessment of the 2-1/4Cr-1Mo database for extrapolation of design lives to 500,000 hours, STP-NU-035 also found that the high-temperature, long-term allowable stress values were not conservative using a much larger data base from the National Institute for Materials Science (NIMS). Importantly, STP-NU-035 also discussed difficulties in assessing the 2-1/4Cr-1Mo creep curves, noting that, for most heats and testing conditions, the creep curves are mostly in third-stage creep with a little primary creep, as opposed to the classical curves assumed for the initial allowable stress development. ANL, 2021 notes that this is generally analogous to the tertiary creep issues in the austenitic SSs, as discussed by Sengupta and Nestell, 2013 in STP-NU-063 and by MPR, 2021.

ANL, 2021 summarizes more recent work by Swindeman, which used a Stress Range Splitting (SRS) approach similar to that introduced by NIMS for 9Cr-1Mo-V steel to analyze seven heats of 2.25Cr-1Mo tubing materials from NIMS. Figure 3-4, reproduced from ANL, 2021, Figure 2, provides curves of applied stress versus average creep rupture life produced by the SRS analysis in combination with the Larson-Miller approach compared with the test data. The vertical red line in the figure shows the 300,000 hours mark. ANL, 2021 indicates that, from the standpoint of establishing a temperature bound for the use of the allowable stresses in Table HBB-I-14 of the 2017 Edition of the ASME Code, the data fit at 500 degrees C (932 degrees F) shows no excursion into the regime of rapid life degradation and a slight excursion at 525 degrees C (977 degrees F) starting at 200,000 hours. Therefore, for temperatures up to 500 degrees C, the staff is endorsing the Section III-5 values for times up to and including 300,000 hours based on the observation of no rapid creep life degradation at longer times as shown by Figure 3-4.

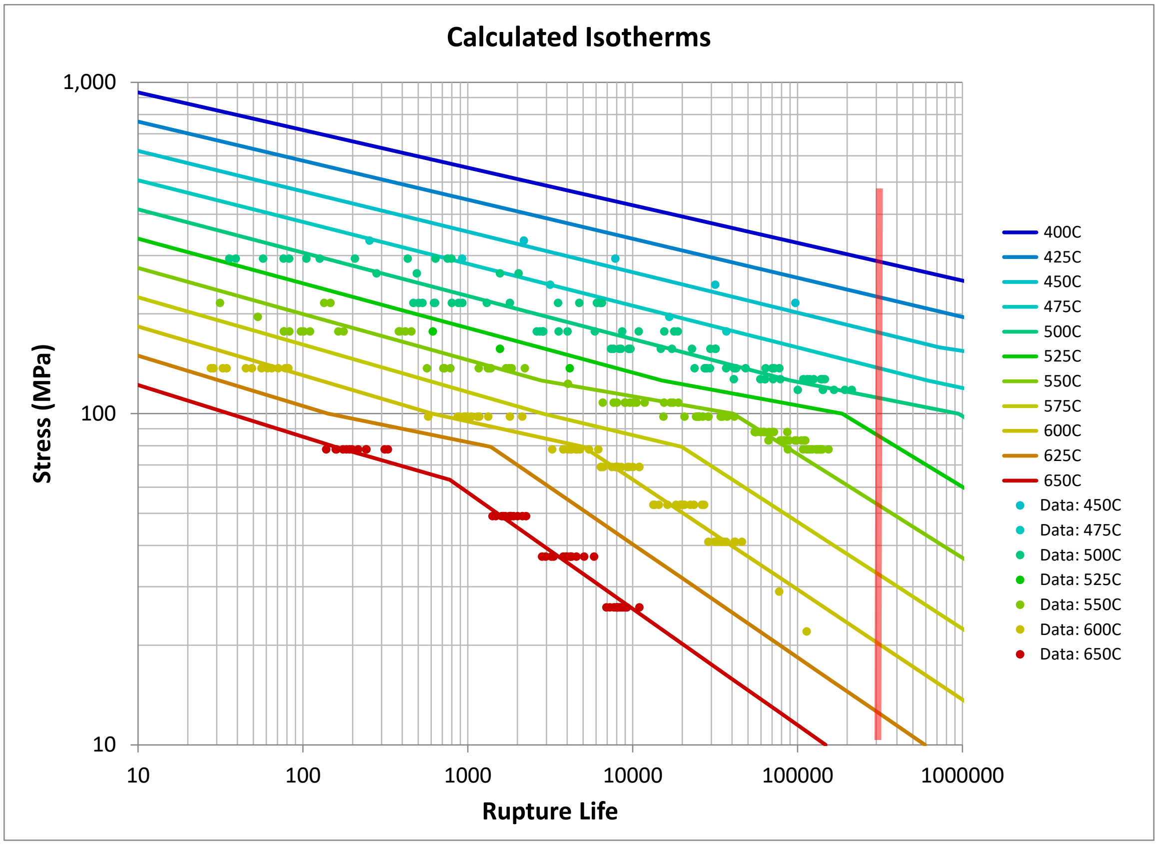


Figure 3-4 Comparison of Average Values from SRS and Larson-Miller Analysis with the Seven Heats of NIMS 2.25Cr-1Mo Tubing Data, from ANL, 2021, Figure 2

In ANL, 2021, the statistical fits are used to calculate the expected minimum stress-to-rupture values, S_r. The $0.67 \times S_r$ values at 100,000 hours from the SRS analysis are compared to the S_t values from Section III-5Table HBB-I-14.4D in ANL, 2021. The percentage differences, D_5, is defined as follows:

$$D_5 = \frac{0.67 \times (S_r)_{SRS} - (S_t)_{2017}}{(S_t)_{2017}} \times 100\%$$

The tabulated values of S_t from HBB-I-14.4D are significantly more conservative with respect to the values of $0.67 \times S_r$ from the SRS analysis of the NIMS data up to 550 degrees C (1,022 degrees F). Table 11 of ANL, 2021 compares the values of $0.67x(S_r)_{SRS}$ and S_t from Section III-5 at 100,000 hours, and provides the percentage difference (D_5) between them. The percent difference is positive up to 550 degrees C and is -6% at 575 degrees C. Although the percent difference at 525 degrees C is positive at 100,000 hours, at this temperature the S_r values begin to decline more sharply at times greater than 100,000 hours, which is not the case at 500 degrees C. Based on the positive percent difference between the $0.67xS_r$ values from the SRS analysis and the Section III-5 S_t values up to 550 degrees C and 1050 degrees F.[9] and 100,000 hours, but considering the decline at 525 degrees C at times greater than 100,000 hours, the staff is endorsing the Section III-5 S_t values at 525-550 degrees C and 950-1050 degrees F for times up to and including 100,000 hours. At 575 degrees C and 1100 degrees F and above, due to the relatively rapid degradation of S_r values at these temperatures (and consequently the $0.67xS_r$ values), the staff is not endorsing the Section III-5 S_t values. Table 3-2 shows the limitations on the S_t values graphically.

Table 3-2 2-1/4Cr-1Mo Allowable Stress Limitations
(Light Gray shaded cells represent time/temperature combinations for which S_{mt}, S_t, and S_r are not endorsed. Dark gray shaded cells are time/temperature combinations for which Section III-5 does not provide allowable stress values)

US Customary Units											
	Time (hr)										
Temp °F	1	10	30	100	300	1k	3k	10k	30k	100k	300k
800											
850											
900											
950											
1000											
1050											
1100											
1150											
1200											
SI Units											
	Time (hr)										
Temp °C	1	10	30	100	300	1k	3k	10k	30k	100k	300k
425											
450											
475											
500											
525											
550											
575											
600											
625											
650											

[9] The limitations on S_t in US Customary units are based on interpolation of the S_r values in SI units to determine the equivalent S_r values at the temperatures in degrees F in the US Customary units portion of Table HBB-I-14.6D, since the SRS analysis results are only provided in SI units.

9Cr-1Mo-V

For 9Cr-1Mo-V, the independent analysis of ORNL, 2020 indicated lower S_t relative to the 2017 Section III-5 values; however, the independent analysis showed the updated values in the 2019 Edition of Section III-5 are conservative.

Summary—S_t Values

Based on the above, the staff is not endorsing the Section III-5 S_t values for:

- Type 304 SS for the following time/temperature combinations (these are also shown graphically in Table 3-1):
  - US Customary Units
    - Times greater than 30,000 hours at 1350 degrees F.
    - Times greater than 3000 hours at 1400 degrees F.
    - Times greater than 1000 hours at 1450 degrees F.
    - Times greater than 100 hours at 1500 degrees F.
  - SI Units
    - Times greater than 30,000 hours at 725 degrees C.
    - Times greater than 3000 hours at 750 degrees C.
    - Times greater than 1000 hours at 775 degrees C.
    - Times greater than 300 hours at 800 degrees C.
- 2-1/4Cr-1Mo for the following time/temperature combinations (these are also shown graphically in Table 3-2)
  - US Customary Units
    - Times greater than 100,000 hours at temperatures of 1000 degrees F and 1050 degrees F.
    - Temperature greater than or equal to 1100 degrees F, for all times.
  - SI Units
    - Times greater than 100,000 hours at temperatures of 525 degrees C and 550 degrees C.
    - Temperature greater than or equal to 575 degrees C, for all times.
- For 9Cr-1Mo-V, the Section III-5 S_t values at all times and temperatures.

In addition, for 9Cr-1Mo-V material, the staff is endorsing the use of the 2019 Edition Section III-5 values in Table HBB-I-14.4E in lieu of the 2017 Edition, Section III-5 values.

3.7.6 Table HBB-I-14.5 Yield Strength Values, S_y, Versus Temperature

ORNL, 2020 documents an independent analysis by ORNL of the yield strength values versus temperature, S_y. ORNL's independent analysis determined higher values than the Section III-5 values, or values no more than 10 percent lower than the Section III-5 values, for all materials at all temperatures, with the exception of those for Type 304 SS at or above 775 degrees C (1,450 degrees F). Based on NRC staff exceptions to its endorsement of ASME Code, Section III, Divisions 5, with respect to allowable stress values for Type 304 SS (S_{mt}, S_t, and S_r), Type 304 SS is unlikely to be used at temperatures above 700 degrees C (1,300 degrees F) and the staff will evaluate any proposal for such use on a case-by-case basis. Accordingly, the staff has determined that Section III-5 is acceptable in regard to S_y values. The staff notes that ORNL's analysis of the Type 304 SS S_y used data from grades of material having specified minimum ultimate tensile strength of both 517 MPa (75 kilopounds of force per square inch (ksi)) and 483 MPa (70 ksi), whereas almost all the specifications for Type 304 SS permitted by Section III-5 specify a minimum ultimate tensile strength (UTS) of 517 MPa (75 ksi), with the exception of one specification that specifies a UTS of 483 MPa (70 ksi). While both grades have minimum specified yield strengths of 207 MPa (30 ksi), the 483 MPa (70 ksi) UTS grades can be expected to have a lower trend for yield strength than the 517 MPa (75 ksi) UTS grades, which could have contributed to the lower values determined by ORNL. Based on the above, the staff finds the Section III-5 S_y values acceptable for Type 304 SS.

ORNL, 2020 noted that for 2-1/4Cr-1Mo, the 2017 (and 2019) Editions of the ASME Code II-D and ASME Code III-5 do not distinguish between annealed material and N&T material. ORNL, 2020 notes that ORNL's analysis, as presented in Figure R.HBB-I-14.5 of ORNL, 2020, shows distinctly different trend curves for material with the two heat treatments, and such difference was also noted in the 1971 ASTM Data Series DS 6S2 (Smith, 1971), with the N&T material having lower strength. ORNL, 2020 notes that the use of data for both heat treatments is a compromise but produces potentially less conservative strength parameters for the N&T material. ORNL's analysis results indicate the differences in yield strength vary from being insignificant to about 12.5 percent. ORNL, 2020 further notes that these findings suggest that the ASME Code may need to consider separate classes of material for annealed and N&T for 2-1/4Cr-1Mo. However, the staff notes that the S_y values determined by ORNL for 2-1/4Cr-1Mo are all no lower than 10 percent less than the ASME Code values.

For reasons detailed in Section 3.7, the staff generally considered values from the independent analysis that are equal to or greater than the Section III-5 values, or within 10 percent less than the Section III-5 values, to support a finding of adequacy of the Section III-5 values. Therefore, since the independent analysis generally found S_y values equal to or higher or within 10 percent less than the Section III-5 values, and the larger discrepancies for Type 304 SS are in a temperature range for which that material is unlikely to be used, the staff finds the S_y values in Section III-5, Table HBB-I-14.5, to be acceptable.

3.7.7 Table HBB-3225-1 Tensile Strength Values, S_u

Table HBB-3225-1 shows the tensile strength (S_u) values as a function of temperature. ORNL, 2020 documents the independent analysis by ORNL of the Section III-5 S_u values. The Section III-5 permissible specifications for Type 304 SS include material having minimum specified room temperature UTS of 517 MPa (75 ksi) and 483 MPa (70 ksi), but Table HBB-3225-1 does not have distinct S_u values for the two different material strengths. However, ORNL, 2020 provides separate analysis results for materials having minimum room temperature UTS of 517 MPa (75 ksi) and 483 MPa (70 ksi). Only one product form has a minimum specified tensile strength of 483 MPa (70 ksi).

The independent analysis determined equal or higher values of S_u to those in Section III-5, or values no more than 10 percent less than the Section III-5 values, for all materials at all temperatures with the exception of Type 304 SS.

For Type 304 SS, the independent analysis determined S_u values more than 10 percent lower than the Section III-5 values at temperatures at or above 800 degrees C

(1,450–1500 degrees F) or for material with a specified minimum room temperature UTS of 517 MPa (75 ksi) and temperatures at or above 700 degrees C (1,300 degrees F) or for material with a specified minimum room temperature UTS of 483 MPa (70 ksi). The independent analysis results are less than the Section III-5 values by a maximum of about 15 percent for material having a minimum UTS of 517 MPa (75 ksi), which is representative of most of the grades of Type 304 SS permitted by Section III-5. Based on NRC staff exceptions to its endorsement of ASME Code, Section III, Divisions 5, with respect to other allowable values for Type 304 SS (S_{mt}, S_t, and S_r), Type 304 SS is unlikely to be used at temperatures at or above 700 degrees C (1,300 degrees F). Further, the only use of the S_u values in Section III, Division 5 is as one of the factors in determining the S_m values at higher temperatures and by extension the S_{mt} values, both of which are already subject to conditions for Type 304. Therefore, a separate condition is not needed for the Type 304 S_u values.

Since the independent analysis generally found S_u values equal or higher or within 10 percent less than the Section III-5 values, and the larger discrepancies for Type 304 SS are in a temperature range for which that material is unlikely to be used, the staff finds the S_u values in Table HBB-3225-1 to be acceptable.

3.7.8 Figures and Tables HBB-I-14.6A–F, Minimum Stress-to-Rupture

Tables HBB-I-14.6A–F contain the minimum stress-to-rupture values, S_r. ORNL, 2020 documents an independent analysis by ORNL of the S_r values using data gathered in a literature search. Section 4.5.5 describes the analysis method for S_r. ORNL's analysis resulted in lower S_r values for some of the materials, particularly at longer times and higher temperatures. The S_r values are determined using LMP analysis as described in Section 4.5.5.

The S_r values from Figures HBB-I-14.6A through HBB-I-14.6F are used in the evaluation procedures for Level D Service Loadings (HBB-3225) and in elastic strain analysis procedures (HBB-T-1324) and creep-fatigue evaluation procedures (HBB-T-1400) in Nonmandatory Appendix HBB-T. For the Level D service limits, factors of either 0.67 or 0.8 x R are applied to S_r, where R is the ratio of the weld metal creep strength to the base metal strength from Tables HBB-I-14.10A-1 through HBB-I-14.10E-1. The staff has determined the procedure of HBB-T-1324 and creep-fatigue design methodology HBB-T-1400 to be conservative, as discussed in Sections 4.9.3 and 4.9.4.

In addition to the factors and conservatisms discussed above, the S_r values in Figures HBB-I-14.6A–F and Tables HBB-I-14.6A–F are essentially 90 percent lower bound values, which adds additional conservatism to the margins and conservatisms discussed above. The staff therefore determined that values of S_r greater than or no more than 10 percent less than the Section III-5 values determined by the independent analysis support a finding of adequacy.

<u>Type 304 SS and Type 316 SS</u>

ORNL's analysis determined values for Type 304 SS and Type 316 SS that are lower than the Section III-5 S_r values by more than 10 percent for some longer times and higher temperatures.

As detailed in Section 3.7.6, updated S_r values for Type 304 SS and Type 316 SS were published in STP-NU-063 but have not been incorporated into Section III-5. ANL, 2021, Table 6 compares the percentage difference between the STP-NU-063 values and the 2017 Section III-5 values. For Type 304 SS some of the STP-NU-063 values were determined to be less than the Section III-5 values by 10 percent or more at temperatures at or above 700 degrees C (1,300 degrees F).

For Type 304 SS, the S_{mt} values (Section 3.7.5) and S_t values (Section 3.7.6) from the staff's independent analysis also were less than the corresponding Section III-5 values for certain times and temperatures at temperatures greater than 700 degrees C (SI units) and 1300 degrees C (US Customary Units). The time-temperature combinations at which the staff identified this potential nonconservatism were slightly different for S_r versus the S_t and S_{mt} values. Accordingly, the staff is not endorsing the S_{mt}, S_t, and S_r values for Type 304 SS for the time-temperature combinations depicted by shaded cells in Table 3-1, which are based on the time-temperature combinations at which one or more of the three allowable stresses, S_{mt}, S_t or S_r are less than the corresponding Section III-5 value by greater than 10%.

For Type 316 SS, some of the STP-NU-063 values were determined to be less than the Section III-5 values by 10 percent or more at temperatures greater than 725 degrees C (SI Units) or 1350 degrees C (US Customary Units). Table 3-3 shows time-temperature combinations for which the Section III-5 S_r values for Type 316 SS are not endorsed. The staff notes that at 750 degrees C (SI Units) or 1400 degrees F (US Customary Units) and times of 100,000 and 300,000 hours, the difference in the STP-NU-063 S_r values and the Section III-5 values is within -10 percent, while at 750 degrees C and times of 1,000-30,000 hours, the difference is greater than -10 percent. However, the staff is also not endorsing the S_r values for 300,000 hours at 750 degrees C since it would be impractical to design components for 300,000 hours without allowable stresses for the shorter times. The STP-NU-063 U.S. Customary S_r values for Type 316 SS at 1400 degrees F follow the same pattern as those at 750 degrees F. Accordingly, the staff is not endorsing the Type 316 SS S_r values at 1400 degrees F for the same reason it is not endorsing the values at 750 degrees F.

Table 3-3 Type 316 SS Limitations on S_r
(Gray shaded cells represent time/temperature combinations for which S_r is not endorsed.)

US Customary Units											
	Time (hr)										
Temp °F	1	10	30	100	300	1k	3k	10k	30k	100k	300k
800											
850											
900											
950											
1000											
1050											
1100											
1150											
1200											
1250											
1300											
1350											
1400											
1450											
1500											

Table 3-3 Type 316 SS Limitations on S_r (Cont.)
(Gray shaded cells represent time/temperature combinations for which S_r is not endorsed.)

SI Units											
	Time (hr)										
Temp °C	1	10	30	100	300	1k	3k	10k	30k	100k	300k
425											
450											
475											
500											
525											
550											
575											
600											
625											
650											
675											
700											
725											
750											
775											
800											

For Type 316 SS, the STP-NU-063 S_r values were also less than the Section III-5 values for some instances for temperatures between 425 degrees C and 550 degrees C (800 degrees F and 1,022 degrees F). Review of the ANL, 2021 results shows that some of the differences in this temperature range for long times (100,000 to 300,000 hours) are greater than 10%. ANL, 2021 indicates that the creep damage associated with these time-temperature conditions would be negligible and thus there will be no impact on the creep damage evaluation. Therefore, the staff concludes that limitations on these values are unnecessary.

Alloy 800H

ORNL, 2020 notes that the S_r values in Table HBB-I-14.6C for Alloy 800H appear marginally (by slightly more than 10 percent) nonconservative at the highest temperatures and longest durations, but judged the table to be overall acceptable given that these values are only slightly nonconservative and limited to the highest temperatures in the table. ANL, 2021 indicates that, based on the results in STP-NU-035, the 2013 Edition of the ASME Code revised the S_r values of Alloy 800H to extend to longer times (500,000 hours) and higher temperatures (816 degrees C). The staff notes these same values are in the 2017 edition of Section III, Division 5. ANL, 2021 also notes that ORNL's independent analysis of the S_r values for Alloy 800H essentially reproduced the results of STP-NU-035.

Since Section III-5 recently updated the S_r values for Alloy 800H, and ORNL's independent analysis yielded similar results to the current Section III-5 values, the staff finds the S_r values for Alloy 800H acceptable.

2-1/4Cr-1Mo

ORNL's analysis determined values for 2-1/4Cr-1Mo that are lower than the Section III-5 S_r values by more than 10 percent for some longer times and higher temperatures. Nonetheless, Figure 3-4 shows that stress rupture values for 2-1/4Cr-1Mo do not rapidly degrade at longer times for temperatures up to 500 degrees C. Therefore, the staff is endorsing the Section III-5 S_r values for all times for temperatures up to and including 500 degrees C (SI Units) and 950 degrees F[10] (US Customary Units). Table 10 of ANL, 2021 shows the S_r values based on the SRS analysis (detailed in Section 3.7.6) and the Section III-5 values of S_r, along with the percent difference between the two (D_4) at 100,000 hours. The differences are positive up to 550 degrees C and the difference is -5% at 575 degrees C. Although the percent difference at 525 degrees C is positive at 100,000 hours, at this temperature the S_r values begin to decline sharply at times greater than 100,000 hours which is not the case at 500 degrees C. Based on the positive percent difference at 100,000 hours for temperatures up to 550 degrees, the staff is endorsing the Section III-5 S_r values at 525-550 degrees and 1000-1050 degrees F for times up to and including 100,000 hours. Above 550 degrees, Figure 3-4 shows more rapid degradation of the S_r values beginning at shorter times. Therefore, the staff is not endorsing the Section III-5 S_r values for temperatures of 575 degrees C and above (SI Units) and 1100 degrees F and above (US Customary Units). The limitations on the endorsement of the S_r values for 2-1/4Cr-1Mo are for the same times and temperatures as the limitations on the S_{mt} and S_t values for 2-1/4Cr-1Mo. These limitations are depicted graphically in Table 3-2.

Alloy 718

The independent analysis in ORNL, 2020 also determined the S_r values in Table HBB-I-14.6E for Alloy 718 are conservative. Accordingly, the Table HBB-I-14.6E S_r values for Alloy 718 are acceptable.

9Cr-1Mo-V

For 9Cr-1Mo-V, although ORNL's independent analysis found some of the 2017 Edition Section III-5 S_r values to be nonconservative, these values were updated in the 2019 Edition of Section III-5. The 2019 values show no significant nonconservatism relative to the values for ORNL's analysis. Therefore, the staff will impose as a limitation that, for 9Cr-1Mo-V material, the S_r values from Table and Figure HBB-I-14.6F from the 2019 Edition of Section III-5 should be used.

Summary – S_r Values

The staff therefore finds the S_r values in Section III-5 to be acceptable, except that the staff is not endorsing:

- Type 304 stainless steel (Type 304 SS) for the following time/temperature combinations (these are also shown graphically in Table 1):
    - US Customary Units
        - Times greater than 30,000 hours at 1350 degrees F.
        - Times greater than 3000 hours at 1400 degrees F.
        - Times greater than 1000 hours at 1450 degrees F.
        - Times greater than 100 hours at 1500 degrees F.

10 The staff interpolated the S_r values corresponding to the temperatures in degrees F in the US Customary values in Table HBB-I-14.6D, since the SRS analysis results are only provided in SI units.

- SI Units
  - Times greater than 30,000 hours at 725 degrees C.
  - Times greater than 3000 hours at 750 degrees C.
  - Times greater than 1000 hours at 775 degrees C.
  - Times greater than 300 hours at 800 degrees C.

- Type 316 stainless steel (Type 316 SS) for the following time/temperature combinations (these are also shown graphically in Table 2):
  - US Customary Units
    - Times greater than 300 hours at 1400 degrees F.
    - Times greater than 30 hours at 1450 degrees F.
    - Times greater than 10 hours at 1500 degrees F.
  - SI Units
    - Times greater than 300 hours at 750 degrees C.
    - Times greater than 30 hours at 775 degrees C.
    - Times greater than 30 hours at 800 degrees C.

- 2-1/4Cr-1Mo for the following time/temperature combinations (these are also shown graphically in Table 3)
  - US Customary Units
    - Times greater than 100,000 hours at temperatures of 1000 degrees F and 1050 degrees F.
    - Temperature greater than or equal to 1100 degrees F, for all times.
  - SI Units
    - Times greater than 100,000 hours at temperatures of 525 degrees C and 550 degrees C
    - Temperature greater than or equal to 575 degrees C, for all times.

- 9Cr-1Mo-V for all times and temperatures.

In addition, for 9Cr-1Mo-V, the staff is endorsing the use of the S_r values from Table and Figure HBB-I-14.6F from the 2019 Edition of Section III-5 in lieu of the values from the 2017 Edition of Section III-5.

3.7.9 Tables HBB-I-14.10A-1–E-1, Stress Rupture Factors for Weldments

These tables contain the stress rupture factor for weldments “R” to be multiplied with the base metal S_r value to account for the reduced strength of the weldment.

HBB-3221 defines the allowable limit for general primary membrane stress for weldments, S_{mt}, as the lower of the S_{mt} values from Tables HBB-I-14.3A through HBB-I-14.3E (e.g, the base metal S_{mt} value), or:

$$0.8 \times S_r \times R$$

HBB-3221 defines the time-dependent allowable stress for welds as follows:

S_t = temperature and time-dependent stress intensity limit at a weldment, and is the lower of the tabulated S_t values from Tables HBB-I-14.4A through HBB-I-14.4E or

$$0.8 \times S_r \times R$$

HBB-3221 defines the R factor as:

R = the appropriate ratio of the weld metal creep rupture strength to the base metal creep rupture strength from Tables HBB-I-14.10A-1 through HBB-I-14.10E-1. The lowest S_t value of the adjacent base metals is utilized for the weldment.

In the titles of Tables HBB-I-14.10A-1 through HBB-I-14.10E-1, the R-factors are referred to as “stress rupture factors,” and this report uses the terms “stress rupture factors” and “R-factors” interchangeably. Each table is for a single base metal with a number of weld fillers of similar compositions, for several different specifications for various weld processes. For example, Table HBB-I-14.10A contains stress rupture factors for Type 304 SS welded with SFA-5.22 E 308T and E 308LT; SFA-5.4 E 308 and E 308L; and SFA-5.9 ER 308 and ER 308L.

There is considerable conservatism in the allowable stresses for welds since, for the time-dependent allowable stress, S_t, the lower of 0.8 x S_r x R or the lowest tabulated S_t for the adjacent base metal is used, and S_{mt} for welds is taken as the lower of 0.8 x S_r x R or the lowest tabulated S_{mt} for the adjacent base metal.

ANL, 2021 notes that the expected minimum stress-to-rupture (i.e., the minimum value of stress before weld rupture can occur) of the weld is an important design parameter in the weldment design procedures for primary load and creep fatigue. Its value is parameterized in terms of the stress rupture factor R and the tabulated base metal expected minimum stress-to-rupture S_r in HBB. Thus, the approach taken in the assessment of the R values is to check the available creep rupture data of welds and weldments against the expected minimum stress-to-rupture of the weld, determined as $R \times S_r$. Figure 3-5 shows a typical example from ANL, 2021 of actual creep rupture data plotted against R x S_r from Section III-5 for Type 304 SS base metal welded with 16-8-2 filler metal.

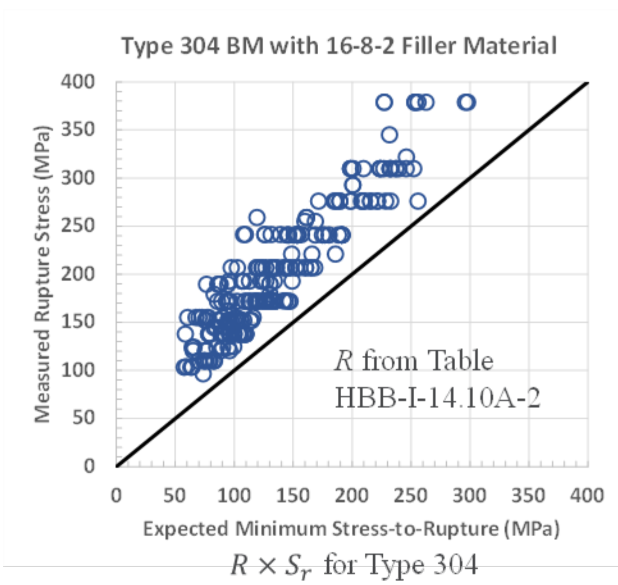


Figure 3-5 Comparison of Measured Creep Rupture Data Against HBB Prediction for Type 304 SS with 16-8-2 Filler Material (ANL, 2021, Figure 7)

ANL, 2021 further notes that the R-factors used in the weldment design procedure for Type 304 SS and 316 SS, Alloy 800H, and 2.25Cr-1Mo parent materials were determined mainly from weld metal creep rupture data, with some limited cross weld and component weld data used for validation. For 9Cr-1Mo-V parent material, the creep rupture data were predominately from cross weld testing, with some limited weld metal data.

The results of the assessment of the R-factors for each base material from ANL, 2021 are discussed below.

Type 304 SS Base Material

Comparisons were performed for Type 304 SS welded with Type 308 SS (Type 308) filler metal and 16-8-2 filler metal. These comparisons address Tables HBB-I-14.10A-1 and HBB-I-14.10A-2. Data for Type 308 SS (308) filler metal are from Appendix C to STP-PT-077 (Shingledecker et al., 2012). Data for 16-8-2 filler metal are from Appendix D to Shingledecker et al., 2012.

Table HBB-I-14.10A-1 Type 304 SS Welded with Type 308 and Variants

The creep rupture data for the Type 308 weld metal and Type 308/Type 304 SS weldment assembled in STP-PT-077 were from Type 308 and Type 308L filler materials welded with the GTAW, gas metal arc welding, shielded metal arc welding, and submerged arc welding processes. The resulting creep rupture stresses for the Type 308 weld metal and Type 308/Type 304 SS weldment are plotted against the $R \times S_r$ values in ANL, 2021. For Type 308 filler metals, the plot indicates that the Section III-5 R x S_r bounds a large majority of the measured data (approximately 95 percent). It is expected that 0.8 x R x S_r would bound virtually all the measured data, with the exception of a handful of data points. Application of the additional multiplier of 0.8 applied to the product of R x S_r yields sufficiently conservative results, provided that R x S_r bounds 95% of the measured data and considering the other conservatisms in the design procedures of Section III, Division 5.

Table HBB-I-14.10A-2 Type 304 SS Welded with 16-8-2 Filler Metal

The creep rupture data for 16-8-2 filler material and Type 316 SS parent material assembled in STP-PT-077 consisted of 16-8-2 weld metal data and 16-8-2/Type 316 SS cross weld data. The rupture stresses from the 16-8-2 weld metal data are compared to $R \times S_r$ for Type 304 SS stainless steel in ANL, 2021. For the 16-8-2 filler metal, the Section III-5 S_r x R bounds 100 percent of the measured data.

Table HBB-I-14.10A-3 Type 304 SS Welded with Type 316 SS Filler

ANL, 2021 indicates that the creep rupture data for the Type 316 SS filler material used for Type 304 SS and Type 316 SS are limited and are contained in Rowe and Stewart (Rowe and Stewart, 1962), Ward (Ward, 1974), and Hill (Hill, 1975). The data are only for the GTAW process. These rupture stress data for Type 316 SS filler metal are compared against $R \times S_r$ for Type 304 SS in ANL, 2021. The Section III-5 R x S_r bounds 100 percent of the measured data.

Summary—Type 304 SS Base Material

Based on the above, the staff finds the R-factors for Type 304 SS using both Type 308 and 16-8-2 filler metals to be acceptable because the R-factors multiplied by the tabulated S_r values for Type 304 SS generally result in expected rupture stresses that are less than the measured data. For Type 316 SS filler with Type 304 SS base metal, although R x S_r also bounds the measured rupture data, the data are more limited and are only for the GTAW process.

Therefore, the staff does not endorse the R-factors in Table HBB-I-14.10A-3 for Type 304 base metal welded with Type 316 SS filler using processes other than gas tungsten arc welding.

Type 316 SS Base Material

Table HBB-I-14.10B-1 Type 316 SS Base Metal Welded with Type 308 Filler Metal

The rupture stress data only from Type 308 weld metal are compared against $R \times S_r$ for Type 316 SS in ANL, 2021. The R-factors are determined from Table HBB-I-14.10B-1 for the Type 308 filler materials and the S_r values are from Table HBB-I-14.6B for Type 316 SS parent material. It can be observed that the R x S_r for the Type 308 filler metal with Type 316 SS base metal bounds a large percentage of the measured rupture data for Type 308 weld metal only specimens. The NRC staff anticipates that 0.8 x R x S_r would bound virtually all the rupture data since R x S_r bounds most of the measured data without the 0.8 multiplier.

Table HBB-I-14.10B-2 Type 316 SS Base Metal Welded with 16-8-2 Filler Metal

The creep rupture data for 16-8-2 filler material and Type 316 SS parent material assembled in STP-PT-077 consisted of 16-8-2 weld metal data and 16-8-2/Type 316 SS cross weld data. The rupture stresses data from both weld metal and cross weld specimens are compared against $R \times S_r$ for Type 316 SS in ANL, 2021. The R-factors are determined from Table HBB-I-14.10B-2 for the 16-8-2 filler material and the S_r values are from Table HBB-I-14.6B for Type 316 SS parent material. It can be observed from the graph of R x S_r versus the measured data that R x S_r for the 16-8-2 filler metal with Type 316 SS base metal bounds a large percentage of the measured rupture data. Based on the small number of unbounded data points and their proximity to the R x S_r line, the NRC staff anticipates that 0.8 x R x S_r would bound virtually all the rupture data.

Table HBB-I-14.10B-3 Type 316 SS Base Metal Welded with Type 316 SS Filler Metal

ANL, 2021 indicates that the creep rupture data for the Type 316 SS filler material used for Type 304 SS and Type 316 SS are limited and are contained in historical records (Rowe and Stewart, 1962), (Ward 1974), and (Hill, 1975). The data are only for the GTAW process. These rupture stress data are compared against $R \times S_r$ for Type 316 SS in ANL, 2021. The R-factors are determined from Table HBB-I-14.10B-3 for the 316 filler material and the S_r values are from Table HBB-I-14.6B for Type 316 SS parent material. The Section III-5 *R x S_r* values bound 100 percent of the measured data and accordingly are acceptable.

Summary—Type 316 SS Base Material

Based on the above, the staff finds the R-factors for Type 316 SS using Type 308 and 16-8-2 filler metal to be acceptable because the R factors multiplied by the tabulated S_r values for Type 316 SS generally result in expected rupture stresses that are less than the measured data. The 0.8 multiplier adds an additional factor of conservatism. For Type 316 SS filler with Type 316 SS base metal, although *R x S_r* also bounds the measured rupture data, the data are more limited and are only for the GTAW process.

Therefore, the staff does not endorse the R-factors in Table HBB-I-14.10B-3 for Type 316 SS base metal welded with Type 316 SS filler using processes other than gas tungsten arc welding.

Alloy 800H Base Material

Table HBB-I-14.10C-1 Stress Rupture Factors for Alloy 800H Welded with SFA-5.11 ENiCrFe-2 (INCO A)

The creep rupture data assembled in STP-PT-077 for Alloy A filler material and Alloy 800H parent material at or below 760 degrees C (1,400 degrees F) were all weld metal data. These rupture stress data are compared against $R \times S_r$ for Alloy 800H in Figure 12 of ANL, 2021. The R-factors are determined from Table HBB-I-14.10C-1 for the Alloy A filler material and the S_r values are from Table HBB-I-14.6C for Alloy 800H parent material. A plot of measured stress rupture data for Alloy 800H base metal welded with INCO A filler metal versus S_r x R from Section III-5 shows that the Section III-5 S_r x R bounds 100 percent of the measured data.

Table HBB-I-14.10C-2 Stress Rupture Factors for Alloy 800H Welded with SFA-5.14 ERNiCr-3 (INCO 82)

The creep rupture data assembled in STP-PT-077 for Alloy 82 filler material and Alloy 800H parent material at or below 760 degrees C (1,400 degrees F) consisted of weld metal and cross weld data. These rupture stress data are compared against $R \times S_r$ for Alloy 800H in ANL, 2021, which shows that $R \times S_r$ from Section III-5 bounds 100 percent of the measured data (one data point is exactly equal to $R \times S_r$). The R-factors are determined from Table HBB-I-14.10C-2 for the Alloy 82 filler material and the S_r values are from Table HBB-I-14.6C for Alloy 800H parent material.

Summary—Alloy 800H Base Material

Based on the above, the staff finds the R-factors for Alloy 800H welded using INCO A or Alloy 82 filler metal to be acceptable because the R-factors multiplied by the tabulated S_r values for Alloy 800H result in predicted weldment rupture stresses that are less than the measured data.

2-1/4Cr-1 Mo Base Material

ANL, 2021 indicates that a comprehensive review of the 2-1/4Cr-1Mo weld data was conducted by R.W. Warke of Edison Welding Institute for EPRI, documented in the EPRI report, TR-110807, “A Review of High Temperature Performance Trends and Design Rules for Cr-Mo Steel Weldments TR-110807,” June 1998 (Warke, 1998). ANL, 2021 compares the 2-1/4Cr-1Mo weld data against the HBB design values (then Code Case N-47). ANL, 2021 contains multiple plots showing qualitative comparisons between the weld and base metal data and HBB design values at various temperatures. The EPRI report, TR-110807, includes quantitative comparisons of the data points with the HBB design values at these temperatures. ANL, 2021 notes that the TR-110807 review showed that the HBB design values for 2-1/4Cr-1Mo welds are adequately conservative.

The staff notes that EPRI TR-110807 compares numerous sets of creep-rupture data for 2-1/4Cr-1Mo to the Code Case N-47 base metal and weld metal curves. The staff notes that the Code Case N-47 base metal curves are based on the stress rupture values from Figure and Table I.14.6.D of the Code Case, which are identical to those of ASME Code III-5, except ASME Code III-5 does not have values for temperatures at or greater than 622 degrees C (1,150 degrees F) at times at or greater than 3,000 hours. The staff also notes that the weld stress rupture values in Code Case N-47-32, which is referenced in the EPRI report, are identical to those in ASME Code III-5. Therefore, the weld metal curves used in the EPRI report are the same as those from ASME Code III-5.

The creep-rupture data used in the EPRI report comparison include (1) cross weld specimens, which contain both weld metal and base metal and (2) weld metal only specimens. The data also include various heat treatment conditions for the base metal, including annealed, N&T, and quenched and tempered. The data cover both as-welded and postweld heat treated (stress relieved) specimens. The data also include different heat treatments after welding such as N&T and annealing. However, the as-welded and postweld heat treated (stress relieved) tests are most relevant because these are the conditions that would exist if the material were welded in accordance with the ASME Code. Various weld processes are also represented, including shielded metal arc welding, submerged arc welding, and GTAW. The comparison plots in the EPRI report also separate the weld metal by carbon content greater than 0.05 percent and equal to or less than 0.05 percent. ASME Code III-5 only allows weld fillers for 2-1/4Cr-1Mo with greater than 0.05 percent carbon. Therefore, the data encompass the full range of material variation to be expected, based on the material specifications and welding processes allowed for 2-1/4Cr-1Mo material in ASME Code III-5.

Summary—2-1/4Cr-1Mo Base Material

Since the EPRI report demonstrates the ASME Code III-5 R-factors are conservative for 2-1/4Cr-1Mo, based on testing a wide range of base material and weld metal variations representative of what ASME Code III-5 allows, the staff finds the R factors for 2-1/4Cr-1Mo in Table HBB-I-14.10D-1 to be acceptable.

<u>9Cr-1Mo-V</u>

Table HBB-I-14.10E-1 Stress Rupture Factors for 9Cr-1Mo-V Welded with SFA-5.28 ER 90S-B9; SFA-5.5 E90XX-B9; SFA-5.23 EB9

The R-factors for 9Cr-1Mo-V in Table HBB-I-14.10E-1 are temperature dependent only and do not have values for different times, unlike all the other R-factors in Tables HBB-I-14.10A-1 through HBB-I-14.10D-1. ANL, 2021 notes that there is a currently balloted ASME Code action, Record No. 17-2817, that provides R-factors that are both time and temperature dependent and that are significantly lower than the R-factors in the 2017 and 2019 Editions of ASME Code III-5 for long design lives. As of November 2020, Record No. 17-2817 had not been approved or incorporated into the ASME Code.

The staff reviewed the proposed revised R-factors for 9Cr-1Mo-V in ASME Code Record No. 17-2817 and notes that these factors are more conservative than the current ASME Code III-5 values for longer times and temperatures. The proposed R-factors are based on a large amount of data (840) consisting of the ASME data (201) used in the development of STP-PT-077 plus 639 data from the Japanese NIMS database. The data span temperatures from 510 degrees C (950 degrees F) to 677 degrees C (1,250 degrees F). The staff also compared the expected rupture stress predicted by the proposed R-factors with actual data from the ASME data set and notes that the R-factors multiplied by the base metal S_r are conservative compared to the actual data.

ANL, 2021 notes that extension of the allowable stresses of 9Cr-1Mo-V from 300,000 to 500,000 hours was made in the 2019 Edition of HBB, and that the values of S_r (expected minimum stress-to-rupture) values are lower than those from the 2017 Edition for long design lives (up to 300,000 hours).

ANL, 2021 includes a comparison of the measured weld stress rupture data against the following:

- the 2017 Edition of ASME Code III-5 S_r multiplied by the 2017 Edition of ASME Code III-5 R-factors
- the 2019 Edition of ASME Code III-5 S_r values multiplied by the 2019 Edition of ASME Code III-5 R-factors
- the 2019 Edition of ASME Code III-5 S_r values multiplied by the Record No. 17-2817 R-factors

Tables 12, 13, and 14 of ANL, 2021 also provide the calculated values of $S_r \times R$ for the three combinations above. These results show that the 2019 Edition of ASME Code III-5 S_r values multiplied by the Record No. 17-2817 R-factors result in lower values at higher temperatures and longer times than either of the other combinations. ANL, 2021 determined the percentage difference between the 2019 Edition of ASME Code III-5 S_r values multiplied by the 2019 Edition of ASME Code III-5 R-factors and the 2019 Edition of ASME Code III-5 S_r values multiplied by the Record No. 17-2817 R-factors using the following formula:

$$D_6 \equiv \frac{R_{17-2817} \times (S_r)_{2019} - R_{2017} \times (S_r)_{2019}}{R_{2017} \times (S_r)_{2019}} \times 100\%$$

where D_6 is the percentage difference.

Summary—9Cr-1Mo-V Base Material

The results showed that, for longer times at temperatures at or greater than 525 degrees C (977 degrees F), the 2019 Edition of ASME Code III-5 S_r values multiplied by the Record No. 17-2817 R-factors were lower than the 2019 Edition of ASME Code III-5 S_r values multiplied by the 2019 Edition of ASME Code III-5 R-factors by more than 10 percent. Although the R-factors from Record No. 17-2817 have not yet been approved by the ASME Code, the negative D_6 values indicate the potential nonconservatism of the existing R-factors. ANL, 2021 concludes that the R-factors in the 2019 Edition of HBB (they are the same as those in the 2017 Edition), together with the base metal S_r values, also from the 2019 Edition, are adequately conservative for 9Cr-1Mo-V welded construction for temperatures up to 525 degrees C (977 degrees F) and lifetimes up to 300,000 hours. ANL, 2021 further stated that, once the new R-factors from Record No. 17-2817 are approved by ASME and published in a future ASME Code edition, they can be used with the 2019 S_r values without any temperature restrictions for 9Cr-1Mo-V welded construction. However, the staff notes that the NRC would still need to formally review and accept Record No. 17-2817.

Therefore, the staff does not endorse the 9Cr-1Mo-V R-factors in Table HBB-I-14.10E for temperatures greater than 525 °C (977 °F).[11]

Conclusions

Based on the above, the staff finds the stress rupture factors for weldments (R-factors) of Tables HBB-I-14.10A-1 through E-1 to be acceptable, subject to the following exceptions:

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[11] Unless ASME approves and the NRC endorses the proposed R-factors in ASME Code Record 17-2817, the NRC will evaluate applications to use them on a case-by-case basis with appropriate justification.

(1) The staff does not endorse the R-factors in Tables HBB-I-14.10A-3 and HBB-I-14.10B-3 for Type 304 or Type 316 SS base metal welded with Type 316 SS filler using processes other than gas tungsten arc welding.[12]

(2) The staff does not endorse the 9Cr-1Mo-V R-factors in Table HBB-I-14.10E for temperatures greater than 525 °C (977 °F).[12]

3.7.10 Table HBB-I-14.11 Permissible Materials for Bolting

Table HBB-I-14.11 includes three bolting materials: Type 304 SS, Type 316 SS, and Alloy 718. The table also provides the permissible material specifications for the bolting material. Type 304 SS and Type 316 SS are also approved materials for nonbolting material. Alloy 718 is a high-strength nickel-chromium-iron-molybdenum-columbium alloy that is chemically compatible with other high-nickel alloys, such as Alloy 800H.

The staff notes that, for Alloy 718, the Unified Numbering System number is written as NO 7718 and should be N07718. The staff recommends the ASME Code committee correct this.

The staff also notes that, for 304 SS and 316 SS, the table does not specify a minimum carbon content (0.04 percent as for nonbolting base material in Table HBB-I-14.1a). The minimum carbon content specified in ASME Code III-5 for base metal except for bolting in Table HBB-I-14.1(a) is 0.04 percent for service above 540 degrees C (1,000 degrees F), which helps to ensure adequate creep (time-dependent) strength. Since the allowable bolting material stresses in Table HBB-I-14.12 (for S_o) and in the Figures HBB-I-14.13A and B (for S_{mt}) are conservative, the staff finds that a minimum carbon content for Type 304 SS and 316 SS bolting is not necessary, but the cognizant ASME Code committee(s) may want to consider adding a minimum carbon content for consistency with the nonbolting materials.

The materials and specifications listed in Table HBB-I-14.11 are found acceptable for bolting because they are compatible with the nonbolting structural materials allowed by ASME Code III-5. Sections 3.7.10 and 3.7.11 evaluate the acceptability of the allowable stresses for these bolting materials.

3.7.11 Table HBB-I-14.12 S_o Values for Design Conditions Calculation of Bolting Materials S_o Maximum Allowable Stress Intensity, ksi (MPa)

Table HBB-I-14.12 provides S_o values for Type 304 SS and Type 316 SS bolting for temperatures at or below 700 degrees C (1,300 degrees F), while for the corresponding nonbolting materials, Table HBB-I-14.2 provides S_o values for temperatures at or below 800 degrees C (1,500 degrees F).

ORNL, 2020 documents an independent analysis of the S_0 values for the bolting material, which was conducted using the same method as the independent analysis of the S_0 values for the nonbolting material (see Section 4.5.3). The independent analysis generally determined higher S_0 values than the ASME Code III-5 values, or no more than 5 percent less than the ASME Code III-5 values, indicating the ASME Code III-5 values are conservative, except for Type 304 SS at and above 700 degrees C or at and above 1250 degrees F and Type 316 SS at and above 700 degrees C or at and above 1,300 degrees F. ORNL's analysis at these

12 Applicants wishing to use these base metal/weld metal combinations for welds made with processes other than gas tungsten arc welding may be able to demonstrate the adequacy of these R-factors by submitting additional data.

temperatures found values that were less than the ASME Code III-5 values by 10 percent or greater; however, the differences were all within 20 percent.

Section III-5 does not describe how the S_0 values for bolting materials were determined, unlike for nonbolting materials, for which the method of determining S_0 is explicitly described in HBB-3221. ORNL, 2020 notes that an examination of the ASME Code III-5, Table HBB-I-14.12, S_0 values at the lower temperatures indicate that these values have been computed using the criteria applicable to ASME Code, II-D, Table 4, for material that has been strength enhanced by heat treatment or strain hardening, limited to 1/3 of the yield strength at temperature.

The S_0 values that ORNL's independent analysis found lower than ASME Code III-5 values were at high temperatures, where the S_0 values are controlled by creep properties. ORNL determined the time-dependent S_0 values in the same manner as for the nonbolting material S_0 values (Section 4.5.3 of this NUREG gives the staff's review of the Table HBB-I-14.2 S_0 values) and, in fact, determined identical values for the bolting and nonbolting S_0 values at the temperatures for which the bolting S_o values were found to be lower than the ASME Code III-5 values.

The "Companion Guide to the ASME Boiler & Pressure Vessel Code," American Society of Mechanical Engineers, Criteria and Commentary on Select Aspects of the Boiler & Pressure Vessel and Piping Codes, Fifth Edition, dated November 29, 2017 (Rao, 2017) states the following:

> The intent of the Design Limits for bolting is to keep primary stresses below the lessor of 1/3 the yield strength or the allowables established for bolting in Section VIII, Division 1. The combination of 1/3 the yield strength and the Section VIII properties provides a smooth transition of design allowables between Subsection NB and Subsection HB, Subpart B. The intent of the paragraph on the maximum average stress across the bolt due to pressure loading is to carry forward the additional safety factor used in Subsection NB bolting rules.

The staff notes that the S_o values in Table HBB-I-14.12 are consistent with the above, being 1/3 of the yield strength from Section II-D, Table Y-1, at lower temperatures, and consistent with the Section II-D, Table 3, values for S (which provides the allowable stress values applicable to bolting for Section VIII, Division 1 applications). As discussed in Section 3.7.3, the S_0 values for non-bolting materials correspond to the S values given in ASME Code, Section II, Part D (Section II-D), Subpart 1, Table 1A, except for a few cases at lower temperatures where values of S_{mt} at 300,000 hours exceed the S values. In those limited cases, the S_o values for non-bolting materials are equal to S_{mt} at 300,000 hours rather than S. The staff notes that the S_0 values for non-bolting materials may be determined by 2/3 of the yield strength (one of the criteria on which the Section II-D, Table 1A "S" values may be based on), so the bolting S_0 values are effectively half of those of the equivalent non-bolting material. Based on the above, the staff agrees that the S_0 values for bolting represent conservative allowable stresses for bolting in high temperature Class A components in Section III, Division 5.

Since the S_0 values for bolting are evidently based on properties from Section II-D of the ASME Code, which the staff has generally accepted in the context of the use of ASME Code III-1, it is not necessary to recalculate the properties (S and S_y) on which the S_o values are based. Further, since the staff agrees that the method of determination of the S_0 values is conservative, the staff finds the S_o values in Table HBB-I-14.12 to be acceptable.

However, the staff recommends that the cognizant ASME Code committee add a description of the criteria for determining bolting S_0 values to ASME Code III-5.

3.7.12 Figures and Table HBB-I-14.13A-C S_{mt} –Allowable Stress Intensity of Bolting Materials

Figures HBB-I-14.13A and HBB-I-14.13B, containing the S_{mt} values for Type 304 and Type 316, serve the same purpose as, and are technically identical to, Figures I-14.13A and I-14.13B of Code Case 1592 endorsed in RG 1.87, Rev. 1.

ORNL performed an independent analysis of the bolting S_{mt} values, which identified potential nonconservatism in the bolting S_{mt} values for Type 304 and Type 316. However, the staff reviewed the results of ORNL's analysis and finds the bolting S_{mt} values for Type 304 and Type 316 remain acceptable, as detailed below.

ASME Code III-5, Figures HBB-I-14.13A and B, contain graphics illustrating S_{mt} (S_m and S_t) versus temperature up to $2x10^5$ hours for 304 SS and 316 SS. ASME Code III-5 does not contain tabulated S_{mt} values for these two alloys. ASME Code III-5 does contain tabulated values for S_{mt} for Alloy 718 in Table HBB-I-14.13C, which are also shown graphically in Figure HBB-I-14.13C. For Type 304 SS and Type 316 SS, S_{mt} values are provided for temperatures at or lower than 700 degrees C (1,300 degrees F), while for the corresponding nonbolting materials in Table and Figures HBB-I-14.3A and HBB-I-14.3B, S_{mt} values are provided for temperatures at or lower than 800 degrees C (1,500 degrees F).

ASME Code III-5 does not define the criteria used in establishing the S_t and S_m stresses for bolting material. ORNL, 2020 notes that the S_t values for the bolting materials appear to be one-half the values that would be determined using the criteria for nonbolting materials, and used this assumption in its independent analysis. ASME, 1976 indicates that the purpose of the Code Case 1592 rules for the maximum average stress through the bolt due to pressure loading is to limit the normal pressure stress sustained by the bolt to the lesser of one-third the yield strength at temperature or $1/2S_t$ of a structural material. ASME, 1976 further states that the S_{mt} values for bolting are one-half of those values given for structural (non-bolting) materials in Code Case 1592. ASME, 1976 also states that a design factor of approximately 2 is utilized in Section III for S_m values of bolts as compared to structural materials, and this philosophy was also used for the elevated temperature rules.

ORNL's independent analysis of the S_t values, indicates that the graphed S_t values for 304 SS and 316 SS appear nonconservative relative to ORNL's independent analysis results, more so at the higher temperatures and longer exposure durations. ORNL, 2020 states that, in the absence of tabulated values, however, the extent of the relative nonconservatism cannot be determined. For Alloy 718, ORNL's independent analysis found that the HBB-I-14.13C tabulated stresses are either in good agreement with, or conservative, relative to the ORNL analysis results.

The staff made some spot comparisons between the S_{mt} values for Type 304 SS and Type 316 SS bolting to the S_{mt} values for the corresponding nonbolting material for several times and temperatures and agrees that the S_{mt} values for bolting, when controlled by S_t, appear to be exactly one-half those for the nonbolting material of the same material type. When controlled by S_m, the bolting S_{mt} values are even less than one-half the S_{mt} value for the corresponding nonbolting material. This appears to be due to the fact that the Section II-D S_m

values for bolting material are lower than those for the corresponding nonbolting material, and the ASME Code III-5 S_m values for bolting were based upon these lower Section II-D S_m values.

Although ORNL, 2020 indicates that ORNL's independent analysis of the bolting S_{mt} values appears to show that the ASME Code values are nonconservative, the staff notes that the rules for bolting allowable stress intensities have some conservatisms and additional provisions compared to the stress intensities for the same conditions for nonbolting components, while other provisions for bolting stresses are approximately equivalent in conservatism to those for non-bolting materials. Conservative provisions for bolting include:

- The provision for average stress in bolts (HBB-3233.1) is comparable to the provision for membrane stress in non-bolting materials and is more conservative since the S_{mt} values for bolting are one-half or less the S_{mt} values for non-bolting materials.
- The criteria for maximum stress in the bolt cross section (HBB-3233.2) has no direct equivalent for non-bolting materials, but the maximum stress in the cross-section of bolts must be less than or equal to $2S_{mt}$ which is roughly equivalent to the criterion for non-bolting materials since the bolting S_{mt} values are one-half or less the S_{mt} values for the equivalent non-bolting material. Further, the inclusion of secondary stresses for bolting increases the overall stress, which is conservative compared to non-bolting material.
- The bolting provisions also apply more conservative use-fraction criteria than the non-bolting materials to guard against creep-rupture.

Although ORNL's independent analysis of the bolting S_{mt} values for Type 304 SS and Type 316 SS found values that appear to be lower than the ASME Code III-5 values, the staff finds that the ASME Code III-5 values of S_{mt} for Type 304 SS and Type 316 SS in Figures HBB-I-14.13A and HBB-I-14.13B remain conservative and acceptable based on the additional conservative provisions for allowable stress intensities of bolting in ASME Code III-5 discussed above, and the fact that the bolting S_{mt} values are one-half (or less) of those for nonbolting materials.

Figures HBB-I-14.13A and HBB-I-14.13B, containing the S_{mt} values for Type 304 and Type 316, serve the same purpose as Figures I-14.13A and I-14.13B of Code Case 1592 endorsed in RG 1.87, Rev. 1. Figures I-14.13A and I-14.13B of Code Case 1592 remain conservative and acceptable, and Figures HBB-I-14.13A and HBB-I-14.13B are technically equivalent to Figures I-14.13A and I-14.13B of Code Case 1592. Therefore, the staff finds Figures HBB-I-14.13A and HBB-I-14.13B containing the S_{mt} values for Type 304 and Type 316 bolting to be acceptable.

In the case of Alloy 718, since ORNL's independent analysis found that the HBB-I-14.13C tabulated stresses are either in good agreement with, or conservative, relative to the ORNL analysis results, the staff finds the S_{mt} values for Alloy 718 in Figure HBB-I-14.13C and Table HBB-I-14.13C acceptable.

The staff recommends that the cognizant ASME Code committee add a description of the criteria for determining the S_t, S_m, and S_{mt} values for bolting to ASME Code III-5 and that ASME add tabulated values of the S_{mt} values for bolting to ASME Code III-5.

3.8 Mandatory Appendix HBB-II Use of SA-533 Type B, Class 1 Plate and SA-508 Grade 3, Class 1 Forgings and Their Weldments for Limited Elevated Temperature Service

Mandatory Appendix HBB-II addresses limited elevated temperature service for components fabricated from SA-533 Type B, Class 1, plates; SA-508 Grade 3, Class 1, forgings; and their weldments.

Appendix HBB-II was developed to provide rules for the use of SA-533 Type B, Class 1 (previously designated Grade B, Class 1), plates and SA-508 Grade 3, Class 1 (previously designated Class 3), forgings and their weldments for a limited time above the normal temperature limit of 371.1 degrees C (700 degrees F) as detailed in Subsection NB. The metal temperatures are limited to 426.7 degrees C (800 degrees F) during Level B events and 537.8 degrees C (1,000 degrees F) during Level C and D events. Service life is limited to 3,000 hours in the temperature range of 371.1–426.7 degrees C (700–800 degrees F) and 1,000 hours in the range of 426.7–537.8 degrees C (800–1,000 degrees F). The number of events above 426.7 degrees C (800 degrees F) is limited to three. ASME used available supporting test data to develop the basis for these limitations. Appendix HBB-II provides the necessary data to implement the design evaluation in accordance with the rules of Appendix HBB-T.

The staff's review references technical input in the NUMARK, 2020a.

3.8.1 Article HBB-II-1000 Scope

Page 140 of 2017 Edition of the ASME Code III-5, states the following:

> Class A nuclear components, fabricated from SA-533 Type B, Class 1 plates; SA-508 Grade 3, Class 1 forgings; and their weldments may be used when metal temperatures exceed 700°F (370°C) during operating conditions associated with Level B, C, and D Service Limits in accordance with the considerations in Articles HBB-II-2000 (Material) and HBB-II-7000 (Overpressure protection).

The staff finds HBB-II-1000 acceptable as written because it only defines the materials and temperatures. (Below, the staff evaluates the technical provisions ensuring the acceptability of the use of these materials at the stated temperatures for specific applications.)

3.8.2 Article HBB-II-2000 Material

Page 141 of the 2017 Edition of the ASME Code III-5, states the following:

> The rules for materials in Division 1, Article NB-2000 and in Article HBB-2000 for Class A components in elevated temperature service shall apply to the materials of this Appendix with the following additions: (a) The material specifications permitted by this Appendix are SA-533 Type B, Class 1; SA-508 Grade 3, Class 1; and their weldments. (b) The allowable stress intensities in Table HBB-II-3000-3 of this Appendix shall be considered as extensions to the values of Section II, Part D, Subpart 1, Table 2A for the materials and conditions addressed by this Appendix.

NUMARK, 2020a conducted a detailed review of the yield strength, S_y; tensile strength, S_u; and design stress intensity (allowable) values, S_m, for both materials in Section II for temperatures less than 371.1 degrees C (700 degrees F), and Table HBB-II-3000-3 for temperatures greater than 371.1 degrees C (700 degrees F). Table 3-4 below shows these values, along with the Margin of Safety (S_u/ S_m) for the entire range of temperatures.

Table 3-4 Yield Strength, S_y, Ultimate Strength, S_u, Design Allowable Stress Values S_m, and Margin of Safety for SA-533 Type B, Class 1, Plates and SA-508 Grade 3, Class 1, Forgings for Temperatures 100 Degrees F to 1,000 Degrees F (37.8 degrees C to 537.8 degrees C) (NUMARK, 2020a)

Basis for Allowable	Temperature, °F	Temperature, °C	Yield Strength, S-y, ksi *		Tensile Strength, S-u, ksi **		Design Stress Intensity, ksi S-m***		Margin, S-u/S-m	
Stresses, Sm			**SA-533**	**SA-508**	**SA-533**	**SA-508**	**SA-533**	**SA-508**	**SA-533**	**SA-508**
Section II, Part D	100	38	50.0	50.0	80.0	80.0	26.7	26.7	**3.0**	**3.0**
Subpart 1 (T < 700 F)	150	66	48.1	48.1	80.0	80.0	26.7	26.7	**3.0**	**3.0**
	200	93	47.0	47.0	80.0	80.0	26.7	26.7	**3.0**	**3.0**
	250	121	46.2	46.2	80.0	80.0	26.7	26.7	**3.0**	**3.0**
	300	149	45.5	45.5	80.0	80.0	26.7	26.7	**3.0**	**3.0**
	400	204	44.2	44.2	80.0	80.0	26.7	26.7	**3.0**	**3.0**
	500	260	43.2	43.2	80.0	80.0	26.7	26.7	**3.0**	**3.0**
	600	316	42.1	42.1	80.0	80.0	26.7	26.7	**3.0**	**3.0**
	650	343	41.5	41.5	80.0	80.0	26.7	26.7	**3.0**	**3.0**
	700	371	40.7	40.7	80.0	80.0	26.7	26.7	**3.0**	**3.0**
Mandatory App HBB-II	700	371	40.7	40.7	80.0	80.0	26.7	26.7	**3.0**	**3.0**
(700 F < T < 1000 F)	750	399	39.8	39.8	80.0	80.0	26.7	26.7	**3.0**	**3.0**
	800	427	38.6	38.6	80.0	80.0	26.7	26.7	**3.0**	**3.0**
	850	454	37.0	37.0	77.3	77.3	25.5	25.5	**3.0**	**3.0**
	900	482	34.9	34.9	73.1	73.1	24.3	24.3	**3.0**	**3.0**
	950	510	32.1	32.1	68.0	68.0	22.5	22.5	**3.0**	**3.0**
	1000	538	28.4	28.4	61.7	61.7	20.7	20.7	**3.0**	**3.0**

Note: The values provided in Table 4.2.2-1 were obtained from ASME BPVC-2017
* - ASME BPVC-2017 Section II, Part D, Subpart 1, Table Y-1: p 660, Line No. 42 for SA-533 & p 664, Line No. 29 for SA-508
** - ASME BPVC-2017 Section II, Part D, Subpart 1, Table U: p 538, Line No. 33 for SA-533 & p 540, Line No. 19 for SA-508
*** - ASME BPVC-2017 Section II, Part D, Subpart 1, Table 2A: p 302, Line No. 23 for SA-533 & p 306, Line No. 1 for SA-508 for Temp up to 700 F; Mandatory Appendix HBB-II Table HBB-II-3000-3 for Temperatures > 700 F

Figure 3-6 below shows the values of S_m, S_y and S_u for the two materials (which are identical) as seen in Table 3-4. As may be noted in Table 3-4, the Margin of Safety (S_u/S_m) for both materials for the entire range of temperatures is consistently 3.0, thereby confirming that the S_m values in Table HBB-II-3000-3 are both conservative and are an extension of those values in Section II, Part D, Subpart 1, as stated in this Appendix. The staff finds the evaluation of the material property values in NUMARK, 2020a to be acceptable because it used ASME Code material properties and methods consistent with those used to determine the allowable stresses in Section III-5.

Therefore, the staff finds HBB-II-2000 acceptable as written.

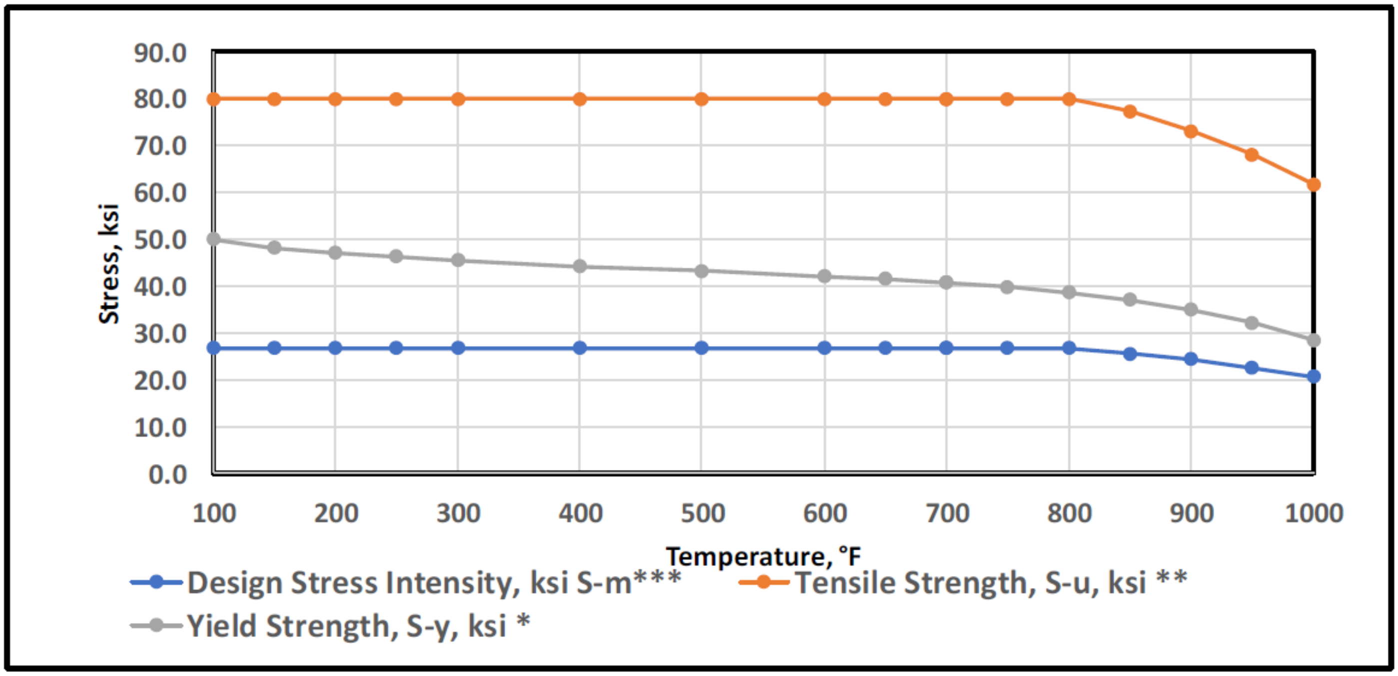

Figure 3-6 Values of S_y, S_u and S_m for SA-533 and SA-508 Materials Confirming that the S_m values for T > 700 Degrees F (371.1 Degrees C) are an Extension of those for T < 700 Degrees F (371.1 Degrees C) and are Conservative (NUMARK, 2020a)

3.8.3 Article HBB-II-3000 Design

Page 142 of the 2019 Edition of the ASME Code III-5, states that the rules for design are presented in Sections (a) through (i) of Article HBB-II-3000.

NUMARK, 2020a recommends this Article for conditional endorsement with further NRC review of the following items from a regulatory perspective:

- Table HBB-II-3000-1 provides the values of S_{mt} – Allowable Stress Intensity Values for SA-533 Type B, Class 1 and SA-508 Grade 3, Class 1 in Mandatory Appendix HBB-II for temperatures ranging from 700 degrees F to 1,000 degrees F (371.1 degrees C to 537.8 degrees C) for time at temperature values between 1 hour and 3,000 hours, as appropriate. As detailed in Section 4.3.3 of NUMARK, 2020a, the Margin of Safety relative to the creep stress rupture values as presented in Table HBB-II-3000-4 for some of the conditions is below 2.0.

Table 3-5 Ratio of Stress-to-Rupture S_r to S_{mt} for SA-533 Type B, Class 1, and SA508 Grade 3, Class 1, Materials (Margin of Safety) Based on Tables HBB-II-3000-4 and HBB-II-3000-1 (NUMARK, 2020a)

Temperature		Time at Temp, hr						
°F	°C	1	10	30	100	300	1000	3000
700	371.1	3.0	3.0	3.0	3.0	2.9	2.9	2.8
750	398.9	3.0	3.0	2.9	2.9	2.7	2.6	2.5
800	426.7	3.0	2.9	2.8	2.6	2.5	2.2	2.0
850	454.4	3.1	2.8	2.7	2.4	2.2	2.0	
900	482.2	3.0	2.6	2.4	2.1	1.9	1.6	
950	510.0	3.0	2.4	2.1	1.8	1.5	1.7	
1,000	537.8	2.8	2.1	1.8	1.6	1.6	1.9	

For the materials allowed for ASME Code III-5, Class A components, S_t (and therefor S_{mt}) can be based on 0.67 x S_r (HBB-3221, see Section 3.6.3 of this NUREG). This is equivalent to a margin of 1.49. Table 3-5 shows margins greater than 1.49 for all materials. Therefore, the margins for the materials in HBB-II are greater than the margins allowed by ASME Code III-5 for Class A materials, which can be as low as 1.49. Therefore, the NRC staff determined that no condition is necessary because the minimum margin of S_{mt} to S_r, as shown in Table 3-5, is consistent with the margin of 1.49 allowed for Class A components and thus this subarticle is acceptable as written.

3.8.4 Article HBB-II-4000 Fabrication and Installation

This Article references the rules of Article HBB-4000, which PNNL, 2020 reviewed for endorsement. Section 3.6.4 of this NUREG documents the NRC's evaluation of HBB-4000.

The staff finds subarticle HBB-II-4000 to be acceptable because it indicates that an applicant or licensee should follow Article HBB-4000, and the staff has approved HBB-4000 for endorsement for the reasons stated in Section 3.6.4 of this NUREG.

3.8.5 Article HBB-II-5000 Examination

This Article references the rules of Article HBB-5000, which PNNL, 2020 reviewed for endorsement. Section 3.6.5 of this NUREG documents the NRC's evaluation of HBB-5000.

The staff finds subarticle HBB-II-5000 to be acceptable because it indicates that an applicant or licensee should follow Article HBB-5000, and the staff has approved HBB-5000 for endorsement for reasons stated in Section 3.6.5 of this NUREG.

3.8.6 Article HBB-II-6000 Testing

This Article references the rules of Article HBB-6000, which PNNL, 2020 reviewed for endorsement. Section 3.6.6 of this NUREG documents the NRC's evaluation of HBB-6000.

The staff finds subarticle HBB-II-6000 to be acceptable because it indicates that an applicant or licensee should follow Article HBB-6000, and the staff has approved HBB-6000 for endorsement for reasons stated in Section 3.6.6 of this NUREG.

3.8.7 Article HBB-II-7000 Overpressure Protection

This Article references the rules of Article HBB-7000, which the NRC staff reviewed for endorsement. Section 3.6.7 of this NUREG documents the NRC's evaluation of HBB-7000.

The staff finds subarticle HBB-II-7000 to be acceptable because it indicates that an applicant or licensee should follow Article HBB-7000, and the staff has approved HBB-7000 for endorsement for reasons stated in Section 3.6.7 of this NUREG.

3.9 Nonmandatory Appendix HBB-T Rules for Strain, Deformation, and Fatigue Limits at Elevated Temperatures

As explained in NUMARK, 2020a, Subsection HBB states that the load-controlled stress limits of HBB are mandatory. In contrast, the deformation-controlled limits in HBB-T are not mandatory. These rules provide strain limits that are also addressed with Code Case N-861 and creep-fatigue limits that are addressed with Code Case N-862, as well as buckling and instability limits. Section 4 of this NUREG documents the staff review of Code Cases N-861 and N-862. The staff reviewed and accepted the technical recommendations of NUMARK, 2020a that find the limits of HBB-T to be an acceptable approach for demonstrating compliance with the design provisions for ASME Code III-5, Class A, components. The staff accepted the NUMARK, 2020a conclusion that HBB-T is acceptable because, based on its review of NUMARK, 2020a, the staff agrees that following the provisions of HBB-T assures conservative component designs in conjunction with the design provisions for ASME Code III-5 Class A components in HBB-3000.

Although the owner may use other methods, as justified in the Design Report (NCA-3550), it is anticipated that ANLWR vendors will use a nonlinear finite-element-based solution to demonstrate compliance for some components, due to the large computational facilities available to these vendors. This may reduce the conservativism inherent in the simple HBB-T design rules based on elastic analysis. Jetter, 1976 provides the justification for many of the rules in Appendix-T in the context of Code Case 1592, and these remain appropriate for the rules of HBB-T of 2017, as described below. For ASME Code III-5, operating experience with high-temperature design under ASME Code Sections I and VIII informed the development of HBB-T. Section 4 of NUMARK, 2020a provides detailed justification for many of the rules in HBB-T.

3.9.1 HBB-T-1100 Introduction

Subarticle HBB-T-1100 and its paragraphs serve the same purpose as the corresponding provisions in Code Case 1592 endorsed in RG 1.87, Rev. 1. The provisions in Code Case 1592 remains conservative and acceptable, and subarticle HBB-T-1100 and its paragraphs are technically equivalent to them. Therefore, the staff finds HBB-T-1100 and its paragraphs acceptable.

3.9.2 HBB-T-1200 Deformation Limits for Functional Requirements

Subarticle HBB-T-1200 and its paragraphs serve the same purpose as the corresponding provisions in Code Case 1592 endorsed in RG 1.87, Rev. 1. The provisions in Code Case 1592 remains conservative and acceptable, and subarticle HBB-T-1200 and its paragraphs are technically equivalent to them. Therefore, the staff finds HBB-T-1200 and its paragraphs acceptable.

3.9.3 HBB-T-1300 Deformation and Strain Limits for Structural Integrity

HBB-T-1310 Limits for Inelastic Strains

Subarticle HBB-T-1310 serves the same purpose as subarticle T-1310 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subarticle T-1310 of Code Case 1592 remains conservative and acceptable, and subarticle HBB-T-1310 is technically equivalent to it. Therefore, the staff finds HBB-T-1310 acceptable.

HBB-T-1320 Satisfaction of Strain Limits Using Elastic Analysis

HBB-T-1321 General Requirements

Subarticle HBB-T-1321 serves the same purpose as subarticle T-1321 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subarticle T-1310 of Code Case 1592 remains conservative and acceptable, and subarticle HBB-T-1310 is technically equivalent to it, except subsubarticle HBB-T-1321 provides clarifications and additions. The review of this updated paragraph is discussed below.

As stated in NUMARK, 2020a, use of elastic methods to account for design in the creep regime is a legacy approach developed before the widespread use of computational modelling. At that time (1970s), most experts thought that considerable expertise and experience was necessary to perform these complex analyses and “their reliability as design tools in the hands of inexperienced users may be questioned” (O’Donnell and Porowski, 1974). Hence, the ASME consensus agreed that the ASME Code needed simple, if overly conservative and complex to apply, elastic and simplified inelastic analysis rules.

As stated in HBB-T-1321, if any one of the three strain limit test cases described in HBB-T-1322, HBB-T-1323, and HBB-T-324 are satisfied, then the strain limits of HBB-T-1310 are considered to be addressed. This includes the procedure for defining loading cycles and stress intensities. Based on the above and because subarticle HBB-T-1321 is general and the results produced using this procedure are expected to be conservative under all design circumstances, the staff finds HBB-T-1321 acceptable as written.

HBB-T-1322 Test No. A-1

HBB-T-1323 Test No. A-2

HBB-T-1322 Test No. A-1 and HBB-T-1323 Test No. A-2 serve the same purpose as those in Code Case 1592 endorsed in RG 1.87, Rev. 1. Code Case 1592 remains conservative and acceptable in regard to these tests, and HBB-T-1322 Test No. A-1 and HBB-T-1323 Test No. A-2 are technically equivalent to them. If any of the test cases (A-1 to A-3) are satisfied, the strain limits and ratcheting (progressive cyclic inelastic deformation) provisions are considered satisfied. The test cases were developed based on work by Bree documented in "Elastic-Plastic Behavior of Thin Tubes Subjected to Internal Pressure and Intermittent High-Heat Fluxes with Applications to Fast Nuclear Reactor Fuel Elements" (Bree, 1967), and "Incremental Growth Due to Creep and Plastic Yielding of Tubes Subjected to Internal Pressure and Cyclic Thermal Stresses" (Bree, 1968). Bree analyzed pressurized cylinders subjected to pressure loading and a cyclic thermal gradient through the cylinder wall. This work led to the original Bree diagram, which identified six regions of thermal and pressure stress combinations.

Three of these regimes resulted in ratcheting, even without the presence of creep straining. Two of the regions resulted in shakedown (which occurs in a structure if after a few cycles of load application, ratcheting ceases) to elastic action in the absence of creep. Finally, an elastic "safe" regime was identified where no ratcheting occurs under plastic and creep conditions. The loading conditions for the analysis based on the Bree diagram were extended to account for realistic load conditions: general primary stress and general secondary stress. Hence, the purpose of the rules is to consider the maximum value of primary and secondary load ranges in the ratcheting assessment, which is conservative because secondary stresses relax. "Elevated Temperature Design – Development and Implementation of Code Case 1592" (Jetter, 1976), pages 224–225, summarizes the conservative nature of these tests with extensive discussion. The independent review in NUMARK, 2020a agrees that this test is indeed conservative.

Subarticle HBB-T-1322 and HBB-T1323 serve the same purpose as subarticle T-1322 and T-1323 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subarticle T-1322 and T-1323 of Code Case 1592 remain conservative and acceptable, and subarticle HBB-T-1322 and HBB-T-1323 are technically equivalent to them. Therefore, the staff finds HBB-T-1322 and HBB-T1323 acceptable.

HBB-T-1324 Test No. A-3

HBB-T-1324, Test No. A-3, updates the one presented in Code Case 1592, and it also incorporates information from Code Case 1592, paragraph T-1325. For the reasons discussed above, this is a conservative test, and the "r" and "s" values of the added Table HBB-T-1324 provide additional conservatism; in short, the "r" value reduces the effective rupture time for some materials, and the "s" value increases the effective stress used to determine the maximum allowable time t_{id}, which results in a lower allowable time .

Based on the above, the staff finds HBB-T-1324 acceptable. The staff notes that Test No. A-3 uses the stress rupture (S_r) values from Figures HBB-I-14.6A through HBB-I-14.6F, which are reviewed in Section 3.7, and that conditions have been identified on the S_r values for some materials.

HBB-T-1325 Special Requirements for Piping Components

The staff finds HBB-T-1325 to be acceptable because this paragraph includes provisions in the A-1, A-2, and A-3 tests to conservatively account for elastic follow-up[13] in piping systems where stress relaxation due to creep may only partially occur. The staff finds that the procedures

[13] The term "elastic follow-up" refers to a situation in which only a small portion of a structure undergoes inelastic strains while the major portion of the structure behaves in an elastic manner. In these cases, certain areas may be subjected to strain concentrations due to elastic follow-up of the rest of the connected structure.

developed and validated ensure that elastic follow-up is conservatively addressed when using elastic analysis.

HBB-T-1330 Satisfaction of Strain Limits Using Simplified Inelastic Analysis

HBB-T-1331 General Requirements

HBB-T-1332 Test No. B-1 and B-2

HBB-T-1333 Test No. B-3

Simplified inelastic analysis methods are based on elastic analysis, which extend the Bree approach for ratcheting control. This procedure, developed by O'Donnell and Poroski, 1974, is based on a mathematical bounding strategy (similar to methods used to validate Code Case N-861) to ensure an upper bound on the accumulated strains due to ratcheting. The enhancements by Sartory in "Effect of Peak Thermal Strain on Simplified Ratcheting Analysis Procedures, PVP–Vol. 163, Structural Design for Elevated Temperature Environments–Creep, Ratchet, Fatigue, and Fracture" (Sartory, 1989) to account for peak thermal stress effects ensure conservative results for all possible conditions. Validation is provided by many authors, including Sartory in "Analytical Investigation of the Applicability of Simplified Ratcheting and Creep-Fatigue Rules to LMFBR Component Geometries – Two Dimensional Axis-symmetric Structures" (Sartory, 1976), using finite element methods to ensure accuracy.

Tests B-1 to B-3 are considered to produce conservative results because (1) the bounding theorems ensure conservative results are predicted using the tests and (2) the strain limits of HBB-T-1310 are considered quite conservative limits because they have been used for more than 50 years with acceptable results. In addition, Section 3.9.7 of this NUREG also discusses the average ISSCs of HBB-T-1800, which are used to obtain upper bounds of the total inelastic strain, including strains due to creep ratcheting with tests B-1 and B-2, with regard to HBB-T-1800.

Based on the above, the staff finds HBB-T-1331, HBB-T-1332, and HBB-T-1333 acceptable. The staff notes that Test No. B-1, B-2 and B-3 use the isochronous stress-strain curves (ISSCs) contained in HBB-T-1800, which the staff reviewed and has determined acceptable for the reasons stated in Section 3.9.7 of this NUREG.

3.9.4 HBB-T-1400 Creep-Fatigue Evaluation

Appendix B of NUMARK, 2020a documents a review of the rules for creep-fatigue interaction in ASME Code III-5, Appendix HBB-T.

HBB-T-1410 General Requirements

HBB-T-1411 Damage Equation

Many possible approaches were considered before developing the HBB-T approach to creep-fatigue assessment in ASME Code III-5 and the precursor code cases. Ultimately, the linear creep-fatigue interaction approach was chosen because it is simple for designers to use, and the material data provisions are the simplest among all approaches considered.

HBB-1411, Equation 10, evaluates creep-fatigue damage in Appendix HBB-T. The fatigue damage is accounted for by using Miner's cumulative damage criteria, as is done at lower temperatures in Subsection NB. The fatigue damage at high temperatures is accumulated in the same fashion as described in Subsection NB and the use of Miner's criteria is therefore acceptable.

NUMARK, 2020a notes that the selected linear damage approach is conceptually straightforward to apply and is consistent with other damage assessment procedures in the ASME Code. The fatigue design curves are obtained from fully reversed cyclic tests at temperature. NUMARK, 2020a describes some of the conservatisms in the creep-fatigue assessment methodology of HBB-T-1400 with which the staff agrees. These include the use of a safety factor K', which is either 0.67 or 0.9. The stress for the applicable operating condition is divided by K', resulting in a larger stress, which is then used to determine the allowable time $(T_d)_k$, resulting in a shorter allowable time. Another conservatism is that the best-fit continuous cycling data were reduced by factors of 2 on total strain range and 20 on cycles to develop the design fatigue curves in Figures HBB-T-1420-1A–1E. Accordingly, HBB-T-1411 is acceptable.

HBB-T-1412 Exemption from Fatigue Analysis

The exemption from fatigue rules does not apply to temperatures above Subsection NB temperature limits, except if service loads can be qualified as not introducing significant time-dependent effects. The staff finds HBB-T-1412 acceptable for this reason, since Subsection NB includes a technically equivalent provision and has been incorporated by reference in 10 CFR 50.55a by the NRC without conditions.

HBB-T-1413 Equivalent Strain Range

The methods for determining the equivalent strain range for use in fatigue design under multiaxial loading are basically the same as those used in Subsection NB, as noted in "Division 5—High-Temperature Reactors" (Jetter, 2017). Moreover, the effect of mean stress is ignored in the code fatigue design curves (Jetter, 2017). Jetter, 2017 mentioned that application of the modified Goodman diagram approach for Subsection NB resulted in no adjustment of the fatigue curves.

The staff finds HBB-T-1413 acceptable because this approach is used in Subsection NB, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. The mean stress effect was studied recently in a report by ORNL, "Evaluation of Mean Stress Correction on Fatigue Curves of Grade 91 and Alloy 617 in ASME Section III Division 5" (Wang et al., 2020). This recent test work showed that the mean stress effect at elevated temperature is not important, which is reasonable because at elevated temperature, creep will tend to remove mean stress effects.

HBB-T-1414 Alternative Calculation Method—Equivalent Strain Range

HBB-T-1414, the alternative approach to define multiaxial strain ranges for fatigue assessment when principal strains do not rotate during the service history, is technically equivalent to the approach used in Subsection NB, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, as noted in NUMARK, 2020a, experience shows that the approach is valid (Rao, 2017). Therefore, the staff finds HBB-T-1414 acceptable.

HBB-T-1420 Limits Using Inelastic Analysis

Full inelastic analysis involves performing a finite element-based analysis of the creep-fatigue problem for the component of interest, with a proper constitutive law that handles combined creep and plasticity (all inelastic behavior) as functions of temperature throughout the service load history. The entire history of loading is modeled to perform the assessment. Conducting such an analysis and fitting the material behavior and constants is challenging. As noted in NUMARK, 2020a, clarity is needed on the standards that are necessary to ensure that the model used is valid for the component being investigated. Rao, 2017, Section 17.4.4.3.9.4, provides six goals for the constitutive relations used for inelastic assessment.

The staff finds HBB-T-1420 acceptable with the following limitation:

- In applying the limits identified in HBB-T-1420 (including parameters such as strain, cycles, and temperature) in inelastic analysis, the user should validate the constitutive models used in assessments for cyclic creep loading. The validity of the inelastic constitutive models should be demonstrated in the design report.

HBB-T-1430 Limits Using Elastic Analysis

HBB-T-1431 General Requirements

According to NUMARK, 2020a, the most recent general rules in ASME Code III-5 were developed in "Creep-Fatigue Assessment Methods Using Elastic Analysis Results and Adjustments" (Severud, 1991), and the current rules for creep-fatigue assessment using elastic analysis methods are based on this work. The carefully developed arguments in "Background to the Elastic Creep-Fatigue Rules of the ASME B&PV Code Case 1592" (Severud, 1978) and in Severud, 1991, which are based on years of work and vetting by the ASME Code committee and operational experience, are considered conservative. Appendix B to NUMARK, 2020a extensively discusses the conservative nature of these rules. The staff finds HBB-T-1430 and HBB-T-1431 acceptable because 1) application of the limits in HBB-T-1431 will normally provide conservative results, 2) the elastic ratcheting provisions of HBB-T-1320 are an initial condition to the approach in HBB-T-1430, which ensures additional conservatism, and 3) elastic follow-up is addressed in the elastic analysis procedures by classifying certain secondary stresses as primary.

HBB-T-1432 Strain Range Determination

HBB-T-1433 Creep Damage Evaluation

In the elastic creep-fatigue analysis procedures of HBB-T-1432 and HBB-T-1433, the allowable time for each accumulated hold time is calculated by using the ISSCs of Figure HBB-T-1800 A-1 through Figure HBB-T-1800 E-11. For several materials (Type 304 and Type 316, Alloy 800H), NUMARK, 2020a found these curves to be slightly nonconservative for higher temperatures and long hold times (typically greater than 100,000 hours). The staff reviewed the evaluation of the ISSCs in NUMARK, 2020a in Section 3.9.7 of this NUREG, and determined that the independent data used to check the HBB-T-1800 ISSCs was appropriate for creep data, thus the ISSCs are acceptable without conditions.

NUMARK, 2020a also noted that ORNL, 2020 on the materials portion of ASME Code III-5 found that the stress rupture curves in Figures HBB-I-14.6A–F used to determine the allowable time duration ($(T_D)_k$ (HBB-T-1411, HBB-T-1433)) are nonconservative for certain materials at certain times and temperatures. The staff identified conditions on the S_r values in Figures and Tables HBB-I-14.6A–F, reviewed in Section 3.7.8. The staff notes that these conditions are applicable when determining the allowable time duration $(T_D)_k$ in HBB-T-1411 or HBB-T-1433.

The creep-fatigue damage envelope of Figure HBB-T-1420-2 (sometimes referred to as the creep-fatigue interaction diagram) is reviewed for each individual Class A material below. The staff's review considered information from Appendix B of NUMARK, 2020a.

Type 304 and 316

For Type 304 and Type 316, comparisons of creep-fatigue test data and the ASME Code III-5 creep-fatigue envelope from Figure HBB-T-1420-2 show that the ASME Code III-5 creep-fatigue interaction diagram curve is conservative when the safety factors from HBB-T are applied to the raw test data. Therefore, the staff finds the creep-fatigue damage envelope for Type 304 and Type 316 in Figure HBB-T-1420-2 acceptable.

Alloy 800H

NUMARK, 2020a cites the results of several studies that concluded that the creep-fatigue damage envelope for Alloy 800H is very conservative. The staff also reviewed information in Ren, 2010, which provides a review of the Alloy 800H creep-fatigue damage envelope based on three different analyses. A graph of the results of the three analyses in Ren, 2010 shows that the intersection point of 0.1, 0.1 is reasonable and conservative. Based on its review of the additional information in Ren, 2010, the staff finds the creep-fatigue damage envelope for Alloy 800H in Figure HBB-T-1420-2 acceptable.

2-1/4Cr-1Mo

NUMARK, 2020a concludes that the ASME Code III-5 safety factors lead to very conservative creep-fatigue life predictions using the linear fraction damage models. NUMARK, 2020a notes that, for 2-1/4Cr-1Mo, the interaction diagram uses (creep damage, fatigue damage) = (0.1, 0.1), which considers very conservative, especially when used with the numerous safety factors within the design procedure. NUMARK, 2020a also notes that the reduction factors for welds are considered very conservative and encourages designers to carefully place welds into the design where cyclic loads are low. The staff reviewed the evaluation in NUMARK, 2020a, as well as the source references, and agrees with its conclusions because comparisons of the creep-fatigue design envelope for 2-1/4Cr-1Mo to the test data in these references show the envelope is conservative, particularly when the conservatisms in the current ASME III-5 design procedures are applied. The staff also agrees with the statement of NUMARK, 2020a that the weld strength reduction factors for 2-1/4Cr-1Mo are conservative and would tend to result in lower stresses and more conservative designs which would also result in lower creep-fatigue damage for 2-1/4Cr-1Mo, which reinforces the conservatism of the creep-fatigue damage envelope for 2-1/4Cr-1Mo. Therefore, the staff finds the creep-fatigue damage envelope in Figure HBB-T-1420-2 for 2-1/4Cr-1Mo acceptable.

9Cr-1Mo-V

NUMARK, 2020a cites comparisons of creep-fatigue test data to the creep-fatigue envelope of the ASME Code (predecessors to ASME Code III-5), which demonstrate that the ASME Code III-5 creep-fatigue envelope for 9Cr-1Mo-V in Figure HBB-T-1420-2 is very conservative. NUMARK, 2020a also notes that, despite the observation from Appendix A to the report that the ISSCs for 9Cr-1Mo-V in ASME Code III-5 may be nonconservative for some higher temperatures and long times, it is judged that the inherent conservatism is adequate from this standpoint to ensure conservative predictions. The staff notes that it found the ISSCs for 9Cr-1Mo-V acceptable, as documented in Section 3.9.7 of this NUREG. The NRC staff reviewed the evaluation of the creep-fatigue design envelope for 9Cr-1Mo-V in NUMARK, 2020a, as well as the source references, and agrees with the conclusions in NUMARK, 2020a with respect to the conservatism of the creep-fatigue design envelope for 9Cr-1Mo-V, because comparisons of the creep-fatigue design envelope to the test data in these references show the envelope is conservative, particularly when the conservatisms in the current ASME III-5 design procedures are applied. Therefore, the staff finds the creep-fatigue damage envelope in Figure HBB-T-1420-2 for 9Cr-1Mo-V acceptable.

HBB-T-1434 Calculation of Strain Range for Piping

HBB-T-1434 provides that the simplified elastic analysis use the stress indices of ASME Code III-1, Table NB-3681(a)-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, and that the equivalent strain range may be calculated directly from the equations of HBB-T-1432, which the staff found acceptable above. HBB-T-1434 also provides that piping be assessed for thermal expansion elastic followup and its effects be accounted for in the strain range and stress intensity assessments of HBB-T-1430, which the staff found acceptable above. HBB-T-1434 further provides that the User disclose and justify the followup analysis in the Design Report. Therefore, for the reasons discussed above and because the calculation of strain range for piping accounts for elastic followup, the staff finds HBB-T-1434 acceptable.

HBB-T-1435 Alternative Creep-Fatigue Evaluation

On a high level, HBB-T-1435 recommends that, if the negligible creep criteria are satisfied, the NB procedures be used with the elevated temperature fatigue curves. HBB-T-1435(a) converts the strain range from the ASME Code III-5 fatigue curves to stress amplitude for Subsection NB. HBB-T-1435(b) provides a conservatism by substituting the primary plus secondary stress, S_n, with the peak stress, S_p. S_p is defined in NB-3653.6, but the use of S_p for S_n is very roughly the equivalent of the use of $3\bar{S}_m$ in HBB-T-1324(c). Finally, an allowable usage factor of 0.9 in HBB-T-1324(d) adds additional conservatism. Therefore, since it appropriately and conservatively modifies the rules of Subsection NB for the alternative creep-fatigue evaluation, the staff finds HBB-T-1435 acceptable.

3.9.5 HBB-T-1500 Buckling and Instability

HBB-T calls for consideration of both time-independent buckling and creep buckling and calculation of buckling loads or strains for all cases where compressive loads may lead to instability. ASME Code III-1-NB provides stability limits for specific configurations under specific loadings only and does not consider creep due to long-term loading applications at elevated temperatures. The HBB-T-1500 rules provide additional stability limits, which are applicable to general configurations for all specified design and loading conditions that may cause buckling or instability due to time-independent as well as time-dependent creep behavior of the material. The staff has determined that HBB-T-1500 is acceptable based on the following evaluations of each portion of it.

HBB-T-1510 General Requirements

The design rules for buckling, along with the design factors for time-dependent buckling, have been significantly enhanced from the original (1974) rules from Code Case 1592. Some of the original guidance from RG 1.87 for buckling (such as Regulatory Position 2 with regard to Code Case 1592-d(1) and d(3)) may no longer be needed because the new rules are more specific, especially with the temperature limits defined in Figures HBB-T-1522-1–3. Moreover, the current rules call for one to use the load-controlled buckling factors in Table HBB-T-1521-1 for conditions where strain- and load-controlled buckling may interact or for conditions where significant elastic followup may occur. Subsubarticle HBB-T-1510 sets limits on the use of HBB-T-1520, HBB-T-1521, and HBB-T-1522 for determining stability limits for load-controlled and strain-controlled buckling. The limits in HBB-T-1510 are acceptable because the independent review documented in NUMARK, 2020a, and references cited therein, shows that assessments of buckling within these limits are conservative. However, as outlined in RG 1.87, Regulatory Position 2.d(2), with regard to Code Case 1592, the following limitation is necessary for using the lower, strain-controlled, buckling factors in Table HBB-T-1521-1:

- When an applicant or licensee uses the strain factors in Table HBB-T-1521-1 for time-independent buckling, the applicant or licensee should justify in the design report that (1) the buckling is purely strain-controlled and not combined with load-controlled buckling and (2) that “significant elastic follow-up” is not occurring.

HBB-T-1520 Buckling Limits

HBB-T-1521 Time Independent Buckling

HBB-T-1521 indicates that for load-controlled buckling, the load factor, and for strain controlled buckling, the strain factor, shall equal or exceed the values given in Table HBB-T-1521-1 for the specified design and service loadings to guard against time-independent (instantaneous) buckling. Review of Table HBB-T-1521-1, with an included limitation, has been performed above under HBB-T-1510. In addition, HBB-T-1521 states that for configurations considered in NB-3133, the NB rules are valid, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Based on the above, the staff finds HBB-T-1521 acceptable given the condition shown above under HBB-T-1510.

HBB-T-1522 Time-Dependent Buckling

NUMARK, 2020a and references cited therein show that conservative buckling predictions are expected when using these rules. The staff reviewed the evaluation in NUMARK, 2020a and agrees with its conclusions. In addition, service experience over the years and validation with modeling and test data further supports the conservative nature of these rules. Based on the above, the staff finds HBB-T-1522 acceptable.

3.9.6 HBB-T-1700 Special Requirements

HBB-T-1710 Special Strain Requirements at Welds

HBB-T-1710 serves the same purpose as subarticle T-1710 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subarticle T-1710 of Code Case 1592 remains conservative and acceptable except with respect to stress relaxation cracking, and HBB-T-1710 is technically equivalent to it. According to the independent review documented in NUMARK, 2020a and references cited therein, despite the application of Code Case 1592, stress-relaxation cracking has occurred in high-temperature applications from relaxation of weld residual stresses, even in regions where the weld residual stresses were partially reduced from postweld heat treatment.

Based on the above, the staff finds subsubarticle HBB-T-1710 to be acceptable with the following limitation:

- When using HBB-T-1710 applicants and licensees should develop their own plans to address the potential for stress-relaxation cracking in their designs.

HBB-T-1711 Scope

HBB-T-1711 serves the same purpose as the corresponding provision in Code Case 1592 endorsed in RG 1.87, Rev. 1. Code Case 1592 remains conservative and acceptable, and HBB-T-1711 is technically equivalent to it Therefore, the staff finds HBB-T-1711 acceptable.

HBB-T-1712 Material Properties

HBB-T-1712 serves the same purpose as the corresponding provision in Code Case 1592 endorsed in RG 1.87, Rev. 1. Code Case 1592 remains conservative and acceptable, and HBB-T-1712 is technically equivalent to it Therefore, the staff finds HBB-T-1712 acceptable.

HBB-T-1713 Strain Limits

HBB-T-1713 serves the same purpose as the corresponding provision in Code Case 1592 endorsed in RG 1.87, Rev. 1. Code Case 1592 remains conservative and acceptable, and HBB-T-1713 is technically equivalent to it Therefore, the staff finds HBB-T-1713 acceptable.

HBB-T-1714 Analysis of Geometry

HBB-T-1714 serves the same purpose as the corresponding provision in Code Case 1592 endorsed in RG 1.87, Rev. 1. Code Case 1592 remains conservative and acceptable, and HBB-T-1714 is technically equivalent to it. Therefore, the staff finds HBB-T-1714 acceptable.

HBB-T-1715 Creep-Fatigue Reduction Factors

The staff finds HBB-T-1715 acceptable because the reduction factors for use in the fatigue evaluation procedures of HBB-T-1715 are expected to produce conservative designs, as explained below. The “Evaluation of Weldment Creep and Fatigue Strength Reduction Factors for Elevated Temperature Design” (Corum, 1989), validated the HBB-T-1715 provisions by comparing their results to test data. According to the independent review documented in

NUMARK, 2020a, the comparison in Corum, 1989 showed that application of these Creep-Fatigue reduction factors provides conservative results. The NRC staff agrees that the comparison of the results to the test data show that the results are acceptable.

HBB-T-1720 Strain Requirements for Bolting

HBB-T-1720 serves the same purpose as subsubarticle -T-1720 of Code Case 1592 endorsed in RG 1.87, Rev. 1. Subsubarticle -T-1720 of Code Case 1592 remains conservative and acceptable, and HBB-T-1720 is identical to subsubarticle -T-1720 of Code Case 1592. Therefore, the staff finds HBB-T-1720 acceptable.

3.9.7 HBB-T-1800 Isochronous Stress-Strain Relations

Subarticle HBB-T-1800 with its subsubarticles HBB-T-1810 and HBB-T-1820, and with the exception of 9Cr-1Mo-V material (reviewed below), are identical to the equivalent portions of Code Case 1592, which has been approved for use through NRC RG 1.87. RG 1.87 identifies no conditions on the use of the ISSCs in Code Case 1592. NUMARK, 2020a provides an independent review of HBB-T-1800.

Figures HBB-T-1800-A-1 through HBB-T-1800-E-11 of this subarticle provide graphs showing ISSCs, each graph being for a specific material at a specific temperature. The graphs are intended to provide the designer with information on the total strain caused by stress under elevated temperature conditions for specified intervals of time, assuming average material properties.

NUMARK, 2020a documents an independent review of the ISSCs in Figures HBB-T-1800-A-2 through HBB-T-1800-E-11. In the analysis documented in NUMARK, 2020a, available creep data for the five ASME Code III-5 materials were compared to the HBB-T ISSCs to verify the conservatism of the HBB-T ISSCs. The independent data were compared to the HBB-T ISSCs plotted using the underlying equations used to generate the HBB-T ISSCs. Figure 3-7 shows an example of a comparison for Type 304 SS at 700 degrees C (1,292 degrees F). In Figure 3-7, the black square points represent independent creep data from the Busshitsu-zairyō kenkyū kikō (NIMS) database. For example, the data point at 76,200 hours and a stress of 28 MPa and a strain of 0.005 lies approximately on the 100,000 hour HBB-T ISSC (brown line). This data point has a lower time for the same stress-strain combination from the HBB-T ISSC, which could imply the HBB-T ISSC is nonconservative. The black square at 29,800 hours at a stress of 40 MPa and strain of 0.01 lies exactly on the 30,000 hour HBB-T, which shows essentially identical results to the HBB-T ISSC.

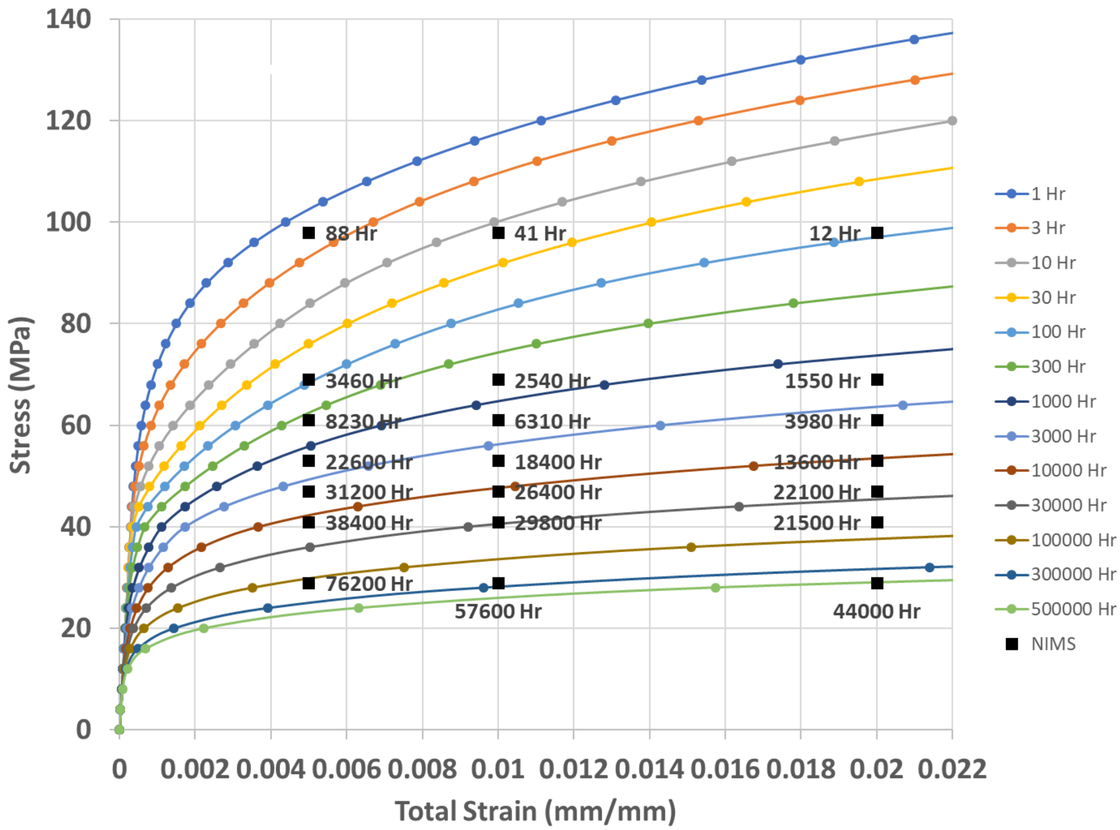

Figure 3-7 Example of a Comparison of Available Creep Data to the HBB-T ISSCs from Reference 2, for Type 304 SS at 700 Degrees C (1,292 Degrees F) (from Figure A-7 of NUMARK, 2020a)

When the independent data show a trend of significantly lower times for the same stress/strain combinations as the HBB-T ISSCs, NUMARK, 2020a suggests the HBB-T ISSCs may be nonconservative. This occurs for several materials, typically at higher temperatures and longer times, and is often attributed in NUMARK, 2020a to inaccuracies in the extrapolation of data to longer times when the HBB-T ISSCs were developed. NUMARK, 2020a further notes that, because creep data are highly variable with a large statistical scatter, the validation provided relies on some interpretation by the authors.

Nonmandatory Appendix HBB-T uses the ISSCs in the following ways:

- The ISSCs are used to obtain the creep-ratcheting strain used in Tests B-1 and B-2 of HBB-T-1332 under the simplified inelastic analysis procedures of HBB-T-1330.
- The ISSCs are used to determine the initial (unrelaxed) stress in the creep damage evaluation procedure of HBB-T-1433.
- The ISSCs may be used to determine the amount of stress relaxation in the creep damage evaluation procedure of HBB-T-1433, Step 5(b), by determining the difference between stress levels corresponding to a certain strain level ϵ_t at different times.

In the procedure of HBB-T-1332, ISSCs with a lower stress for a given strain would yield more conservative results than ISSCs with a higher stress for the same strain. In the creep damage evaluation procedure of HBB-T-1433, the stress for various different time intervals is used with a time fraction approach with the allowable time based on the minimum stress-to-rupture curves of Figures HBB-I-14.6A through HBB-I-14.6F. For this procedure, a higher stress for a given strain would be "more conservative." Therefore, it is not more conservative to shift the ISSCs along the y (stress) axis in either direction.

Conservatisms in HBB-T Procedures that Use the Isochronous Stress-Strain Curves

ANL, 2021 discusses several conservatisms inherent in the procedures of HBB-T that use the ISSCs. One conservatism is the use of the expected minimum stress-to-rupture, S_r, in the creep damage calculation, rather than an average stress-to-rupture. As such, any additional conservatism in addition to using this expected minimum stress-to-rupture can be reasonably assumed to account for variations in the component design conditions, geometry, and, especially, variations in the material deformation and stress-relaxation response.

ANL, 2021 notes the design-by-elastic-analysis creep-fatigue procedures are based on a bounding analysis. Therefore, it is difficult to quantify the conservatism inherent in the assumptions of the total strain range used in the analysis, the modifications to that strain range accounting for inelasticity, and how the code methodology accommodates multiaxial states of stress.

ANL, 2021 also indicates that there are two sources of explicit conservatisms that cover the variation in actual stress relaxation rates. The first is that the stresses from the relaxation analysis used to calculate the creep damage fraction are divided by an explicit safety factor, K'. The staff notes this increases the stress used in the creep damage fraction calculation, resulting in a larger creep damage fraction term in Equation (10) of HBB-T-1411. The staff notes that K' is 0.9 for design-by-elastic analysis for all Class A materials except for 9Cr-1Mo-V for which $K' = 1.0$. The staff also notes $K' = 0.67$ for the design-by-inelastic analysis for all Class A materials. The factor K' provides an explicit margin accounting for variation in stress relaxation rates for the remaining Class A materials.

Second, the relaxation procedure using the ISSCs is inherently conservative. Figure 3-8 compares the relaxation profile calculated using the algebraic ISSC relaxation procedure in the design-by-elastic analysis rules (HBB-T-1433 Step 5(b)) to the relaxation profile given by integrating the actual creep model underlying the 2017 ISSCs through the stress relaxation condition. This example uses an initial stress of 310 MPa (0.5 strain according to the HBB-T hot tensile curves), at a temperature of 550 degrees C (1,022 degrees F), and a hold time of 1,000 hours. The algebraic method produces higher stresses and is, therefore, conservative compared to integrating the relaxation differential equation, which is more accurate.

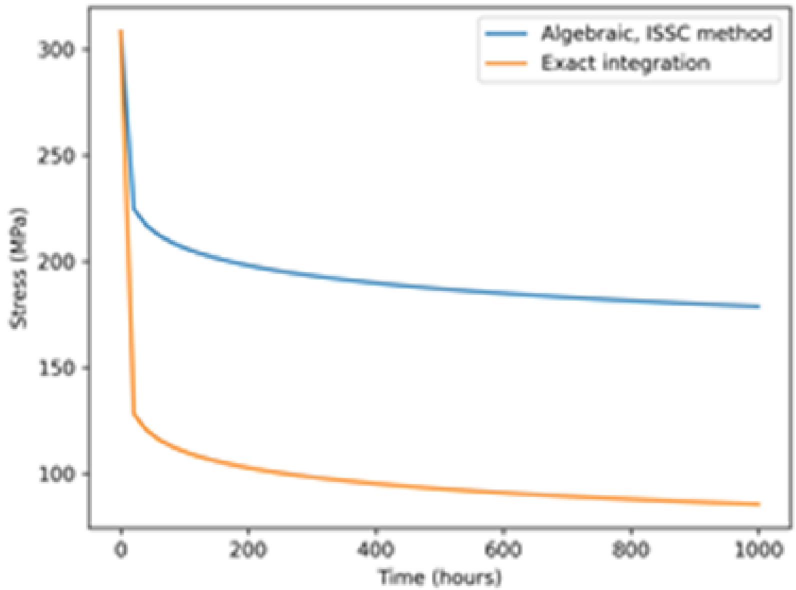

Figure 3-8 Comparison of the Stress Relaxation Profile Produced by the Algebraic Design-By-Elastic-Analysis ISSC Method to the Profile Produced by Integrating the Creep Model Underlying the HBB-T ISSCs through the Stress Relaxation Condition from Figure 19 of ANL, 2021

As an additional example of the conservatism of the HBB-T stress relaxation procedure, Table 24 of ANL, 2021 gives the margins for various temperatures and stresses provided by the ISSC method for 9Cr-1Mo-V. This table gives the creep damage fraction calculated using the method described in HBB-T-1433, with the stress relaxation profile determined either in accordance with HBB-T-1433 Step 5(b) or by integrating the differential creep model underlying the HBB-T ISSCs, and the ratio between these two creep damage fractions. The ratio between the ASME Code III-5 method and the direct integration method ranged from 1.5 to 3, illustrating the significant conservatism in the HBB-T procedure for determining creep damage.

Justification for Basing Isochronous Stress-Strain Curves on Average Properties

ANL, 2021 discusses why ISSCs should reflect average properties rather than lower bound properties.

ANL, 2021 indicates the ISSCs in HBB-T should reflect average properties, as it is not more conservative for all analyses to shift the ISSCs along the y (stress) axis in either direction.

ANL, 2021 provides the following points to support the use of average ISSCs:

- NUMARK, 2020a assumes the higher ISSCs are more conservative. Higher ISSCs imply that the material deforms more slowly (the ISSCs are closer together) and, following the HBB design procedure, that the material relaxes more slowly under a fixed stress. Higher ISSCs resulting in more stress for a given amount of creep strain are conservative for evaluating creep-fatigue damage, as the HBB-T design procedure assumes creep damage is proportional to the stress, and slower stress relaxation keeps a component at higher states of stress for longer times. (The staff notes that the creep-fatigue damage procedure referred to in ANL, 2021 is the procedure of HBB-T-1433.)

- The HBB-T procedure also uses the ISSCs to calculate the amount of strain accumulated against the deformation limits. Specifically, the Tests B-1 and B-2 of HBB-T-1332 use the ISSCs for this purpose. ISSCs at higher applied stresses reflect faster than actual creep deformation and are more conservative, as the component will accumulate strain more quickly. The staff notes that the aforementioned “B” procedures are part of the simplified inelastic analysis procedures of HBB-T-1330.

- The HBB-T rules work with average ISSCs, reflecting the average material hot tensile curves and the average material creep deformation, rather than shifting the ISSCs to account for the scatter in measured creep deformation rates. The procedures of HBB-T-1332 and HBB-T-1433 apply additional safety factors and conservatism to the design calculations to account for the scatter in the material deformation response.

Based on these three points, ANL, 2021 indicates the assumption that higher ISSCs are always more conservative is not valid, and thus, it is appropriate that ISSCs reflect average properties. ANL, 2021, therefore, concludes the ISSCs in HBB-T are adequate. The NRC staff agrees with the descriptions in ANL, 2021 of the effects on analyses using the ISSCs from shifting the curves, and therefore agrees that use of ISSCs reflecting average material properties is acceptable.

ANL, 2021 demonstrates there is a large scatter of the flow strength and creep deformation data, and the current ISSCs fall within this scatter. Given this, ANL, 2021 states that the task for ISSCs used in HBB-T for the design by elastic analysis deformation and creep-fatigue design criteria is to match the average tensile creep behavior of the materials and that there is a wide scatter in these measurements for 9Cr-1Mo-V and the other Class A materials.

<u>Large Scatter in Flow Strength and Creep Deformation Data</u>

ANL, 2021 provides several examples of the large scatter in creep and deformation data, specifically for 9Cr-1Mo-V material. The first example, reproduced in Figure 3-9, is a plot of measured yield strength data versus the yield stress from the HBB-T ISSCs and the ISSCs from STP-PT-80, “Development of Average Isochronous Stress-Strain Curves and Equations and External Pressure Charts and Equations for 9Cr-1Mo-V Steel,” dated June 30, 2016 (Jawad et al., 2016). The plot demonstrates that the yield stress from both the HBB-T and the STP-PT-80 ISSCs are within the scatter of the actual data.

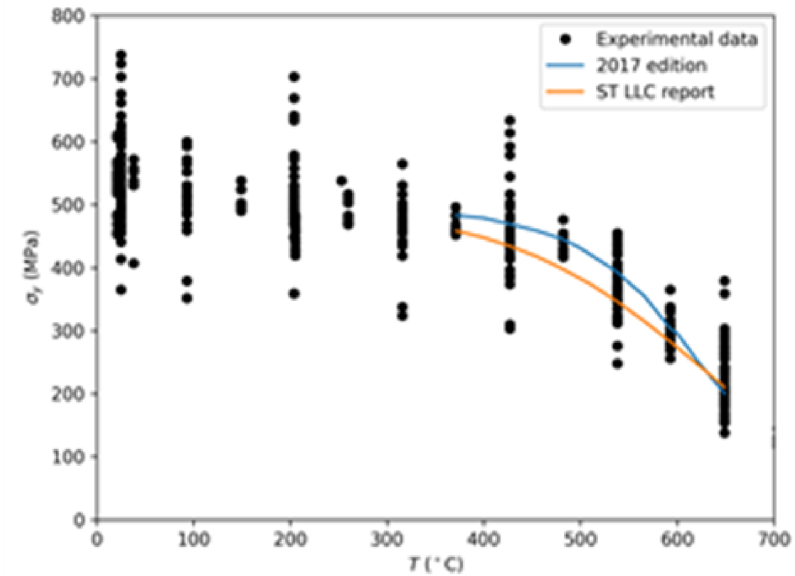

Figure 3-9 Yield Stress Comparison Between Experimental Data, the ASME Code III-5-HBB Hot Tensile Curves, and the STP-PT-080 Hot Tensile Curves, from Figure 20 of ANL, 2021

A second example, shown by Figure 3-10, is a graph of several actual creep curves for 9Cr-1Mo-V material, for the same stress and temperature, against the creep strains predicted by the creep models underlying the ASME Code III-5 and STP-PT-080 ISSCs. This plot illustrates the large scatter in creep curves for the same temperature and stress, and both HBB-T and STP-PT-080 ISSCs fall within the scatter.

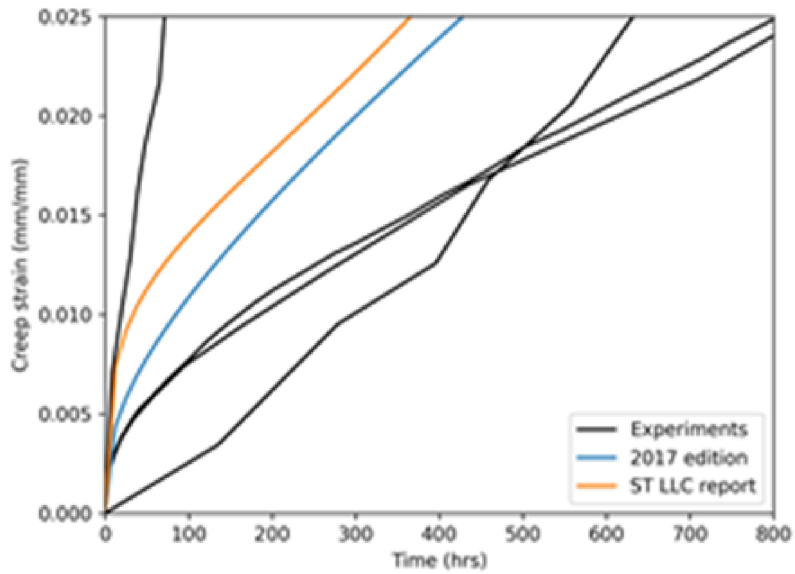

Figure 3-10 Comparison Between a Set of Experimental Creep Curves at 550 and 240 MPa Load and the Predicted Creep Curves Using the Models Underlying ASME Code III-5-HBB and STP-PT-080 ISSCs, from Figure 21 of ANL, 2021

The third example in Figure 3-11 is a plot of creep strain rate versus stress for actual data from ORNL and the NIMS database, with curves of the creep rates predicted by HBB-T superimposed, which shows the HBB-T creep rates generally fall within the scatter of both sets of actual data.

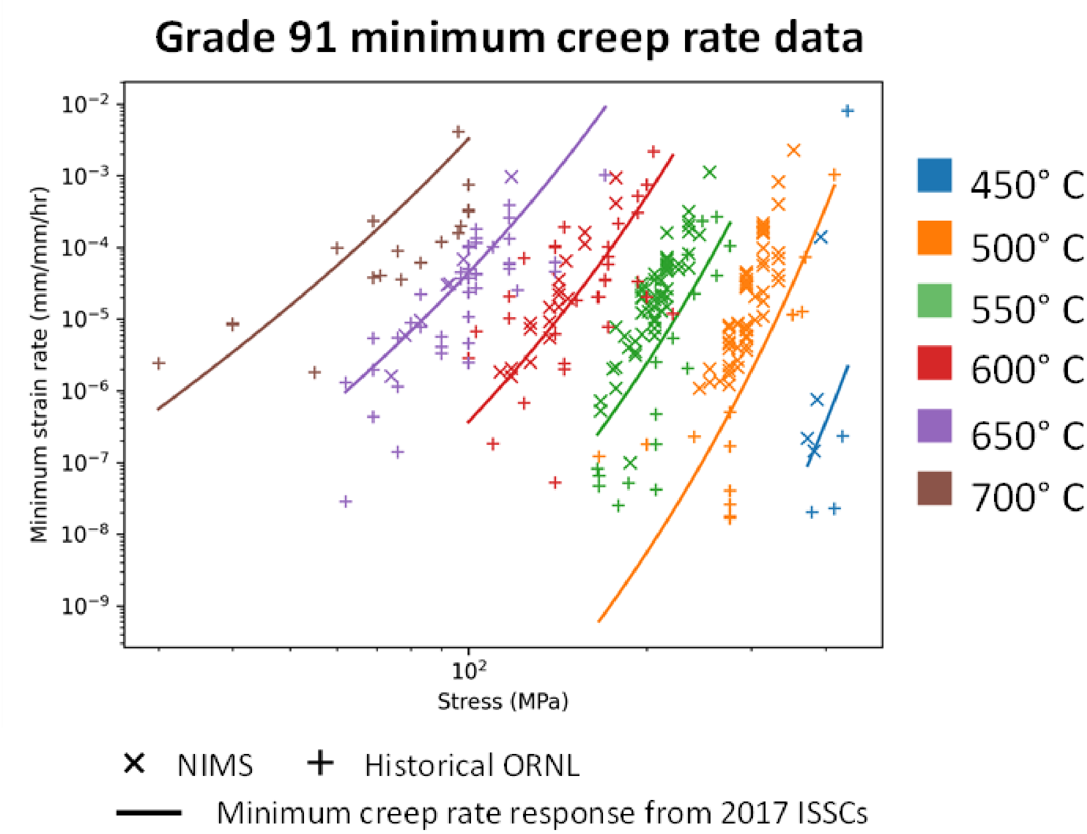

Figure 3-11 Comparison of Grade 91 (9Cr-1Mo-V) Minimum Strain Rate Data from the United States and Japan with Predictions from Strain Equation for the HBB-T ISSCs, from Figure 22 of ANL, 2021

The examples provided in ANL, 2021 show that measured creep rates and resulting creep strains can often vary by a factor of one to two orders of magnitude (10 to 100) for the same temperature and stress.

Given the conservatisms in the HBB-T design procedures that use the ISSCs, and the known large amount of scatter in measured creep data, the staff considers that if the independent data generally fall within a factor of approximately one to two orders of magnitude (a factor of 10 to 100) or less of the HBB-T ISSCs with respect to the time for a given stress/strain combination, the independent data are consistent with the HBB-T ISSCs.

The following discusses the results of the staff's review of the ISSCs for each Class A material.

<u>Type 304</u>

The ISSCs in Figures HBB-T-1800-A-1 to A-15 cover temperatures from 427 degrees C (800 degrees F) to 816 degrees C (1,500 degrees F) for Type 304 SS. NUMARK compared the ISSCs to measured creep data for temperatures ranging from 593 degrees C (1,099 degrees F) to 700 degrees C (1,292 degrees F). NUMARK, 2020a concludes the HBB-T ISSCs are considered conservative for almost all cases. NUMARK, 2020a notes that there may be a case to reconsider the HBB-T ISSCs for higher temperatures, above 700 degrees C

(1,292 degrees F) for long times since the extrapolation used to produce the HBB-T ISSCs may need improvement. Although at 700 degrees C (1,292 degrees F), the independent data for times longer than 100,000 hours show significantly lower times for the same stress/strain combinations, the independent data are within the expected scatter of one to two orders of magnitude for creep data. Since the independent data are within the expected scatter, the staff concludes the ISSCs for Type 304 are reasonable. Considering the reasonable results of the check against independent data, along with the conservatism of the design procedures in which the ISSCs are used, the staff determined that the HBB-T ISSCs for Type 304 are acceptable.

Type 316

The ISSCs in Figures HBB-T-1800-B-1 to B-15 cover temperatures from 427 degrees C (800 degrees F) to 816 degrees C (1,500 degrees F) for Type 316 SS. NUMARK compared results based on the ISSCs to data for temperatures ranging from 600 degrees C (1,112 degrees F) to 700 degrees C (1,292 degrees F). NUMARK, 2020a concludes that the HBB-T ISSCs for 316 SS appear to be conservative for most temperatures and times. NUMARK, 2020a notes that for higher temperatures, i.e., those above 700 degrees C (1,292 degrees F), and times of 100,000 hours, some of the HBB-T ISSCs may be nonconservative. NUMARK, 2020a states that this was probably due to the need to extrapolate the data to produce the HBB-T ISSCs. NUMARK, 2020a concludes the HBB-T ISSCs for Type 316 SS are considered adequate given data uncertainty. The staff notes that comparisons of the HBB-T ISSCs to the independent data for Type 316 SS are within the expected scatter of one to two orders of magnitude for creep data. Since the independent data are within the expected scatter the staff concludes the ISSCs for Type 316 are reasonable. Considering the reasonable results of the check against independent data, along with the conservatism of the design procedures in which the ISSCs are used, the staff determined that the HBB-T ISSCs for Type 316 are acceptable.

Alloy 800H

The ISSCs in Figures HBB-T-1800-C-1 to C-13 cover temperatures from 427 degrees C (800 degrees F) to 760 degrees C (1,400 degrees F) for Alloy 800H. NUMARK compared results based on the ISSCs to data for temperatures ranging from 649 degrees C (1,200 degrees F) to 760 degrees C (1,400 degrees F). NUMARK, 2020a concludes that the HBB-T ISSCs for Alloy 800H material may be nonconservative for temperatures at 700 degrees C (1,292 degrees F) and above, at times of 100,000 hours and above. The staff observed that the independent data generally fall within the expected scatter for the HBB-T ISSCs with respect to the time for a given strain/stress combination, even at the higher temperatures and longer times. The staff observes that, at 750 degrees C (1,382 degrees F) and 760 degrees C (1,400 degrees F), the independent data are sparse; however, the existing data points are still within the expected scatter of one to two orders of magnitude for creep data. Since the independent data are within the expected scatter of one to two orders of magnitude, the staff concludes the ISSCs for Alloy 800H are reasonable. Considering the reasonable results of the check against independent data, along with the conservatism of the design procedures in which the ISSCs are used, the staff determined that the HBB-T ISSCs for Alloy 800H to be acceptable.

2-1/4Cr-1Mo

The ISSCs in Figures HBB-T-1800-D-1 to D-11 cover temperatures from 371 degrees C (700 degrees F) to 649 degrees C (1,200 degrees F) for 2-1/4Cr-1Mo. NUMARK compared results based on the ISSCs to additional, independent data ranging from 500 degrees C (932 degrees F) to 600 degrees C (1,112 degrees F). NUMARK, 2020a concludes that the HBB-T ISSCs are quite conservative for most times and temperatures. In addition, NUMARK, 2020a states that the HBB-T ISSCs at 500 degrees C (932 degrees F) may be nonconservative compared to independent data but the difference is not considered outside the uncertainty band of creep data. NUMARK, 2020a concludes that, for 600 degrees C (1,112 degrees F) and higher, the extrapolation procedure used to obtain the HBB-T ISSCs may need to be modified and that additional data should be checked as well. The staff notes that, at 600 degrees C (1,112 degrees F), some independent data are nonconservative compared to the HBB-T ISSCs for the same stress/strain combination for times greater than 100,000 hours; however, the data are within the expected scatter of one to two orders of magnitude for creep data. Since the independent data are within the expected scatter, the staff concludes the ISSCs for 2-1/4Cr-1Mo are reasonable. Considering the reasonable results of the check against independent data, along with the conservatism of the design procedures in which the ISSCs are used, the staff determined that the HBB-T ISSCs for 2-1/4Cr-1Mo to be acceptable.

9Cr-1Mo-V

The ISSCs in Figures HBB-T-1800-E-1 to E-11 cover temperatures from 371 degrees C (700 degrees F) to 649 degrees C (1,200 degrees F) for 9Cr-1Mo-V. NUMARK compared results based on the ISSCs to data at 438 degrees C (820 degrees F) and 649 degrees C (1,200 degrees F). NUMARK, 2020a cites STP-PT-80 as the source of new ISSCs for 9Cr-1Mo-V developed recently with data obtained from the NIMS database. NUMARK, 2020a states that, for both temperatures, the ISSCs from STP-PT-80 are generally more conservative than the HBB-T ISSCs. NUMARK, 2020a further states that the discrepancy between the current HBB-T ISSCs and those of STP-PT-80 should be explained because the data from the ISSCs in STP-PT-80 are lower, especially at longer times, and this suggests that the current ISSCs may not be conservative.

The staff reviewed the comparisons in NUMARK, 2020a of the STP-PT-80 ISSCs to the HBB-T ISSCs and also performed some spot checks of the times for a given temperature/stress/strain combination from STP-PT-80 versus the HBB-T ISSCs. The staff notes that both the STP-PT-80 ISSCs and HBB-T ISSCs agree within the expected scatter of one to two orders of magnitude for creep data. Since independently developed ISSCs for 9Cr-1Mo-V agree with the HBB-T ISSCs within the expected scatter, the staff concludes the HBB-T ISSCs for 9Cr-1Mo-V are reasonable. Considering the reasonable results of the comparison to the independently developed ISSCs, along with the conservatism of the design procedures in which the ISSCs are used, the staff determined that the HBB-T ISSCs for 9Cr-1Mo-V are acceptable.

Conclusions—HBB-T-1800, Isochronous Stress-Strain Curves

The staff reviewed the independent checks of the HBB-T ISSCs versus independent data in NUMARK, 2020a, and the comparison of new ISSCs to the HBB-T ISSCs for 9Cr-1Mo-V. The staff finds the ISSCs of HBB-T-1800 to be acceptable because (1) the ISSCs in HBB-T, with the exception of 9Cr-1Mo-V, are identical to those contained in Code Case 1592, which is endorsed by the NRC staff through RG 1.87, and no conditions are placed on the use of the ISSCs in RG 1.87; and (2) the comparisons in NUMARK, 2020a shows that independent data are within the expected scatter for creep data, which, combined with the conservatisms in the HBB-T design procedures that use the ISSCs, lead to the conclusion by the staff that the ISSCs are acceptable.

3.10 Nonmandatory Appendix HBB-U

3.10.1 HBB-U-1100 Scope

Nonmandatory Appendix HBB-U provides guidelines on specification restrictions for Types 304 SS and 316 SS, which are intended to improve the performance of the permitted materials in certain elevated temperature nuclear applications where creep effects are significant. The restrictions include narrowing the chemical composition, grain size, and other aspects of material quality while staying within the broader specification limits defined in Table HBB-I-14.1(a) and its notes. HBB-U-1100 clearly describes the scope of the Appendix, and the staff agrees the substantive provisions of the Appendix may be applied within this defined scope, for reasons explained below.

3.10.2 HBB-U-1200 Service Conditions

HBB-U-1200 states that the restrictions of the appendix for alloy chemistry will provide improved performance when materials are used within the temperature regimes of 425 degrees C to 595 degrees C (800 degrees F to 1,100 degrees F). For application outside of those regimes, HBB-U-1200 provides no guidance. Because HBB-U-1200 improves material performance in the specified temperature range, it is acceptable.

3.10.3 HBB-U-1300 Recommended Restrictions

Table HBB-U-1 provides specified ranges for chemical composition and grain size. Table HBB-U-1 also specifies allowable melting practices and provides a suggested upper temperature limit for use of 595 degrees C (1,100 degrees F) for improved performance. With respect to chemical composition, for both Type 304 and Type 316, Table HBB-U-1 specifies carbon content between 0.04–0.06 weight percent, as compared to a maximum of 0.08 weight percent with no minimum for Type 304 in most of the specifications listed in Table HBB-I-14.1(a). The staff notes that the specifications for Type 304H and Type 316H, which have better high-temperature properties than Type 304 and Type 316, call for a range of carbon content of 0.04–0.10 weight percent. A lower maximum on carbon of 0.06 could help mitigate intergranular corrosion due to sensitization, which could occur in the temperature range allowed by ASME Code III-5. Since the carbon content specified by HBB-U is more restrictive and falls within the range for Type 304H and Type 316H in the applicable material specifications in ASME Code III-5, the staff finds it acceptable. With respect to other chemical elements, the ranges specified in HBB-U are also either the same or more restrictive than the range specified in the allowable material specifications in Table HBB-I-14.1(a) and are, therefore, acceptable. Table HBB-U-1 also provides restrictions on other trace elements, which generally have no specified limits in the materials specifications for Type 304, 304H, 316, and 316H listed in Table HBB-I-14.1(a), including antimony, boron, lead, selenium, tin, vanadium, and zinc. Restrictions on the content of these trace elements are conservative because these elements are not restricted in the materials specifications for Type 304 and Type 316 listed in Table HBB-I-14.1(a), and because restricting unspecified trace elements generally improves material properties.

Table HBB-U-1 specifies a range for ASTM grain size of 3–6 for both Type 304 and Type 316. Larger grain size is known to improve creep performance (a smaller number represents a larger grain size in the ASME grain size numbering system); therefore, a restriction on grain size should improve creep strength. “High-Temperature Characteristics of Stainless Steel—A Designers’ Handbook Series No 9004” (Nickel, 2020), discusses the beneficial effects of coarser grain size on high-temperature creep-rupture strength. In the "Atlas of Creep and Stress-Rupture Curves" (Boyer and Howard, 1988), Figure 11.62 shows the benefit of coarser grain size on creep-rupture strength for an austenitic SS. The staff notes that an ASTM grain size of 3–6 is more restrictive than the grain size specified for Type 304H and Type 316H in the specifications listed in Table HBB-I-14.1(a), which generally recommend a grain size of either 6 or coarser or 7 or coarser.

With respect to melting practice, Table HBB-U-1 specifies either argon oxygen decarburization (AOD) or AOD plus electroslag remelting. Both AOD and electroslag remelting are refining methods used to reduce impurities and improve the quality of SSs (ASM, 1990). The use of these methods is not in conflict with the applicable material specifications in Table HBB-I-14.1(a) and is therefore acceptable to the staff.

Table HBB-U-1 includes a suggested upper long-term use limit on temperature of 595 degrees C (1,100 degrees F). This is below the maximum temperature for which allowable stresses and other properties are provided for Type 304 and Type 316 in HBB-2000 and Mandatory Appendix HBB-I-14 of 800 degrees C (1,500 degrees F), and is also bounded by the conditions on maximum temperature identified by the staff in Section 3.7, and is, therefore, acceptable to the staff.

In summary, Nonmandatory Appendix HBB-U recommends specification restrictions for Types 304 SS and 316 SS, which are intended to improve the performance of the permitted materials in certain elevated temperature nuclear applications where creep effects are significant. It is beyond the scope of the staff's review to take a position on whether these restrictions will provide improved performance at elevated temperatures. However, the staff reviewed the recommended restrictions and finds that they are either within or consistent with the applicable material specifications of Table HBB-I-14.1(a), which the staff has determined acceptable for the reasons stated in Section 3.7 of this NUREG. Therefore, the recommended restrictions of Nonmandatory Appendix HBB-U are acceptable, subject to any exceptions or limitations that may be imposed on the use of the materials in Section 3.7 of this NUREG.

3.11 Nonmandatory Appendix HBB-Y Guidelines for Design Data Needs for New Materials

The staff did not review Nonmandatory Appendix HBB-Y and therefore is not endorsing it.

3.12 Subsection HC Class B Metallic Pressure Boundary Components, Subpart A Low Temperature Service (HCA)

3.12.1 Article HCA-1000 Introduction

HCA-1100 General

HCA-1110 Scope

HCA-1110 states that the rules of Subsection HC, Subpart A (HCA), constitute the requirements associated with Class B metallic components used in the construction of high-temperature reactor systems and their supporting systems when subjected to low-temperature service.

HCA-1110 has minor subparagraphs (a) through (g).

HCA-1110 (a), (c), (d), and (e) provide clarifying statements with respect to the scope, terminology, and procedural provisions of HCA-1100. The staff has determined that these provisions are adequate to clearly define the scope, terminology, and procedural provisions of Subsection HCA.

HCA-1110(b) states, in part, that the rules of Subsection HC, Subpart A, are contained in ASME Code III-1-NC, except for those paragraphs or subparagraphs (with numbered headers) replaced by corresponding numbered HCA paragraphs or subparagraphs in this Subpart or new numbered HCA paragraphs or subparagraphs added to this Subpart.

HCA-1110(f) states that Class B vessels are to be designed using the standard design method in NC-3300 or the alternative design rules of NC-3200, which allow the use of analysis with the higher design stress intensity values of Section II, Part D, Subpart 1, Tables 2A, 2B, and 4.

Subsection HC, Subpart A, is for Class B metallic pressure boundary components in low-temperature service. Low-temperature service is defined in HAA-9200 as service where the component(s), support(s), or core support structure(s), during normal, upset, emergency, or faulted operating conditions do not experience temperatures that exceed those indicated in Table HAA-1130-1 for the material under consideration. These temperatures are either 370 degrees C (700 degrees F) or 425 degrees C (800 degrees F), depending on the material type. The maximum temperatures for the corresponding material types, as defined in ASME Code III-1, NC-1120, are the same as the ASME Code III-5 temperature limits applicable to this section. In addition, Class B components as defined in ASME Code III-5 are analogous to Class 2 components in ASME Code III-1, the requirements for which are covered in ASME Code III-1-NC. ASME Code III-1 of the 2015 and 2017 Editions of the ASME Code, which includes ASME Code III-1-NC, is incorporated by reference in 10 CFR 50.55a. Since components within the scope of Subsection HC, Subpart A, will be exposed to the same temperature range and have analogous component classification to components within the scope of ASME Code III-1-NC, the staff finds use of the rules of ASME Code III-1-NC, as referenced in HCA-1110 (b) and (f), to be acceptable for components within the scope of Subsection HC, Subpart A.

HCA-1100(g) states that, as an alternative for Class B components, the requirements in HAA-2134 may be used for construction with higher class requirements. HAA-2134 allows the rules for Class A components in Subsection HB to be used for Class B components. The staff finds the use of Class A rules for Class B components acceptable because the rules for Class A components in Subsection HB are more stringent than those in Subsection HC and are, therefore, conservative for Class B components.

Based on the above, the staff finds the provisions of HCA-1000 to be acceptable for Class B metallic components in low-temperature service.

3.12.2 Article HCA-8000 Nameplates, Stamping with the Certification Mark, and Reports

HCA-8100 Requirements

HCA-8100 indicates that the provisions of Article HAA-8000 also apply to Class B metallic pressure boundary components. HAA-8110 indicates that the rules for certificates, nameplates, the Certification Mark, and Data Reports for metallic components, metallic supports, and metallic core support structures under ASME Code III-5 shall be the same as those established for Division 1.

HCA-8100 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HCA-8100 acceptable. Further, HCA-8100 does not contain any technical requirements and does not otherwise impact other requirements.

3.13 Subsection HC Class B Metallic Pressure Boundary Components, Subpart B Elevated Temperature Service (HCB)

3.13.1 Article HCB-1000 Introduction

HCB-1100 Scope

HCB-1100 mainly describes the scope of the 2017 Edition of the ASME Code III-5-HCB. Specifically, HCB-1110 states that the rules of Subsection HC, Subpart B, associated with Class B metallic components are used in the construction of high-temperature reactor systems and their supporting systems when subjected to elevated temperature service. Specifically, HCB-1110 explains that these rules apply when service loading temperatures exceed the appropriate temperature limits established in Table HAA-1130-1 for the material under consideration. The staff has determined that these provisions are adequate to clearly define the scope, terminology, and procedural provisions of Subsection HCB and are therefore acceptable.

HCB-1120 Alternative Rules

This subarticle refers to HAA-2134, which allows Class B components to be constructed in accordance with Class A provisions (Subsection HB, Subpart B), provided all applicable HBB provisions are followed. The staff finds this acceptable since HBB provisions are conservative for Class B (HCB) components, given the lower safety significance of these components.

3.13.2 Article HCB-2000 Material

HCB-2100 General Requirements for Material

The staff finds the 2017 Edition of the ASME Code III-5, HCB-2100, acceptable as written because the general provisions are plain procedural statements referring to the 2017 Edition of the ASME Code III-1, Article NC-2000 (with stated exceptions reviewed below) and Mandatory Appendix HCB-II, that the NRC must approve separately and that are beyond the review scope for the present subarticle in this NUREG.

HCB-2400

HCB-2430

HCB-2433

HCB-2433.2 Acceptance Standards

ORNL, 2020 recommends that the 2017 Edition of the ASME Code III-5, HCB-2433.2, be accepted with a clarification of applicability to material types because some alloys covered in Table HBB-I-14.1(a) can be dominantly ferritic, and Mandatory Appendix HCB-II referenced in

HCB-2100 causes further ambiguity. Specifically, HCB-2100 refers, in part, to materials listed in the tables in Mandatory Appendix HCB-II. Some of these materials are ferritic steels, which would generally be welded with ferritic weld filler materials, which do not contain, nor need to contain, delta ferrite. The staff therefore clarifies that the acceptance standards of HCB-2433.2 only apply to austenitic weld filler materials as described in HBB-2433. The staff finds the acceptance standards of HCB-2433 to be acceptable because they are applicable to the same material type as the standards in HBB-2433. Section 3.6.2 of this NUREG provides a detailed discussion of the acceptability of the delta ferrite acceptance standards in HBB-2433.

HCB-2500

HCB-2570

HCB-2571 Required Examination

ORNL, 2020 recommends that the 2017 Edition of the ASME Code III-5, HCB-2571, be accepted as written because it provides plain procedural statements referring to other portions of the ASME Code that the NRC must approve separately and that are beyond the review scope for the present paragraph. ORNL, 2020 also recommends adding a clarification of material type applicability in HCB-2433.2. However, the staff finds that this clarification is not necessary because HCB-2571(c) specifically indicates that the delta ferrite determination is only necessary for austenitic SS-type castings.

HCB-2571 includes a provision to determine the delta ferrite content of austenitic SS castings, with an acceptance standard of a maximum 12 FN (ferrite number) specified in HCB-2751.2, for castings with a design temperature greater than or equal to 425 degrees C (800 degrees F). HCB-2571.1 states that the delta ferrite determinations shall be performed using the chemical analysis called for by the material specification in conjunction with the 2017 Edition of the ASME Code III-1, Figure NC-2433.1-1. The staff finds this method acceptable because it is used in the 2017 Edition of the ASME Code III-1, which has been previously approved through incorporation by reference in 10 CFR 50.55a without conditions for austenitic SS weld fillers, which also contain delta ferrite.

With respect to the acceptance standard for delta ferrite in HCB 2571.2, the staff notes that a limit on delta ferrite content of 12 FN at temperatures equal to or above 425 degrees C (800 degrees F) would mitigate the potential for loss of fracture toughness due to the transformation of delta ferrite to other embrittling metallurgical constituents, because it is unlikely the delta ferrite would form a continuous network if limited to 12 FN. Metallurgical constituents that can embrittle cast SS include σ phase, which forms at temperatures equal to or above 540 degrees C (1,000 degrees F) (ASM, 1990), and α' phase, which forms below 500 degrees C (930 degrees F) (NRC, 2016c). Additionally, carbides form between 425 degrees C and 650 degrees C (800 degrees F and 1,200 degrees F) (ASM, 1990). Therefore, a ferrite limit for castings used at temperatures equal to or above 425 degrees C (800 degrees F) would mitigate embrittlement by all these various constituents. The staff also notes that there are no restrictions on delta ferrite content in austenitic SS castings in the 2017 Edition of the ASME Code III-1, which addresses temperatures below 425 degrees C (800 degrees F), so it is acceptable to not have such restrictions in the 2017 Edition of ASME Code III-5 in that temperature range. Therefore, the staff finds the ferrite acceptance criteria for SS castings of 12 FN to be acceptable.

3.13.3 Article HCB-3000 Design

HCB-3100 General Design

Subarticle HCB-3100 states that pressure -retaining material and material welded thereto shall meet the requirements of ASME Code III-1, NC-3000, except as modified in HCB-3000 (the modifications are discussed below). NC-3000 has previously been approved through incorporation by reference in 10 CFR 50.55a. Therefore, the staff finds HCB-3100 acceptable.

HCB-3110

HCB-3114 Acceptability

This paragraph states that an acceptable component design shall meet the applicable requirements of NC-3100, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions; the appropriate component rules from ASME Code III-5-HCB (i.e., HCB-3300 (vessels), HCB-3400 (pumps), HCB-3500 (valves), or HCB-3600 (piping)); or any optional approved alternative methods that demonstrate compliance related to buckling, ratcheting, and creep-fatigue. Additionally, this will be demonstrated in the applicant's Design Report. Therefore, the staff finds the general design provision of paragraph HCB-3114 acceptable.

HCB-3115 Design Report and Certification

HCB-3115 states the standards of the Design Report for components at elevated temperature and states that the Design Report must be certified by a Certifying Engineer. HCB-3115 allows the use of a Certifying Engineer who is not a Registered PE but the NRC, in 10 CFR 50.55a, imposed a condition that Certifying Engineers must be Registered PEs. Based on the above, the staff finds HCB-3115 acceptable with the following exception:

> The NRC staff does not endorse paragraph XXIII-1223 from Mandatory Appendix XXIII in ASME Code, Section III, "Appendices." When applying the 2017 and later editions of ASME Code Section III, the NRC does not endorse applicant and licensee-use of a Certifying Engineer who is not a Registered Professional Engineer qualified in accordance with paragraph XXIII-1222 for Code-related activities that are applicable to NRC-regulated facilities.

HCB-3140 Buckling Instability Loadings

HCB-3141 General Requirements

HCB-3141(a) indicates that for Class B (Class 2 for ASME Code III-1-NC) components at elevated temperatures, the rules of NC-3133, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, shall apply for external pressure loadings if the conditions of Mandatory Appendix HCB-III are satisfied. Otherwise, HCB-3141(b) indicates the applicant should use the rules of HCB-3141, HCB-3142, and HCB-3143 for limits on buckling loads.

HCB-3141.1, Scope of Rules, states that NC-3133 only pertains to specific geometrical configurations under specific loading conditions and does not consider the effects of creep due to long-term loadings at elevated temperatures or the effects of the other loads or geometries. This subparagraph indicates the applicant should use the rules of HCB-3141, HCB-3142, and HCB-3143 for limits applicable to general configurations and loading conditions that may lead to buckling or instability due to the time-dependent creep behavior of the material. The staff finds HCB-3141.1 acceptable because it clearly defines when the Section III-1 rules may be used and when the rules that account for creep effects in HCB-3141, HCB-3142 and HCB-3143 must be used.

HCB-3141.2, Load-Controlled and Strain-Controlled Buckling, states that for the limits of HCB-3140, a distinction is made between load-controlled buckling and strain-controlled buckling and gives an example and definition.

HCB-3141.3, Interaction of Load-Controlled and Strain-Controlled Buckling, conservatively states that when a combination of these loadings is present, the larger Load Factor associated with load-controlled buckling shall be used.

HCB-3141.4, Effects of Initial Geometry Imperfections, provides, in HCB-3141.4(a), for consideration of the effects of initial geometrical imperfections and tolerances for time-independent and time-dependent calculations for load-controlled buckling according to the provisions of HCB-3142 and HCB-3143, respectively. HCB-3141.4(b) provides that effects of excessive deformation or strain caused by instability strain under pure strain-controlled buckling be accounted for only if significant geometrical imperfections are initially present, and does not call for consideration of the effects of deformation due to geometrical imperfections or tolerances, whether initially present or service-induced. The staff determined this is acceptable because HCB-3141.4 does call for consideration of the effects of significant geometrical imperfections, and geometrical imperfections do not have an effect on instability strain.

HCB 3141.5, Stress-Strain Data, indicates use of the expected minimum stress-strain curve for the material. The staff finds this acceptable because use of the minimum stress-strain curve is conservative since the actual properties must be equal to or greater than the minimum.

The staff determined that HCB-3142 and HCB-3143 are acceptable for reasons set forth below. The staff determined Mandatory Appendix HCB-III acceptable for the reasons set forth in Section 3.16.

Based on the above, the staff finds paragraph HCB-3141 with its subparagraphs acceptable.

HCB-3142 Time-Independent Buckling Limits

This paragraph conservatively states that the Load Factor for load-controlled buckling and the strain factor for strain-controlled buckling shall equal or exceed the value in Table HBB-T-1521-1 for the specified Design and Service Loadings to protect against instantaneous buckling. The review of HBB-T-1521 in Section 3.9.5 shows that the Load Factors used for buckling assessment produce conservative results and guard against instability. Therefore, the staff finds HCB-3142 acceptable.

HCB-3143 Time-Dependent Buckling Limits

This paragraph states that to protect against load-controlled time-dependent buckling, it must be demonstrated that instability will not occur during the specified lifetime for a load history obtained by multiplying the specified service loads by the factors in Table HBB-T-1522-1. The review of HBB-T-1522 in Section 3.9.5 of this NUREG shows that conservative buckling predictions are expected when using these factors. Therefore, the staff finds paragraph HCB-3143 acceptable.

HCB-3150 Limitations on Use

HCB-3150 indicates various components that cannot be used unless the provisions of Mandatory Appendix HCB-III are satisfied. Section 3.16 states the reasons the staff accepted Mandatory Appendix HCB-III. HBB-3150 also specifies that socket welds may be used only for nominal diameter 50 millimeters (2 inches) or less. However, and as has been stated above (under HBB-3600), 10 CFR 50.55a conditions the use of socket welds for ASME Section III applications. Therefore, the staff finds subsubarticle HCB-3150 acceptable with the following exception:

- The staff does not endorse the use of Section III provisions in accordance with HBB-3600, HBB-3660, HCB-3150, and HCB-4000 for socket welded fittings used in pressure-retaining joints and referenced in HBB-3000, HCB-3000 and HCB-4000, for welds with leg size less than 1.09* t_n, where t_n is the nominal pipe thickness.

HCB-3160 Components Containing Lethal or Hazardous Substances

Paragraph HCB-3160 gives the acceptable weld types for Categories A, B, C, and D. HCB-3160 serves the same purpose and is technically equivalent to NC-4262, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds subsubarticle HCB-3160 acceptable. In addition, HCB-1110(g) lists additional standards for welds in systems containing lethal or hazardous substances that will result in higher quality welds. Therefore, the staff finds use of the same weld types as are allowed by Section III-1, Subsection NC to be acceptable.

HCB-3300 Vessel Design

HCB-3310 General Requirements

HCB-3310 addresses general design provisions for Class B vessels and states that the requirements of ASME Code III-1, NC-3300, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, are to be satisfied except as modified in HCB-3100, as described above. HCB-3310 also states that the allowable stress values used in the design calculations at elevated temperatures shall be obtained from Mandatory Appendix HCB-II. For the reasons stated in Section 3.15 of this NUREG, the staff has determined Mandatory Appendix HCB-II to be acceptable. Based on the above, the staff finds subsubarticle HCB-3310 acceptable.

HCB-3400 Pump Design

HCB-3400 addresses general design provisions for Class B pumps and states that the requirements of ASME Code III-1, NC-3400, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, are to be satisfied except as modified in HCB-3100. HCB-3400 also states that the rules of NC-3400, as modified by HCB-3100, do not explicitly address fatigue damage resulting from cyclic service and that the allowable stress values used in the design calculations at elevated temperatures shall be obtained from Mandatory Appendix HCB-II. For the reasons stated in Section 3.15 of this NUREG, the staff has determined that Mandatory Appendix HCB-II is acceptable. The modifications of HCB-3100 include provisions related to general design and buckling and are acceptable for reasons stated above in Section 3.13.3 of this NUREG. Therefore, the staff finds subarticle HCB-3400 acceptable.

HCB-3500 Valve Design

HCB-3510 General Requirements

HCB-3510 addresses general design provisions for Class B valves and states that the requirements of ASME Code III-1, NC-3500, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, are to be satisfied except as modified in HCB-3100. HCB-3510 also states that the rules of NC-3500, as modified by HCB-3100, do not explicitly address fatigue damage resulting from cyclic service and that the allowable stress values used in the design calculations at elevated temperatures shall be obtained from Mandatory Appendix HCB-II. For the reasons stated in Section 3.15 of this NUREG, the staff has determined that Mandatory Appendix HCB-II is acceptable. The modifications of HCB-3100 include provisions related to general design and buckling and are acceptable for reasons stated above in Section 3.13.3 of this NUREG. Therefore, the staff finds subsubarticle HCB-3510 acceptable.

HCB-3600 Piping Design

HCB-3630 General Requirements

This paragraph states that for elevated temperature Class B (Class 2 for ASME Code III-1 use) piping designs, the rules for piping with negligible creep effects and for piping with creep effects must conform to the rules of HCB-3632 and HCB-3634, respectively. For reasons set forth below, the staff has determined that HCB-3632 and HCB-3634 are acceptable. Therefore, the staff finds HCB-3630 acceptable as written.

HCB-3632 Piping with Negligible Creep Effects

Paragraph HCB-3632 replaces specific sections in ASME Code III-1-NC, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, with general design provisions in ASME Code III-5-HCB, and provides for the use of the criteria of Mandatory Appendices HCB-II and HCB-III. For reasons stated in Sections 3.15 and 3.16, respectively, the staff has determined that Mandatory Appendix HCB-II and Mandatory Appendix HCB-III are acceptable. Therefore, the staff finds HCB-3632 acceptable.

HCB-3634 Piping with Creep Effects

The subparagraphs in HCB-3634 refer to NC-3600*,* which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions.
Subparagraph HCB-3634(a) states that the requirements of subarticle NC-3600, as modified by subarticle HCB-3600, must be satisfied and that stress allowable values should be obtained from Mandatory Appendix HCB-II. For the reasons set forth in Section 3.15 of this NUREG, the NRC staff has determined that Mandatory Appendix HCB-II is acceptable. Subarticle HCB-3600 includes three modifications to NC-3600, each of which is discussed below.

Subparagraph HCB-3634(b) states that the allowable stress value in Equation (10a) of NC-3653.2(a) shall be determined using Equation (10b) of HCB-3634. Equation (10b) of HCB-3634 is identical to Equation (1) of NC-3611.1(e). The modification between Subsection HCB and Subsection NC is the determination of the stress range reduction factor, f. HCB-3634(b) indicates that this value be determined using Mandatory Appendix HCB-I. HCB-3634(b) provides that an additional equation to NC-3653.2, Equation (10c), be satisfied for all thermal cycles. For reasons stated in Section 3.14 of this NUREG, the staff has determined that Mandatory Appendix HCB-I is acceptable.

In subparagraph HCB-3634(c), the modification of NC-3653.2(c) Equation (11) has the allowable stress values as the lesser of the existing Equation (11) (NC-3653.2(c)) allowable stress values and the allowable stress values of the new Equation (10b) (HBB-3634(b)). The staff finds this change acceptable because the allowable stress values for ASME Code III-5-HCB use may potentially be lower than those for ASME Code III-1-NC use by accounting for the effects of all thermal cycles.

Subparagraph HCB-3634(d) states that NC-3611.2(c) includes the definitions for the undefined terms in HCB-3634(b) and HCB-3634(c).

Subparagraph HCB-3634(e) makes additional modifications to NC-3600, which indicate that portions of NC are satisfied by parts of Subsection HCB, excluded by parts of Subsection HCB, or not acceptable for use in parts of Subsection HCB and that all elevated temperature service durations shall be duplicated in tests, which the staff finds acceptable because duplicating the service temperature durations will ensure testing at conditions representative of the service conditions for these components.

Based on the above, the staff finds paragraph HCB-3634 acceptable because HCB-3634 conservatively modifies Subsection NC for ASME Code III-5 applicability.

3.13.4 Article HCB-4000 Fabrication and Installation

Article HCB-4000 provides that fabrication and installation follow Division 1, Article NC-4000, as modified by HCB-4000. Article HCB-4000 specifies that those portions of the component that do not experience elevated temperature service and those portions of systems or components of elevated temperature service where creep and stress rupture effects do not need to be considered (as defined by Mandatory Appendix HCB-III), shall either use the rules of HCB-4000 or Division 1, Article NC-4000, as applicable. Zones of elevated temperature service of the component that do not meet the conditions above should conform to Article HCB-4000. For portions or zones of elevated temperature service of the component, the portion(s) of the ASME

Code used should be identified during all steps of fabrication. Based on the above, the staff finds HCB-4000 acceptable with the following exception:

The staff does not endorse the use of Section III provisions in accordance with HBB-3600, HBB-3660, HCB-3150, and HCB-4000 for socket welded fittings used in pressure-retaining joints and referenced in HBB-3000, HCB-3000 and HCB-4000, for welds with leg size less than 1.09* t_n, where t_n is the nominal pipe thickness.

HCB-4100 General Requirements

HCB-4160 Components Containing Lethal or Hazardous Substances

HCB-4160 indicates that components containing lethal substances or other hazardous substances should receive postweld heat treatment (PWHT) in accordance with HCB-4000 when the pressure boundary material includes carbon or low-alloy steels. Article NC-4000 lists PWHT provisions for components fabricated under Article HCB-4000. Article NC-4000 provides exemptions from PWHT for certain thicknesses of carbon and low-alloy steels when a preheat is applied during welding. PWHT is the only effective way to significantly reduce or eliminate weld residual stress after welding. Reduction or elimination of weld residual stress provides a higher quality weld that is less susceptible to corrosion, fatigue, crack initiation, and crack growth as well as other potential degradation mechanisms. Therefore, the staff finds the PWHT provision in HCB-4160 acceptable, as it provides a high-quality weld that can be less susceptible to degradation and premature failure than a weld that does not receive PWHT.

HCB-4200

HCB-4210

HCB-4215 Additional Requirements for Forming and Bending Processes

HCB-4215 includes some provisions from Code Case 1593, which were approved for use through NRC RG 1.87, and new added sections. NC-4000 has been modified since the publication of Code Case 1593 and now includes more detailed and updated provisions. The provisions of HCB-4000 apply in addition to the rules of NC-4000, as applicable. For its review of Article HCB-4000, the staff referred to RG 1.87, Rev. 1 where appropriate and used PNNL, 2020. The staff's review of HCB-4215 appears below.

HCB-4215 (Class B) is technically equivalent to paragraph HBB-4212 (Class A). HCB-4215 calls for the application of NC-4212 and NC-4213, and HBB-4212 calls for the application of NB-4212 and NB-4213. NC-4212 and NC-4213 are technically equivalent to NB-4212 and NB-4213, respectively. It is an acceptable approach to use the Class A pressure-retaining component fabrication and installation rules for Class B pressure-retaining components.
Class A rules are generally assigned to components with a higher level of importance that need a higher level of assurance of structural integrity and quality than Class B components and are, therefore, acceptable to use for Class B component construction. For reasons set forth in Section 3.6.4 of this report, the staff has determined that HBB-4212 is acceptable. Accordingly, HCB-4215 is acceptable.

HCB-4400

HCB-4420

HCB-4427 Shape and Size of Fillet Welds

HCB-4427(a) and HCB-4427(b) serve the same purpose and are technically equivalent to ASME Code III-1, NC-4427(a) and NC-4227(b), respectively, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a. Accordingly, HCB-4427(a) and (b) are acceptable. HCB-4427(c) is technically equivalent to HBB-4240 and calls for application of the rules for construction of Class A pressure-retaining components to construction of Class B components. As stated above for HCB-4215, it is an acceptable approach to use the rules for Class A pressure-retaining components construction for Class B pressure-retaining components construction. For the reasons stated in Section 3.6.4 of this NUREG, the staff has determined that HBB-4240 is acceptable. Accordingly, the staff has determined that HCB-4427 is acceptable.

3.13.5 Article HCB-5000 Examination

HCB-5100 General Requirements for Examination

Subarticle HCB-5100 states that pressure-retaining material and material welded thereto shall meet the requirements of ASME Code III-1, NC-5000, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a. Therefore, the staff finds HCB-5100 acceptable.

HCB-5160 Components Containing Lethal or Hazardous Substances

Paragraph HCB-5160 provides that for those components containing lethal substances or other hazardous substances such as sodium, all permitted weld joints at the pressure boundary shall be fully radiographed. This paragraph is more conservative than NC-5000 because all pressure boundary weld joints, regardless of the weld joint design, need to be fully radiographed (i.e., 100 percent of the weld volume). Therefore, the staff finds HCB-5160 acceptable.

3.13.6 Article HCB-6000 Testing

HCB-6100 General Requirements

Subarticle HCB-6100 states that the requirements of ASME Code III-1, NC-6000 be followed except as modified in HCB-6000 and discussed below. The NRC has previously approved ASME Code III-1-NC through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HCB-6100 acceptable.

HCB-6110

HCB-6111 Scope of Pressure Testing

Subparagraphs HCB-6111(a) and HCB-6111(b) serve the same purpose and are technically equivalent to subparagraphs NC-6111(a) and NC-6111(b), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions.

Subparagraph NC-6111(c) specifies that discharge into Class 2 vessels, or the gaseous regions of MC containment vessels through spargers or spray nozzles, only that portion of the system external to the vessel is required to be pressure tested. Subparagraph HCB-6111(c) specifies that where systems discharge into Class B vessels, only that portion of the system external to the vessel needs to be pressure tested. Subparagraph HCB-6111(c) serves the same purpose and is technically equivalent to subparagraph NC-6111(c), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions.

Subparagraph HCB-6111(d) adds a condition that states that a helium mass spectrometer test may replace the specified pressure test under the special provisions of HCB-6630 and HCB-6640. This exemption is acceptable for the special conditions of HCB-6630 and HCB-6640 because pressure testing these welds may not be possible and the helium mass spectrometer test will provide sufficient information to demonstrate the leak tightness of these welds.

HCB-6600

HCB-6630 Alternative Tests of Closure Welds and Access Hatches

Paragraph HCB-6630 is technically equivalent to HBB-6117(a), which is found acceptable by the staff for reasons stated in Section 3.6.6. In addition, the provisions for Class B construction (ASME Code III-5-HCB) are identical to the provisions for Class A construction (ASME Code III-5-HBB), which is a more stringent construction code, and are therefore acceptable for Class B construction. Therefore, the staff finds HCB-6630 acceptable.

HCB-6640 Alternative Tests at Specially Designed Welded Seals

HCB-6640 is technically equivalent to HBB-6118(b), which is found acceptable by the staff for reasons stated in Section 3.6.6. In addition, the provisions for Class B construction (ASME Code III-5-HCB) are identical to the provisions for Class A construction (ASME Code III-5-HBB), which is a more stringent construction code, and are therefore acceptable for Class B construction.

3.13.7 Article HCB-7000 Overpressure Protection

HCB-7100 General Requirements

Subarticle HCB-7100 serves the same purpose and is technically equivalent to ASME Code III-1, NC-7000, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HCB-7100 acceptable.

HCB-7110 Scope

Subsubarticle HCB-7110 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, NC-7110 which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HCB-7110 acceptable.

HCB-7143 Draining of Pressure Relief Devices

Paragraph HCB-7143 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, NC-7143 which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HCB-7143 acceptable.

HCB-7220 Content of Report

HCB-7220 states that the Overpressure Protection Report shall define the protected systems and the integrated overpressure protection provided, and it indicates what the report must include as a minimum. HCB-7220 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, NC-7220, which the NRC previously approved through incorporation by reference into 10 CFR 50.55a without conditions, except for subparagraphs HCB-7220(n), (o), and (p). Subparagraphs HCB-7220(n), (o), and (p) are technically equivalent to the corresponding provisions in Code Case 1596 endorsed in RG 1.87, Rev. 1. The provisions of Code Case 1596 corresponding to HCB-7220(n), (o), and (p) remain conservative and acceptable. Therefore, the staff finds HCB-7220 acceptable.

HCB-7611 General Requirements

Paragraph HCB-7611 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, NC-7611 which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HCB-7611 acceptable.

HCB-7621 Provisions for Venting or Draining

Paragraph HCB-7621 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, NC-7621 which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HCB-7621 acceptable.

3.13.8 Article HCB-8000 Nameplates, Stamping with the Certification Mark, and Reports

HCB-8100 Requirements

HCB-8100 indicates that the provisions in Article HAA-8000 also apply to Class B metallic pressure boundary components.

HCB-8100 serves the same purpose and is equivalent to the corresponding provision in ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Further, HCB-8100 does not contain any technical standards and does not otherwise impact other technical provisions. Therefore, the staff finds HCB-8100 acceptable.

3.14 Mandatory Appendix HCB-I Stress Range Reduction Factor for Piping

As explained in Rao, 2017, the most significant modification for creep effects in HCB-3630 is the definition of the stress reduction factor “f,” which is covered in Appendix HCB-I. Conceptually, this is an extension of the definition of the stress reduction factor in NC-3611.2. However, for elevated temperature, the factor r_1 has been modified to include a term to account for the higher of the peak stresses due to either the through-the-wall temperature gradients or the axial temperature difference. A second modification is to the stress reduction factor in Table HCB-I-2000-1 and Table HCB-I-2000-2 for the number of cycles N_1. These tables have been modified to account for the effects of creep on cyclic life. Depending upon the material and service temperature, the effects can be quite significant. NUMARK, 2020a discusses the technical basis as well as the data and analyses used to develop Tables HCB-I-2000-1 and HCB-I-2000-2 and shows that the values in these two tables in Mandatory Appendix HCB-I are conservative, as discussed below.

3.14.1 Article HCB-I-1000 Stress Range Reduction Factor

Table HCB-I-2000-1 is a direct extension of Table NC-3611.2(e)-1 in the 2017 Edition of the ASME Code III-1-NC. Furthermore, the methodology is consistent with that in ASME Code III-1-NC. The NRC approved Article NC-3000 for use in 10 CFR 50.55a for materials that are not susceptible to creep. The stress range reduction factors “f” in Table HCB-I-2000-1 are significantly lower than those in NC (as low as 0.2 for the lower bound case instead of 0.5), which accounts for the effect of the combination of creep and fatigue at elevated temperatures and ensures conservative design limits. The staff finds that the significantly lower stress range reduction factors are appropriate to account for the combination of creep and fatigue that high temperature components will experience. Therefore, the staff finds Article HCB-I-1000 acceptable.

3.14.2 Article HCB-I-2000 Maximum Number of Allowable Cycles with f = 1

This Article states that the maximum number of cycles, N_1, permissible with f = 1 is determined from Table HCB-I-2000-2. The NRC staff reviewed the detailed justification provided in the NUMARK, 2020a and determined that these values are conservative because the number of cycles decreases with increasing temperature, and, when used in conjunction with Table HCB-I-2000, would generally result in lower and thus more conservative stress range reduction factors at temperatures where creep is significant. Therefore, the staff finds Article HCB-I-2000 acceptable.

3.14.3 Article HCB-I-3000 Equivalent Cycle

The approach to determining Equivalent Cycles when the temperature varies with time as described in this Article involves a methodology similar to that described in ASME Code III-1-NC, Article NC-3611.2, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. The equation of NC-3611.2 is modified by addition of an additional term to account for high temperature effects. The staff determined that, with the additional term, this methodology would be equally applicable to piping components operating at elevated temperatures (Section III-5) as it is to piping components operating in the low temperature range (Section III-1). Therefore, the staff finds Article HCB-I-3000 acceptable.

3.15 Mandatory Appendix HCB-II Allowable Stress Values for Class B Components

Mandatory Appendix HCB-II contains tables and figures with information used to perform design calculations in accordance with HCB-3000 under Service Levels A, B, C, and D for a variety of materials permissible for use in Class B applications. The tables and figures provide allowable stresses that extend the allowable stress values in Section II, Part D, Subpart 1, Tables 1A and 1B, to elevated temperatures for applications involving negligible creep (HCB-II-2000) and those that may include creep effects (HCB-II-3000). The materials covered include carbon steel, low alloy steel, Grade 91 (9Cr-1 Mo), Cast 304 SS, Cast 316 SS, 304 SS, 316 SS, and Alloy 800H.

The staff's review references technical input in NUMARK, 2020a.

3.15.1 Article HCB-II-1000 Scope

Article HCB-II-1000 guides the determination of the allowable stress, S, for Class B components by means of a flow chart. The flow chart in Figure HCB-II-1000-1, "Determination of Allowable Stress, S, for Class B Components," contains four optional paths leading to four possible values for the allowable stress, depending on the Service Level and creep significance. The four categories of possible allowable stresses are designated A1 through A4 as follows:

A1 allowable stress for base metal given in Tables HCB-II-3000-1 through HCB-II-3000-4 and may be used for any service history, including service histories that include creep

A2 allowable stress for welds given in Tables HCB-II-3000-1 through HCB-II-3000-4, multiplied by weld reduction factors from Tables HCB-II-3000-5 through HCB-II-3000-9 and may be used for any service history, including service histories that include creep

A3 allowable stress from Tables HCB-II-2000-1 through HCB-II-2000-4 multiplied by an aging factor from Table HCB-II-2000-5 for cases involving creep-significant events less than one hour and for Level D service conditions less than one hour

A4 allowable stress from Tables HCB-II-2000-1 through HCB-II-2000-4 for cases involving negligible creep

Figure HCB-II-1000-1 provides that certain criteria in Mandatory Appendix HCB-III be satisfied to use the allowable stress values in Tables HCB-II-2000-1 through HCB-II-2000-4 for negligible creep with and without the application of the aging factors in Table HCB-II-2000-5 for Level A, B, C, and D service conditions. Section 3.16 of this NUREG covers Mandatory Appendix HCB-III in more detail, but HCB-III essentially provides guidance for determining what constitutes negligible creep.

Figure HCB-II-1000-1 indicates that A1 and A2 provide the most conservative allowable stress values for base metals and welds, respectively, and the user may choose them over the other options. The staff finds Subarticle HCB-II-1000 to be acceptable for two reasons. First, the process for determining allowable stress provides the option for users to choose the most conservative allowable stress for any service condition. Second, provisions for determining allowable stresses for service conditions involving negligible creep and creep-significant events less than one hour in duration include limitations that, if met, assure the allowable stress is acceptable, as described in more detail below.

3.15.2 Article HCB-II-2000 Service with Negligible Creep Effects

Article HCB-II-2000 provides allowable stress values for service involving negligible creep when the time-temperature limits of Mandatory Appendix HCB-III are satisfied. The allowable stress values in Article HCB-II-2000 extend the values in ASME Code, Section II, Part D, Subpart 1, Tables 1A and 1B, to elevated temperatures and are designated as A4 in Figure HCB-II-1000-1.

The NUMARK TLR (NUMARK, 2020) determined the allowable stresses for specific materials from each of the seven material types listed in Mandatory Appendix HCB-III and compares the allowable stresses for each designator A1 through A4. The general note to Figure HCB-II-1000-1 indicates that allowable stress designators A1 and A2 should be the most conservative allowable stresses for any and all service conditions. The results of the NUMARK analysis show that, for several of the materials, the allowable stresses for designators A3 and A4 were lower than A1 and A2 and, thus, the A1 and A2 allowable stresses were not the most conservative for certain service conditions, particularly at lower temperatures. However, as described further below, ANL, 2021 evaluated the allowable stresses in HCB-II-2000 for service with negligible creep and determined that the allowable stresses for service that may include creep, designators A1 and A2, which are given in ASME Code, Section II, Part D, Subpart 1, Tables 1A and 1B, are up to date and will always be the most conservative allowable stresses for any and all service conditions.

ANL determined the root cause of the apparent nonconservatism of stress designators A1 and A2 was that the allowable stress values in HCB-II-2000 (used for stress designators A3 and A4) have not been maintained in the several decades since they were first established. However, the allowable stresses in HCB-II-3000, the source of stress designators A1 and A2, are up to date, as they are maintained through regular updates to ASME Code, Section II, Subpart D. Therefore, as indicated in Figure HCB-II-1000-1, the stress designators A1 and A2 may be used for any and all service conditions. The NRC staff agrees that the stress designators A1 and A2 are acceptable because they are based on the most recent data and methods. Additionally, if the criteria in Mandatory Appendix HCB-III for service with negligible creep are met, the allowable stresses in HCB-II-2000 may be used because in the limited cases where A3 and A4 allowable stresses are lower than those of A1 and A2, A3 and A4 are conservative. Therefore, the staff finds subarticle HCB-II-2000 acceptable.

3.15.3 Article HCB-II-3000 Service That May Include Creep Effects

Article HCB-II-3000 provides allowable stress values for service that may include creep by providing the rules to determine allowable stress designators A1, A2, and A3. For allowable stress designator A1 (base metal), the allowable stresses in Article HCB-II-3000 are the same as those in ASME Code, Section II, Part D, Subpart 1, Tables 1A and 1B, except that the notes do not apply. For allowable stress designator A2 (welds), the allowable stresses for designator A1 are reduced by the specific weld factors in Article HCB-II-3000. When the conditions in HCB-III-1000 or HCB-III-1200 are not met but the creep-significant event is less than 1 hour, allowable stress designator A3 may be used, which is determined by reducing the allowable stress designator A4 using aging factors in HCB-II-3000(c).

The NUMARK TLR determines the allowable stresses for specific materials from each of the seven material types listed in Mandatory Appendix HCB-III and compares the allowable stresses for designators A1 through A4. The general note to Figure HCB-II-1000-1 indicates that allowable stress designators A1 and A2 should be the most conservative allowable stresses for any and all service conditions. The results of the NUMARK analysis show that, for several of the materials, the allowable stresses for designators A1 and A2 were not the most conservative allowable stresses for certain service conditions, particularly at lower temperatures. However, as discussed in the previous section, ANL, 2021 evaluated the allowable stresses in HCB-II-3000 and determined that the allowable stresses in ASME Code, Section II, Part D, Subpart 1, Tables 1A and 1B, are up to date and may be used for any and all service conditions. Additionally, the allowable stresses determined for designator A3 may be used for a service history involving less than 1 hour of creep, in accordance with HCB-II-3000. Therefore, the staff finds subarticle HCB-II-3000 acceptable.

3.16 Mandatory Appendix HCB-III Time-Temperature Limits for Creep and Stress-Rupture Effects

3.16.1 Article HCB-III-1000 Introduction

The introduction to Mandatory Appendix HCB-III states the conditions under which creep and stress rupture effects need not be considered directly when evaluating elevated temperature failure modes. The staff finds Article HCB-III-1000 acceptable because, as discussed below, the independent analysis in NUMARK, 2020a showed that the criteria are conservative.

HCB-III-1100 Service Level A and B Loadings

Subarticle HCB-III-1100 defines the time-temperature limits for Service Level A and B loadings such that the total time duration at the metal temperature divided by the corresponding allowable time defined by Figure HCB-III-1000-1 shall be less than or equal to 0.9. Figure HCB-III-1000-1 shows the time-temperature limits for seven material types: carbon steel, low alloy steel, cast 304 SS, cast 316 SS, 304 SS, 316 SS, and Alloy 800H.

NUMARK, 2020a independently analyzes the curves in Figure HCB-III-1000-1 to determine whether they are conservative. NUMARK evaluated ISSCs in Nonmandatory Appendix HBB-T and determined that the total strain at a given temperature for the allowable times in Figure HCB-III-1000-1 was less than 0.2 percent, which meets the criteria for not exceeding elastic strain limits (i.e., negligible creep) in Mandatory Appendix HBB-T-1324. Table 3-6 shows the results of the analysis in NUMARK, 2020a. The NRC staff evaluated NUMARK's analysis and confirmed that the time-temperature limits for Service Level A and B loadings in subarticle HCB-III-1100 do not exceed the elastic strain limits for negligible creep in Mandatory Appendix HBB-T-1324. Therefore, the staff finds subarticle HCB-III-1100 acceptable.

Table 3-6 Confirmation of "Negligible Creep" Criteria for Service Level A and B Loadings (NUMARK, 2020a)

Material	Case	Temperature*	Allowable Time *	Allowable Stress for Negligible Creep**	Approx Total Strain at Allowable Stress	Reference for Total Strain at Allowable Stress (Isochronous Curve)	Notes/ Comments***
	Curve*	F	hours	ksi	%	Figure No.	
Alloy 800 H	G	1200	20	7.40	0.05	Figure HBB-T-1800-C-8	Confirms negligible creep strain limits; < 0.2%
		1000	30000	14.10	0.08	Figure HBB-T-1800-C-4	Confirms negligible creep strain limits; < 0.2%
316 SS	F	1100	20	11.80	0.10	Figure HBB-T-1800-B-7	Confirms negligible creep strain limits; < 0.2%
		900	200000	12.50	0.07	Figure HBB-T-1800-B-3	Confirms negligible creep strain limits; < 0.2%
304 SS	E	1000	50	11.20	0.08	Figure HBB-T-1800-A-5	Confirms negligible creep strain limits; < 0.2%
		850	100000	14.90	0.07	Figure HBB-T-1800-A-2	Confirms negligible creep strain limits; < 0.2%
Low Alloy Steel	B	850	40	12.80	0.10	Figure HBB-T-1800-D-4	Confirms negligible creep strain limits; < 0.2%
(2 1/4 Cr-1 Mo)		750	6000	14.50	0.15	Figure HBB-T-1800-D-2	Confirms negligible creep strain limits; < 0.2%
Grade 91		850	40	12.00	0.05	Figure HBB-T-1800-E-4	Confirms negligible creep strain limits; < 0.2%
		750	6000	12.70	0.04	Figure HBB-T-1800-E-2	Confirms negligible creep strain limits; < 0.2%

*- per Figure HCB-III-1000-1 curve designations
** - see Figure 4.4.2-X below for the given material
*** - Negligible creep is defined as <0.2% strain (inelastic strain at yield stress)consistent with HBB-T-1324

HCB-III-1200 Service Level C Events

Subarticle HCB-III-1200 defines the criteria for when creep and stress-rupture effects need not be considered for Service Level C loading events. The criteria state that the total number of Service Level C loading events shall not exceed 25. HCB-III-1200 also states that the total duration of all Service Level C loading events shall not exceed 25 hours and the temperatures shall not exceed the temperature limits in Table HCB-III-1000-1, "Maximum Metal Temperatures During Level C Events."

NUMARK, 2020a shows the results of an independent analysis of the time-temperature limits for the Service Level C loading criteria to determine whether they are conservative by evaluating the ISSCs from Nonmandatory Appendix HBB-T for the materials in Figure HCB-III-1000-1. The analysis shows that for 25 hours of total duration at the metal temperature, the temperature limits in Table HCB-III-1000-1 result in less than 0.2 percent strain, which meets the criteria for not exceeding elastic strain limits (i.e., negligible creep) in Mandatory Appendix HBB-T-1324 (Table 3-7). The staff confirmed the results of the NUMARK analysis.

The staff finds subarticle HCB-III-1200 to be acceptable because the time-temperature limits for Service Level C loading conditions are conservative.

Table 3-7 Confirmation of "Negligible Creep" Criteria for Service Level C Loadings (NUMARK, 2020)

Material	Peak Temp, °F	Peak Temp, °C	Allowable Stress, ksi	Approx. Total Strain at 25hrs, %	Notes/Comments
Low-Alloy Steel	950	510.0	10.60	0.08	Figure HBB-T-1800-D-6
304 SS	1150	621.1	6.00	0.05	Figure HBB-T-1800-A-8
316 SS	1250	676.7	4.3	0.03	Figure HBB-T-1800-B-10
Alloy 800 H	1250	676.7	5.9	0.04	Figure HBB-T-1800-C-9

3.17 <u>Subsection HF Class A and Class B Metallic Supports, Subpart A Low Temperature Service (HFA)</u>

3.17.1 Article HFA-1000 Introduction

HFA-1100 General

HFA-1110 Scope

HFA-1110 indicates that the rules of Subsection HF, Subpart A (HFA), constitute the provisions associated with metallic component supports used in the construction of high-temperature reactor systems and their supporting systems.

HFA-1110 has minor subparagraphs (a) through (g).

HFA-1110 (a), (c), (d), (e), and (f) provide clarifying statements with respect to the scope, terminology, and procedural requirements of HFA-1100. The staff has determined that these provisions are adequate to clearly define the scope, terminology, and procedural provisions of Subsection HFA. However, the staff notes that HFA-1110(a) states, in part, that these rules are intended to address metallic component supports that do not exceed the temperature limits established in Table HAA-1130-1 for the material under consideration.

HFA-1100(d) states that the rules do not cover deterioration that may occur in service as a result of corrosion, erosion, radiation effects, or metallurgical instability of the materials, which the staff notes is the same approach taken in other parts of ASME Code III-5 and is acceptable.

HFA-1110(b) states, in part, that the rules of Subsection HF, Subpart A, are contained in ASME Code III-1-NF, except for those paragraphs or subparagraphs (with numbered headers) replaced by corresponding numbered HFA paragraphs or subparagraphs in this Subpart.

Subsection HF, Subpart A, is for metallic component supports in low-temperature service. Low-temperature service is defined in HAA-9200 as service where the component(s), support(s), or core support structure(s), during normal, upset, emergency, or faulted operating conditions, do not experience temperatures that exceed those established in Table HAA-1-30-1 for the material under consideration. These temperatures are either 370 degrees C (700 degrees F) or 425 degrees C (800 degrees F), depending on the material type. ASME Code III-1-NF refers to the material properties in ASME Code II-D. The applicable maximum temperatures in ASME Code II-D do not exceed the maximum temperatures of Table HAA-1130-1.

ASME Code III-1-NF is applicable to supports of Class 1, 2, 3, and MC components in ASME Code III-1. NF-1122 states that supports shall be constructed to the requirements of Subsection NF that are applicable to the class of the component, including the piping system, they are intended to support. The provisions of ASME Code III-1-NF would therefore be appropriate for supports of ASME Code III-5 Class A or Class B components, since these classifications are analogous to Class 1 and Class 2 components in ASME Code III-1. ASME Code III-1 of the 2015 and 2017 Editions of the ASME Code, which includes ASME Code III-1-NF, is incorporated by reference in 10 CFR 50.55a without conditions. Component supports within the scope of Subsection HF, Subpart A, are constructed with the same materials and will be exposed to the same temperature range as components within the scope of ASME Code III-1-NF. Further, these support components are of analogous classification to those covered by ASME Code III-1-NF. Accordingly, the staff finds use of the rules of ASME Code III-1-NF as referenced in HFA-1110(b) to be acceptable for components within the scope of Subsection HF, Subpart A.

HF-1110(g) lists a number of types of parts of supports for which the provisions of the subpart do not apply and also lists 10 specific provisions that do apply to the listed parts. Several of the 10 specific provisions call for application of ASME Code III-1-NF provisions; therefore, they are acceptable. The staff has determined that these provisions are adequate to clearly define the procedural and documentation provisions of Subsection HFA.

Based on the above, the staff finds the provisions of HFA-1000 to be acceptable for metallic component supports used in the construction of high-temperature reactor systems and their supporting systems.

3.18 Subsection HG Class A Metallic Core Support Structures, Subpart A Elevated Temperature Service (HGA)

3.18.1 Article HGA-1000 Introduction

HGA-1100 General

HGA-1110 Scope

HGA-1110 indicates that the rules of Subsection HG, Subpart A (HGA), constitute the provisions associated with Class A metallic core support structures used in the construction of high-temperature reactor systems and their supporting systems when they are subjected to low-temperature service.

HGA-1110 has minor subparagraphs (a) through (c).

HGA-1110(a) and (c) provide clarifying statements with respect to the scope, terminology, and procedural provisions of HGA-1100. HGA-1100(a) indicates, in part, that the rules of Subsection HG, Subpart A, are for use when Service Loading temperatures do not exceed the appropriate temperature limits established in Table HAA-1130-1 for the material under consideration. The staff has determined that these provisions are adequate to clearly define the scope, terminology, and procedural provisions of Subsection HGA and are therefore acceptable.

HGA-1110(b) states that the rules of Subsection HG, Subpart A, are contained in ASME Code III-1-NG, except for those paragraphs or subparagraphs (with numbered headers) replaced by corresponding numbered HGA paragraphs or subparagraphs in this Subpart.

Subsection HG, Subpart A, is for Class A metallic core support structures in low-temperature service. Low-temperature service is defined in HAA-9200 as service where the component(s), support(s), or core support structure(s), during normal, upset, emergency, or faulted operating conditions, do not experience temperatures that exceed those established in Table HAA-1130-1 for the material under consideration. These temperatures are either 370 degrees C (700 degrees F) or 425 degrees C (800 degrees F), depending on the material type. ASME Code III-1, NG-2121, states, in part, that materials for core supports shall conform to the specifications for material given in Section II, Part D, Subpart 1, Tables 2A and 2B. The maximum applicable temperatures for ASME Code III materials given in these tables are less than or equal to the temperature limits of Table HAA-1130-1.

ASME Code III-1-NG states provisions for core support structures. Subsection NG does not distinguish between core support structures for Class 1 (to which ASME Code III-5, Class A components are analogous) and Class 2 or Class 3 components. However, component supports designed to Subsection NG provisions have the same function as component supports designed to the provisions of Subsection HG, Subpart A. Although Subsection NG does not specifically state it is applicable to metallic core supports only, all materials referenced in Subsection NG are metallic. Therefore, it is clear that the scope of Subsection NG is limited to metallic core support structures.

The NRC has approved ASME Code III-1 of the 2015 and 2017 Editions of the ASME Code, which includes ASME Code III-1-NG, through incorporation by reference in 10 CFR 50.55a, with the conditions specified in 10 CFR 50.55a(b). The metallic core support structures within the scope of Subsection HG, Subpart A, will be exposed to the same temperature range and have the same function as metallic core support structures within the scope of ASME Code III-1-NG. Accordingly, the staff finds use of the rules of ASME Code III-1-NG as referenced in HGA-1110(b) to be acceptable for Class A metallic core support structures within the scope of Subsection HG, Subpart A, for low-temperature service, provided that the conditions specified in 10 CFR 50.55a(b) for ASME Code III-1-NG are applied to Subsection HG, Subpart A.

Therefore, the staff finds the requirements of HGA-1000 to be acceptable for Class A metallic core support structures in low-temperature service.

3.18.2 Article HGA-8000 Nameplates, Stamping with the Certification Mark, and Reports

HGA-8100 Requirements

HGA-8100 indicates that the provisions in Article HAA-8000 also apply to Class A metallic core support structures. HAA-8110 indicates that the rules for certificates, nameplates, the Certification Mark, and Data Reports for metallic components, metallic supports, and metallic core support structures under ASME Code III-5 shall be the same as those established for Division 1.

HGA-8100 serves the same purpose and is substantively equivalent to the corresponding provision in ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HGA-8100 acceptable. Further, HGA-8100 does not contain any technical requirements and does not otherwise impact other provisions.

3.19 Subsection HG Class A Metallic Core Support Structures, Subpart B Elevated Temperature Service (HGB)

3.19.1 Article HGB-1000 Introduction

HGB-1000 mainly describes the scope of Subsection HG, Subpart B. Specifically, HGB-1000 states that the rules of Subsection HG, Subpart B, constitute the provisions associated with metallic core support structures or portions of those core support structures that are intended to conform to the provisions for Class A construction for service when Service Loading temperatures exceed the appropriate temperature limits established in Table HAA-1130-1 for the material under consideration. HGB-1111 also specifies when the rules of ASME Code III-1-NG may be used.

HGB-1000 serves the same purpose and is substantively equivalent to the corresponding provision in ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HGB-1000 acceptable. Further, HGB-1000 does not contain any technical requirements and does not otherwise impact other provisions.

HGB-1124 Temperature and Service Life Limits

HGB-1124 does not approve the use of Subsection HG, Subpart B for structural parts that will be subjected either to metal temperatures or to times greater than those values associated with the S_{mt} data for the specified material in Tables HBB-I-14.3A through HBB-I-14.3E. The staff finds this provision acceptable because it would be undesirable for metallic core support structures to be allowed to operate at temperatures above which material properties are available.

3.19.2 Article HGB-2000 Material

HGB-2100 General Requirements for Material

The staff finds ASME Code III-5, HGB-2100, acceptable because the general provisions are plain procedural statements referring to Division 1, Article NG-2000 (with stated exceptions reviewed below), all of which are acceptable for the reasons stated below in the staff evaluations of other subarticles in HGB-2000.

HGB-2120

HGB-2121 Permitted Material Specifications

HGB-2121 serves the same purpose as ASME Code III-1-NG, Subparagraph NG-2121, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. HGB-2121(a), (b), and (c) are identical to the corresponding subsubparagraphs in NG-2121, except that HGB-2121(a) adds additional provisions for metallic core support materials used in zones of elevated temperature. Specifically, HGB-2121(a) provides that materials used in zones of elevated temperature, conform to the same tables for allowable materials specifications (Table HBB-I-14.1a for base materials, Table HBB-I-14.11 for threaded structural fasteners, and Table HBB-I-14.1(b) for weld materials), as HBB-2121 does for Class A materials in high temperature service. HGB-2121(a) also calls for such materials to conform to the guidance of Nonmandatory Appendix HBB-U for restricted materials specifications to improve performance in elevated temperature applications where creep is significant. The staff therefore finds the provisions of HBB-2121(a) for materials in zones of elevated temperature to be acceptable because core support structures in elevated temperature service will be exposed to the same range of operating temperatures as the Class A components in elevated temperature service that are within the scope of HBB-2121, and the application of Class A provisions to such components will assure their structural integrity for the same reasons they assure the structural integrity of Class A components. The staff approved the referenced tables for Class A components for the reasons stated in Section 3.7, and approved HBB-U for the reasons stated in Section 3.10. Therefore, the staff finds HGB-2121 acceptable.

HGB-2160 Deterioration of Material in Service

The staff finds Section III-5, HGB-2160, acceptable because it does not specify detailed provisions but appropriately indicates the responsibility of the Owner in considering materials factors affecting inservice deterioration. Further, HBG-2160 is technically equivalent to HBB-2160, and is acceptable for the same reasons HBB-2160 is acceptable, as set forth in Section 3.6.2 of this NUREG. Section 3.6.2 of this NUREG provides information relating to the handling of material strength deterioration in elevated temperature service for materials covered in Subpart HBB. ASME Code XI-2 also provides stipulations on inservice deterioration and degradation mechanisms.

HGB-2400

HGB-2430

HGB-2433

HGB-2433.2 Acceptance Standards

HGB-2433.2 contains the acceptance standards for delta ferrite content in materials. In accordance with HGB-2100, the provisions of NG-2000 apply except as modified therein. NG-2000 applies the delta ferrite provisions of NG-2433 to metallic core supports constructed to Subsection HG, Subpart B. The acceptance standards of HGB-2433.2 with respect to the acceptable ranges of delta ferrite are the same as those in HBB-2433.2. Since both HGB and HBB cover similar service conditions, the staff finds the same acceptance criteria applicable. Accordingly, the staff finds the acceptance criteria of HGB-2433.2 to be acceptable. Section 3.6.2 of this NUREG states the reasons for the staff acceptance of HBB-2433.2.

3.19.3 Article HGB-3000 Design

HGB-3100 General Requirements

HGB-3100 indicates that all core support structure material and material welded thereto shall meet the provisions of ASME Code III-1, NG-3000, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a, without conditions, except as modified in HGB-3000. For HGB-3000, the staff compared ASME Code III-5-HGB to ASME Code III-5-HBB. This is appropriate because core support structures operate at the same high temperature range as that established for Class A components under ASME Code III-5-HBB. The staff evaluation of ASME Code III-5-HGB is set forth below.

HGB-3110

HGB-3112 Design Parameters (Pressure Difference, Temperature, Mechanical Force, Design Stress Intensity Value)

The staff finds paragraph HGB-3112 to be acceptable because it serves the same purpose and is technically equivalent to paragraph HBB-3112. The design stress intensity values for materials are listed in the ASME Code II-D, and for higher temperatures are extended using the values are in Tables HBB-I-14.3A through HBB-I-14.3E. The design stress intensity values are in Tables HBB-I-14.3A through HBB-I-14.13E, and the staff evaluates their acceptability in the review of Mandatory Appendix HBB-I-14 in Section 3.7 of this NUREG, which states the reasons the staff accepted HBB-I-14. The staff approves HGB-3112 for the same reasons it approved HBB-3112, which are stated in Section 3.6.3 of this NUREG.

HGB-3113 Loading Categories (Design Loadings and Service Loadings (Levels A, B, C, and D))

The staff finds paragraph HGB-3113 to be acceptable because it is a definition and is technically equivalent to paragraph HBB-3113. The staff accepts HGB-3113 for the same reasons it accepts HBB-3113, which are stated in Section 3.6.3 of this NUREG.

HGB-3114 Load Histogram (Level A, B, and C Service Events)

The staff finds subparagraph HGB-3114 to be acceptable because it is a definition and is technically equivalent to subparagraph HBB-3114. The staff accepts HGB-3114 for the same reasons it accepts HBB-3114, which are stated in Section 3.6.3 of this NUREG.

HGB-3120

HGB-3122 Cladding

The staff finds paragraph HGB-3122 to be acceptable. This paragraph indicates that the provisions ASME Code III-1, NG-3122, are not acceptable for cladding. HGB-3227.8 contains cladding provisions and is evaluated below.

HGB-3124 Environmental Effects

The staff finds paragraph HGB-3124 to be acceptable because it has the same scope as and is technically equivalent to paragraph NG-3124, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions.

HGB-3130

HGB-3132 Reinforcement for Openings

The staff finds paragraph HGB-3132 to be acceptable because it applies Class A vessel and piping design rules to core support structures. The staff determined HBB-3136 to be acceptable for reasons stated in Section 3.6.3 of this NUREG. HGB-3132 is acceptable for the same reasons HBB-3136 is acceptable.

HGB-3133 External Pressure Difference

The staff finds paragraph HGB-3133 to be acceptable. This paragraph indicates that the provisions of ASME Code III-1, NG-3133 are not used for analyzing external pressure differences. Therefore, the applicant should describe how any external pressure difference will be evaluated, if applicable, in the Design Report.

HGB-3138 Elastic Follow-Up

The staff finds paragraph HGB-3138 to be acceptable because it is technically equivalent to paragraph HBB-3138, which is acceptable for the reasons stated in Section 3.6.3 of this NUREG. HGB-3138 is acceptable for the same reasons HBB-3138 is acceptable.

HGB-3139 Welding

HGB-3139.1 Abrupt Changes in Mechanical Properties at Weld and Compression Contact Junctions

The staff finds subparagraph HGB-3139.1 to be acceptable because it is technically equivalent to subparagraph HBB-3139.1 and the staff determined HBB-3139.1 to be acceptable for the reasons stated in Section 3.6.3 of this NUREG. HGB-3139.1 is acceptable for the same reasons HBB-3139.1 is acceptable.

HGB-3139.2 Weld Design

The staff finds the general provision for design subparagraph HGB-3139.2 to be acceptable. HGB-3139.2 indicates that the applicant should conform, at a minimum, with the rules of ASME Code III-1 NG-3350, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Section 3.6.3 of this NUREG evaluates and documents the acceptance of additional provisions delineated elsewhere in this Article.

HGB-3200 Design By Analysis

HGB-3210 Design Criteria

HGB-3211 Requirements for Acceptability

The staff finds paragraph HGB-3211 to be acceptable. This paragraph indicates that the applicant should conform to the provisions of HGB-3211(a) through HGB-3211(d) for acceptability of a design based on analysis.

The staff finds subparagraph HGB-3211(a) to be acceptable because it specifies that the calculated or experimentally determined stresses, strains, and deformations will not exceed the limits of HGB-3200, which is technically equivalent to HBB-3200. Section 3.6.3 of this NUREG states the reasons that HBB-3200 is acceptable, and the staff has determined that HGB-3211(a) is acceptable for the same reasons.

The staff finds subparagraph HGB-3211(b) to be acceptable because it indicates that the design should conform to the rules of ASME Code III-1, NG-3100 and NG-3350, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, and the scope of NG-3100 and NG-3350 is equivalent to that of HGB-3211(b).

The staff finds subparagraph HGB-3211(c) to be acceptable since it indicates that buckling should be considered in accordance with HGB-3250, along with the provisions of HGB-3211(a) and HGB-3211(b), if compressive stresses occur.

The staff finds subparagraph HGB-3211(d) to be acceptable since it calls for protection against nonductile fracture in accordance with HGB-3241, which is in addition to the provisions of ASME Code III-NG such that HGB-3211(d) is conservative compared to the corresponding provision in Division 1.

HGB-3212 Basis for Determining Stress, Strain, and Deformation Quantities

The staff finds paragraph HGB-3212 to be acceptable since it is technically equivalent to paragraph HBB-3212, which is acceptable for the reasons stated in Section 3.6.3 of this NUREG. HGB-3212 is acceptable for the same reasons HBB-3212 is acceptable.

HGB-3213 Terms Relating to Analysis

The staff finds paragraph HGB-3213 to be acceptable because it is technically equivalent to paragraph HBB-3213, which is acceptable for the reasons stated in Section 3.6.3 of this NUREG. HGB-3213 is acceptable for the same reasons HBB-3213 is acceptable.

HGB-3214 Stress Analysis

The staff finds paragraph HGB-3214 to be acceptable because it is technically equivalent to paragraph HBB-3214. Section 3.6.3 of this NUREG states the reasons why HBB-3214 is acceptable and HGB-3214 is acceptable for the same reasons.

HGB-3214.1 Elastic Analysis

The staff finds subparagraph HGB-3214.1 to be acceptable because it is technically equivalent to subparagraph HBB-3214.1. Section 3.6.3 of this NUREG states the reasons why HBB-3214.1 is acceptable and HGB-3214.1 is acceptable for the same reasons.

HGB-3214.2 Inelastic Analysis

The staff finds subparagraph HGB-3214.2 to be acceptable because it is technically equivalent to subparagraph HBB-3214.2. Section 3.6.3 of this NUREG states the reasons why HBB-3214.2 is acceptable and HGB-3214.1 is acceptable for the same reasons.

HGB-3214.3 Mechanical Properties

The staff finds subparagraph HGB-3214.3 to be acceptable because it is technically equivalent to subparagraph HBB-3214.3. Section 3.6.3 of this NUREG states the reasons why HBB-3214.3 is acceptable and HGB-3214.3 is acceptable for the same reasons.

HGB-3215 Derivation of Stress Intensities

The staff finds paragraph HGB-3215 to be acceptable because it is technically equivalent to paragraph HBB-3215. Section 3.6.3 of this NUREG states the reasons why HBB-3215 is acceptable and HGB-3215 is acceptable for the same reasons.

HGB-3216 Derivation of Stress Differences and Strain Differences

The staff finds paragraph HGB-3216 to be acceptable because it is technically equivalent to paragraph HBB-3216. Section 3.6.3 of this NUREG states the reasons why HBB-3216 is acceptable and HGB-3216 is acceptable for the same reasons.

HGB-3217 Classification of Stresses

The staff finds paragraph HGB-3217 to be acceptable because it is technically equivalent to paragraph HBB-3217. Section 3.6.3 of this NUREG states the reasons why HBB-3217 is acceptable and HGB-3217 is acceptable for the same reasons. The staff notes that the cladding type of stress classification should be peak stress, as documented in Table NG-3217-1 of ASME Code III-1 and HGB-3213.11(a).

HGB-3220 Design Rules and Limits for Load-Controlled Stresses in Structures Other than Threaded Structural Fasteners

HGB-3221 General Requirements

The staff finds paragraph HGB-3221 to be acceptable because it is technically equivalent to paragraph HBB-3221. The detailed explanation of why the use of HBB-3221 is acceptable also applies to HGB-3221. Section 3.6.3 of this NUREG states the reasons why HBB-3221 is acceptable.

HGB-3222 Design Limits

The staff finds paragraph HGB-3222 to be acceptable because it is technically equivalent to subparagraph HBB-3222. Section 3.6.3 of this NUREG states the reasons why HBB-3222 is acceptable and HGB-3222 is acceptable for the same reasons.

HGB-3223 Level A and B Service Limits

The staff finds paragraph HGB-3223 to be acceptable because it is technically equivalent to paragraph HBB-3223. Section 3.6.3 of this NUREG states the reasons why HBB-3223 is acceptable and HGB-3223 is acceptable for the same reasons.

HGB-3224 Level C Service Limits

Paragraph HGB-3224 serves the same purpose and is technically equivalent to paragraph HBB-3224. One minor difference is that HGB-3224(d) indicates, in part, that it is permissible to extrapolate the allowable stress intensity at temperature curve (Figures HBB-I-14.3A through HBB-I-14.3E and Figures HBB-I-14.4A through HBB-I-14.4E) to determine time value (t_{ib}) when computing use-fractions, and that any such extrapolation and the method used should be reported in the Design Report (ASME Code, NCA-3551.1). The staff notes that Figures HBB-I-14.3A through HBB-I-14.3E provide S_{mt} values while Figures HBB-I-14.4A through HBB-I-14.4E provide S_t values, and that the procedure described in HGB-3224(d) only uses the S_t values. The staff also notes that the procedure of HGB-3224(b) to determine the use-fraction associated with primary membrane stresses and the corresponding paragraph in HBB-3224 for the time fractions associated with primary membrane stresses and primary membrane plus bending stresses are silent on whether extrapolation is permitted. In general, if the ASME Code does not prohibit a common engineering practice such as extrapolation, then the practice is permitted. In addition, extrapolation may be needed or desirable for low stress conditions and other conditions where not extrapolating would lead to excessively high time fractions, which would unnecessarily limit designers. Therefore, the staff finds that extrapolation when using Figures HBB-I-14.4A through HBB-I-14.4E to determine the t_{ib} value in accordance with HGB-3224(d) is acceptable, and does not change the conclusion that paragraphs HBB-3224 and HGB-3224 are technically equivalent. The reference to Figures HBB-I-14.3A through HBB-I-14.3E in HGB-3224(d) appears to be an error, and the staff recommends that ASME review and correct this error if necessary. Based on the above, the staff finds HGB-3224 acceptable because it serves the same purpose and is technically equivalent to Paragraph HBB-3224.

HGB-3225 Level D Service Limits

The staff finds paragraph HGB-3225 to be acceptable because it is technically equivalent to paragraph HBB-3225. Section 3.6.3 of this NUREG states the reasons why HBB-3225 is acceptable and HGB-3225 is acceptable for the same reasons.

HGB-3227 Special Stress Limits

The staff finds paragraph HGB-3227 to be acceptable because it is technically equivalent to paragraph HBB-3227. Section 3.6.3 of this NUREG states the reasons why HBB-3227 is acceptable and HGB-3227 is acceptable for the same reasons.

HGB-3227.1 Bearing Loads

The staff finds subparagraph HGB-3227.1 to be acceptable because it is technically equivalent to subparagraph HBB-3227.1. Section 3.6.3 of this NUREG states the reasons why HBB-3227.1 is acceptable and HGB-3227.1 is acceptable for the same reasons.

HGB-3227.2 Pure Shear

The staff finds subparagraph HGB-3227.2 to be acceptable because it is technically equivalent to subparagraph HBB-3227.2. Section 3.6.3 of this NUREG states the reasons why HBB-3227.2 is acceptable and HGB-3227.2 is acceptable for the same reasons.

HGB-3227.3 Progressive Distortion of Nonintegral Connections

The staff finds subparagraph HGB-3227.3 to be acceptable because it is technically equivalent to subparagraph HBB-3227.3. Section 3.6.3 of this NUREG states the reasons why HBB-3227.3 is acceptable and HGB-3227.3 is acceptable for the same reasons.

HGB-3227.4 Triaxial Stresses

The staff finds subparagraph HGB-3227.4 to be acceptable because it is technically equivalent to subparagraph HBB-3227.4. Section 3.6.3 of this NUREG states the reasons why HBB-3227.4 is acceptable and HGB-3227.4 is acceptable for the same reasons.

HGB-3227.5 Nozzle Piping Transition

The staff finds subparagraph HGB-3227.5 to be acceptable because it is technically equivalent to subparagraph HBB-3227.5. Section 3.6.3 of this NUREG states the reasons why HBB-3227.5 is acceptable and HGB-3227.5 is acceptable for the same reasons.

HGB-3227.8 Cladding

The staff finds subparagraph HGB-3227.8 to be acceptable because it is technically equivalent to subparagraph HBB-3227.8. Section 3.6.3 of this NUREG states the reasons why HBB-3227.8 is acceptable and HGB-3227.8 is acceptable for the same reasons.

HGB-3230 Stress Limits for Load-Controlled Stresses in Threaded Structural Fasteners

HGB-3231 General Requirements

The staff finds the general requirement paragraph HGB-3231 to be acceptable for the reasons set forth below.

HGB-3231(a) states that the rules of paragraph HGB-3231 apply to mechanical connections joining parts in core support structures within a pressure-retaining boundary and refers to this as threaded structural fasteners. Additionally, the design stress intensity values for S_{mt} for threaded structural fasteners are the values given in Tables HBB-I-14.3A through HBB-I-14.3E. This approach for threaded structural fasteners appears to be acceptable because the value of S_{mt} is the lesser of the time-independent value S_m and the time-dependent value S_t. For Class A threaded fasteners, there are separate figures and tables for S_0 (Tables HBB-I-14.12 and S_{mt} (for S_0 and Figures HBB-I-14.13A-B and Figure HBB-I-14.13C and Table HBB-I-14.13C.) However, as noted in Section 3.7.12, the allowable stress values for the Class A fasteners are one-half (or less) than those of the corresponding non-fastener material. There are also differences in the design and service Level A stress limits for fasteners in metallic core supports as compared to Class A components, which when combined with the different S_{mt} values for fasteners in Subsection HG Subpart B as compared to Subsection HB Subpart B, result in essentially equivalent allowable stress criteria, as detailed in the subsequent sections.

HGB-3231(b) states that the special stress limits of HGB-3227 do not apply to threaded structural fasteners. HGB-3231(b) is technically equivalent to ASME Code III-1 NG-3231(b), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HGB-3231(b) acceptable.

The staff finds HGB-3231(c) to be acceptable because it states that the rules of ASME Code III-5-HBB govern the connections that join parts of pressure-retaining boundaries. It is an acceptable approach to use the Class A pressure-retaining components construction code for connections joining parts of pressure-retaining boundaries in Class A core support structures because Class A core support structures have the same materials and operating conditions as Class A components.

HGB-3232 Design and Level A Service Limits

The staff finds paragraph HGB-3232 to be acceptable. This paragraph indicates that the number and cross-sectional area of threaded structural fasteners should be such that the stress intensity limits of the Design Loadings and Level A Service Limits are satisfied. The applicant will demonstrate this in the Design Report.

HGB-3232.1 Average Stress

The staff finds HGB-3232.1 to be acceptable because it is technically equivalent to HBB-3233.1 and HBB-3233.2. It is an acceptable approach to use the Class A pressure-retaining components construction code for Class A core support structures because Class A core supports have the same materials and temperature range as Class A pressure-retaining components. The staff has determined that HGB-3232.1 is acceptable for the reasons stated below.

HGB-3232.1(a) is technically equivalent to HBB-3233.1. There is one major difference between HBB-3233.1 and HGB-3232.1(a), which is that HGB-3232.1 has an additional allowable 0.5 S_m that is not present in HBB-3233.1. The staff finds this acceptable because it will lead to a lower allowable stress value since the allowable stress value of HGB-3232.1 is the lesser of 0.5 S_m and S_{mt}, and the allowable stress value of HBB-3233.1 is less than or equal to S_{mt}. As noted above, the allowable stresses for Class A bolts are one-half or less the allowable stresses for the corresponding non-fastener material, while in HGB-3231, the allowable stresses for the fasteners are the same as those for the corresponding non-fastener materials. This will result in the limits for average stress in HGB-3232.1 being roughly equivalent to those in HBB-3233.1, although 0.5S_m may not be exactly half of S_{mt} for fasteners in HBB-3233.1.

HGB-3232.1(b) is technically equivalent to subparagraph HBB-3233.2. There is one major difference in HGB-3232.1(b) when compared to HBB-3233.2. HGB-3232.1(b) does not have a multiplication factor on S_{mt}, while HBB-3233.2 has a multiplication factor of 2 on S_{mt}. The staff finds this acceptable because it will lead to an allowable stress value for HGB threaded structural fasteners that is equivalent to the allowable stress value for HBB bolted components, considering that the S_{mt} values for Class A threaded fasteners are one-half or less of those for the corresponding non-fastener material. Additionally, HGB-3232.1 states that stress intensity instead of maximum stress is to be used when threaded structural fasteners are loaded in transverse shear. This is an added provision compared to HBB-3233.2, and the staff finds it to be acceptable because shear stress due to bending should be compared to stress intensity, thus all the stress components will be addressed.

The staff finds HGB-3232.1(b)(2) to be acceptable because it states that the preload shall be shown to be greater than the primary and secondary membrane stress if a tight joint is necessary.

HGB-3232.2 Maximum Stress

The staff finds HGB-3232.2 to be acceptable because it is technically equivalent to HBB-3233.3. Section 3.6.3 of this NUREG states the reasons why HBB-3233.3 is acceptable and HGB-3232.2 is acceptable for the same reasons. There is one major difference in HGB-3232.2

compared to HBB-3233.3. HGB-3232.2 has a multiplication factor of 1.5 on S_{mt}, while HBB-3233.3 has a multiplication factor of 3 on S_{mt}. The reduction of the multiplication factor by half is acceptable and will lead to an equivalent allowable stress value because the allowable stress criteria of HGB-3232.2 is the lesser of 1.5 S_{mt} and K_tS_t and the allowable stress criteria of HBB-3233.3 is the lesser of 3 S_{mt} and K_tS_t, considering that the S_{mt} values for Class A fasteners are one-half or less of those for the corresponding non-fastener material. Additionally, HGB-3232.2 states that stress intensity instead of maximum stress is to be used when threaded structural fasteners are loaded in transverse shear. This is an added provision compared to HBB-3233.3 but is considered acceptable because shear stress due to bending should be compared to stress intensity, which addresses all the stress components.

HGB-3232.3 Nonductile Fracture

The staff finds subparagraph HGB-3232.3 to be acceptable because it is technically equivalent to subparagraph HBB-3233.4. Section 3.6.3 of this NUREG states the reasons why HBB-3233.4 is acceptable and HGB-3232.3 is acceptable for the same reasons.

HGB-3233 Level B Service Limits

Paragraph HGB-3233 states that Level A Service Limits apply for Level B Service Limits. HGB-3233 is technically equivalent to Section III-1 NG-3233, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a, without conditions. Therefore, the staff finds HGB-3233 acceptable.

HGB-3234 Level C Service Limits for Threaded Structural Fasteners

The staff finds paragraph HGB-3234 to be acceptable. This paragraph indicates that the number and cross-sectional area of threaded structural fasteners should be such that the provisions of HGB-3224 are satisfied for the Service Loadings for which Level C Service Limits are designated in the Design Specification. The acceptance criteria for Service Level C loadings for fasteners are technically equivalent to those for non-fastener materials, and this is acceptable because a given material has the same properties whether used for a fastener or non-fastener.

HGB-3235 Level D Service Limits for Threaded Structural Fasteners

The staff finds paragraph HGB-3235 to be acceptable. This paragraph indicates that the number and cross-sectional area of threaded structural fasteners should be such that the provisions of HGB-3225 are satisfied for the Service Loadings for which Level D Service Limits are designated in the Design Specification. The acceptance criteria for Service Level D loadings for fasteners are technically equivalent to those for non-fastener materials, which is acceptable because a given material has the same properties whether used for a fastener or non-fastener.

HGB-3240 Special Requirements for Elevated Temperature Components

HGB-3241 Nonductile Fracture

The staff finds paragraph HGB-3241 to be acceptable because it is technically equivalent to paragraph HBB-3241. Section 3.6.3 of this NUREG states the reasons why HBB-3241 is acceptable and HGB-3241 is acceptable for the same reasons.

HGB-3250 Limits on Deformation-Controlled Quantities

HGB-3251 General Requirements

The staff finds paragraph HGB-3251 to be acceptable because it is technically equivalent to paragraph HBB-3251. It is an acceptable approach to use the Class A pressure-retaining components construction code for Class A core support structures because Class A core supports have the same materials and temperature range as Class A pressure-retaining components.

HGB-3252 Criteria

The staff finds paragraph HGB-3252 to be acceptable because it is technically equivalent to paragraph HBB-3252. Section 3.6.3 of this NUREG states the reasons why HBB-3252 and the material properties of Nonmandatory HBB-T are acceptable and HGB-3252 is acceptable for the same reasons.

HGB-3300

HGB-3350

HGB-3352 Permissible Types of Welded Joints

The staff finds paragraph HGB-3352 to be acceptable for the following reasons. The first written sentence of HGB-3352 is technically equivalent to the first written sentence of paragraph NG-3352, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a, without conditions. Accordingly, the first written sentence of HGB-3352 is acceptable. The remaining portion of HGB-3352 is similar to NG-3352 but is reworded and tailored to ASME Code III-5-HGB use. The major differences are that HGB-3352 calls out the appropriate ASME Code III-5-HGB sections for the allowable stress limits instead of ASME Code III-1-NG, and the fatigue factor, f, is considered a minimum stress concentration factor with a larger value to be used if obtained in accordance with HGB-3353(b). Use of a larger stress concentration factor is a conservative approach to calculate the stress at a welded joint.

HGB-3352.2 Type II Joints

Subparagraph HGB-3352.2 serves the same purpose and is technically equivalent to subparagraph ASME Code III-1, NG-3352.2, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a, without conditions. Therefore, the staff finds HGB-3352.2 acceptable.

HGB-3353 Design of Welded Construction at Elevated Temperatures

The staff finds paragraph HGB-3353 to be acceptable because it is technically equivalent to paragraph HBB-3353. The only difference is that HGB-3353 provides an additional sentence related to strain concentration. It is an acceptable approach to use the Class A pressure-retaining components construction code for Class A core support structures. Section 3.6.3 of this NUREG states the reasons why HBB-3353 is acceptable and HGB-3353 is acceptable for the same reasons except for the last sentence. The last sentence of HGB-3353 states that the assumed strain concentration shall not be smaller than the applicable fatigue factor from ASME

Code III-1, Table NG-3352-1. The staff finds this acceptable because the sentence provides a conservative limitation, because it results in consideration of higher stresses.

3.19.4 Article HGB-4000 Fabrication and Installation

HGB-4100 General Requirements

HGB-4110 Introduction

Subarticle HGB-4100 states that core support structure material and material welded thereto shall meet the requirements of ASME Code III-1, Article NG-4000, except as modified in HGB-4000. The staff finds this acceptable because the provisions in HGB-4000 provide for explicit consideration of creep and stress rupture at elevated temperature service during fabrication, which is not addressed in Subsection NG-4000. The specific modifications are evaluated below.

HGB-4200

HGB-4210

HGB-4212 Forming and Bending Processes

Paragraph HGB-4212 is technically equivalent to paragraph HBB-4212. The staff finds it to be an acceptable approach to use the Class A pressure-retaining components fabrication and installation requirements for Class A core support structures because Class A core support structures will be subject to temperatures and stresses in the same range as those for Class A pressure-retaining components fabricated from similar materials.

The rules of HGB-4212 add provisions to NG-4212 that are more detailed than those listed in Code Case 1593. HGB-4212 calls for a post-fabrication heat treatment, or a written justification for not performing a heat treatment, when local strains exceed 5 percent. HGB-4212 limits the use of a written justification in lieu of performing a post-fabrication heat treatment for cold-worked 304 SS, 316 SS, and Alloy 800H, as discussed below.

When post-fabrication heat treatment of ferritic materials is called for, Division 1, Table NG-4622.1-1, is specified. Table NG-4622.1-1 provides the time and temperature for PWHTs. The NRC staff finds this acceptable because the specified time and temperature for PWHT of ferritic welds are also adequate to relieve stress after forming or bending operations. Alternatively, the base material and welds may be reheat treated and recertified with the applicable material specification and the provisions of Division 1, NG-2400, which is acceptable because reheat treatment and recertification after forming and bending operations in accordance with the original material specification will restore the material to its original prefabrication condition.

For austenitic materials except Alloy 800H, HGB-4212 indicates that post-fabrication heat treatment, when necessary, should consist of heat treatment in accordance with the base material specification. The staff finds this acceptable because the heat treatment indicated in the original material specification will restore the material to the solution annealed condition. For Alloy 800H, HGB-4212 provides the appropriate heat treatment provisions and specified resulting grain size to ensure optimal performance at higher temperatures.

HGB-4212 references Figure HBB-4212-1. Section 3.6.4 of this NUREG states the reasons why HBB-4212 and Figure HBB-4212-1 is acceptable and HGB-4212 is acceptable for the same reasons and those stated immediately above.

HGB-4400

HGB-4420

HGB-4233 Alignment Requirements When Component Inside Surface Is Inaccessible

HGB-4233 is technically equivalent to NB-4233(a) and NB-4233(b), which the NRC previously approved through incorporation by reference in 10 CFR 50.55a without conditions. The staff finds it is an acceptable approach, as provided in HGB-4233, to use the Class 1 pressure-retaining components alignment provisions for Class A core support structures because these provisions are not temperature dependent and provide more conservative alignment provisions than those provided in Article NG-4000. Therefore, the staff finds HGB-4233 acceptable.

HGB-4424 Surfaces of Welds

Paragraph HGB-4424 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except that HGB-4424 adds one provision. The added provision is that the surface geometry should be considered in the stress analysis in accordance with the rules for the design of core support structures in elevated surfaces. HGB-4424 states that the as-welded surface geometry is permitted, provided the surface geometry is considered in the stress analysis in accordance with the rules for the design of Class A elevated temperature components. The staff finds paragraph HGB-4424 to be acceptable because the provision to include the surface geometry in the stress analysis will ensure that the impact of as-welded surfaces will be appropriately accounted for by using the proper stress indices when performing an analysis in accordance with HGB-3000.

3.19.5 Article HGB-5000 Examination

HGB-5100 General Requirements for Examination

Subarticle HGB-5100 states that core support structure material and material welded thereto shall meet the requirements of ASME Code III-1 NG-5000, except as modified in HGB-5000. The NRC has previously approved ASME Code III-1 NG-5000 through incorporation by reference in 10 CFR 50.55a without conditions. The modifications to NG-5000 are evaluated below.

HGB-5200

HGB-5220 Requirements for Radiography or Ultrasonic and Liquid Penetrant or Magnetic Particle Examination

Paragraph HGB-5220 serves the same purpose and is technically equivalent to the corresponding provision in ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. In addition, the NDE methods and examination volumes are consistent with those identified in HBB-5000 for pressure boundary components. Therefore, the staff finds HGB-5000 acceptable.

HGB-5221 Category A Welded Joints

Paragraph HGB-5221 is technically equivalent to paragraph HBB-5210. The staff finds it is an acceptable approach to use Class A pressure-retaining component weld examination provisions for Class A core support structure weld examinations because Class A core support structures use similar materials and weld joint configurations and will be subject to temperatures and stresses in the same range as those for Class A pressure-retaining components. In addition, Class A pressure retaining component examination provisions provide the highest level of examination when compared to all other Division 5 components classifications, therefore these provisions are conservative when used to examine core support structures.

HGB-5222 Category B Welded Joints

Paragraph HGB-5222 is technically equivalent to paragraph HBB-5220. The staff finds it is an acceptable approach to use Class A pressure-retaining component weld examination provisions for Class A core support structure weld examinations because Class A core support structures use similar materials and weld joint configurations and will be subject to temperatures and stresses in the same range as those for Class A pressure-retaining components. In addition, Class A pressure retaining component examination provisions provide the highest level of examination when compared to all other Division 5 components classifications, therefore these provisions are conservative when used to examine core support structures.

HGB-5223 Category C Welded Joints

Paragraph HGB-5223 is technically equivalent to paragraph HBB-5230. The staff finds it is an acceptable approach to use Class A pressure-retaining component weld examination provisions for Class A core support structure weld examinations because Class A core support structures use similar materials and weld joint configurations and will be subject to temperatures and stresses in the same range as those for Class A pressure-retaining components. In addition, Class A pressure retaining component examination provisions provide the highest level of examination when compared to all other Division 5 components classifications, therefore these provisions are conservative when used to examine core support structures.

The staff finds Figure HGB-5223-1 to be acceptable because it is technically equivalent to ASME Code III-1-NB, Figure NB-4243-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions.

HGB-5224 Category D Welded Joints

Paragraph HGB-5224 is technically equivalent to paragraph HBB-5240. The staff finds it is an acceptable approach to use Class A pressure-retaining component weld examination provisions for Class A core support structure weld examinations because Class A core support structures use similar materials and weld joint configurations and will be subject to temperatures and stresses in the same range as those for Class A pressure-retaining components. In addition, Class A pressure retaining component examination provisions provide the highest level of examination when compared to all other Division 5 components classifications, therefore these provisions are conservative when used to examine core support structures.

HGB-5224.1 Butt-Welded Nozzles

Subparagraph HGB-5224.1 is technically equivalent to paragraph HBB-5242. The staff finds it is an acceptable approach to use Class A pressure-retaining component weld examination provisions for Class A core support structure weld examinations because Class A core support structures use similar materials and weld joint configurations and will be subject to temperatures and stresses in the same range as those for Class A pressure-retaining components. In addition, Class A pressure retaining component examination provisions provide the highest level of examination when compared to all other Division 5 components classifications, therefore these provisions are conservative when used to examine core support structures.

HGB-5224.2 Full Penetration Corner-Welded Nozzles

Subparagraph HGB-5224.2 is technically equivalent to paragraph HBB-5243. The staff finds it is an acceptable approach to use Class A pressure-retaining component weld examination provisions for Class A core support structure weld examinations because Class A core support structures use similar materials and weld joint configurations and will be subject to temperatures and stresses in the same range as those for Class A pressure-retaining components. In addition, Class A pressure retaining component examination provisions provide the highest level of examination when compared to all other Division 5 components classifications, therefore these provisions are conservative when used to examine core support structures.

Figure HGB-5224.2-1 is technically equivalent to ASME Code III-1-NB, Figure NB-4244(b)-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds Figure HGB-5224.2-1 acceptable.

HGB-5224.3 Deposited Weld Metal as Reinforcement for Openings and Attachment of Nozzles

Subparagraph HGB-5224.3 is technically equivalent to paragraph HBB-5244. The staff finds it is an acceptable approach to use Class A pressure-retaining component weld examination provisions for Class A core support structure weld examinations because Class A core support structures use similar materials and weld joint configurations and will be subject to temperatures and stresses in the same range as those for Class A pressure-retaining components. In addition, Class A pressure retaining component examination provisions provide the highest level of examination when compared to all other Division 5 components classifications, therefore these provisions are conservative when used to examine core support structures.

Figure HGB-5224.3-1 is technically equivalent to ASME Code III-1-NB, Figure NB-4244(c)-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds Figure HGB-5224.3-1 acceptable.

HGB-5224.4 Full Penetration Welds at Oblique Connections

Subparagraph HGB-5224.4 is technically equivalent to paragraph HBB-5246. The staff finds it is an acceptable approach to use Class A pressure-retaining component weld examination provisions for Class A core support structure weld examinations because Class A core support structures use similar materials and weld joint configurations and will be subject to temperatures and stresses in the same range as those for Class A pressure-retaining components. In addition, Class A pressure retaining component examination provisions provide the highest level of examination when compared to all other Division 5 components classifications, therefore these provisions are conservative when used to examine core support structures.

Figure HGB-5224.4-1 is technically equivalent to ASME Code III-1-NB, Figure NB-4244(e)-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds Figure HGB-5224.4-1 acceptable.

HGB-5225 Category E Welded Joints

Paragraph HGB-5225 indicates that Category E welds, defined in ASME Code III-1-NG, NG-3351.5, should be examined in accordance with the provisions of HGB-5221. The provisions of HGB-5221 are detailed and sufficient to examine welds the same as Category A welds. This results in the Category E welds being examined with more rigor than is necessary, and the staff finds this acceptable.

3.19.6 Article HGB-8000 Nameplates, Stamping with the Certification Mark, and Reports

HGB-8100 Requirements

HGB-8100 indicates that the provisions in Article HAA-8000 also apply to Class A metallic core support structures.

HGB-8100 serves the same purpose and is equivalent to the corresponding provision in ASME Code III-1, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. Therefore, the staff finds HGB-8100 acceptable. Further, HGB-8100 does not contain any technical requirements and does not otherwise impact other provisions.

3.20 Mandatory Appendix HGB-I Rules for Strain, Deformation, and Fatigue Limits at Elevated Temperatures

3.20.1 Article HGB-I-1000 Introduction

The staff finds Mandatory Appendix HGB-I to be acceptable as written because it provides rules that may be used by the applicant with respect to evaluation by analysis of strain, deformation, and fatigue limits for components whose load-controlled stresses are evaluated by the rules of ASME Code III-5-HGB. Article HGB-I-1000 states that ASME Code III-5-HGB governs load-controlled stresses. Nonmandatory Appendix HBB-T contains these evaluation rules. The staff considers these rules appropriate for metallic core support structures exposed to elevated temperatures because the core supports are constructed from the same materials and operate in the same temperature range as the Class A materials covered by HBB-T.

Article HGB-I-1000 lists clarifications to Nonmandatory Appendix HBB-T with ASME Code III-5-HGB. The clarifications ensure consistency throughout ASME Code III-5 and are therefore acceptable. Article HGB-I-1000 states the following clarifications:

(a) ASME Code III-5-HGB does not use the local primary membrane stress intensity allowable, P_L; therefore, all P_L entries in HBB-T are to be replaced with the general primary membrane stress intensity allowable, P_m.

(b) References to ASME Code III-1-NB and ASME Code III-5-HBB in HBB-T remain as referenced.

(c) HBB-T-1325 and HBB-T-1434 do not apply to core support structure evaluations in accordance with ASME Code III-5-HGB.

(d) HBB-T-1435 references ASME Code III-A-XIII. XIII-3450 is now ASME Code III-1-NG NG-3228.3 and the reference to NB-3653.6 is not applicable to core support structures.

(e) HBB-T-1714 has an additional sentence that states that the stress concentration factor shall not be smaller than the applicable fatigue factor from Table NG-3352-1.

(f) Reference to Test Loadings is not applicable to core support structures because there is no NG-6000.

3.21 Mandatory Appendix HGB-II Rules for Construction of Core Support Structures, Extended for Restricted Service at Elevated Temperature, without Explicit Consideration of Creep and Stress-Rupture

3.21.1 Article HGB-II-1000 Introduction

HGB-II-1100 General

The staff finds paragraph HGB-II-1100 to be acceptable because it calls for the applicant to use the rules of ASME Code III-1-NG, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except as modified by Article HGB-II. The exceptions are evaluated below for elevated temperature.

HGB-II-1110 Aspects of Construction Covered by These Rules

Mandatory Appendix HGB-II provides rules for construction of core support structures that will experience only limited service at elevated temperature, such that creep and stress-rupture do not need to be explicitly considered. Therefore, these rules are generally similar to the rules of the ASME Code III-1, Subsection NG. However, HGB-1110 states that special rules are established in this Appendix that are necessary only for those zones of elevated temperature service of core support structures whose service metal temperatures (during the specified conditions of service) exceed those to which Section II, Part D, Subpart 1, Tables 2A and 2B apply, provided the time and temperature provisions of Mandatory Appendix HGB-IV are satisfied. HGB-II-1110 also states that the interface, if any, between low temperature portions and elevated temperature portions (zones of elevated temperature service) of the core support structure shall be identified in the Design Report (Divisions 1 and 2, NCA-3550).

Division 1, Subsection NG provides rules for materials, design, fabrication, examination, and certification in the manufacture and installation of core support structures whose service metal temperatures (during the specified conditions of service) do not exceed those for which Section II, Part D, Subpart 1, Tables 2A and 2B provide design stress intensity values. The staff finds that use of rules in Subsection HG that are based on Subsection NG is acceptable for core support structures that do not exceed the temperatures for which Section II, Part D, Subpart 1, Tables 2A and 2B provide design stress intensity values, since these core support structures will operate in the same temperature range as core support structures allowed to be constructed in accordance with Subsection NG.

Therefore, the staff finds paragraph HGB-II-1110 to be acceptable. The purpose of this paragraph is to dictate the aspects of construction covered by these rules. This paragraph states that the rules of ASME Code III-1-NG apply to core support structures where the service metal temperature does not exceed the III-1 continuous use temperature and confirms that the rules of ASME Code III-1-NG, as modified in ASME Code III-5-HGB, HGB-II, apply to core support structures for elevated temperature service.

3.21.2 Article HGB-II-2000 Materials

HGB-II-2100

The staff finds paragraph HGB-II-2100 to be acceptable because it calls for the applicant to use the rules of ASME Code III-1-NG, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except as modified by Article HGB-II-2000. The rules of ASME Code III-1-NG are appropriate for core support components for that do not exceed the temperatures for which Section II, Part D, Subpart 1, Tables 2A and 2B provide design stress intensity values (the III-1 continuous use temperature).

HGB-II-2120

HGB-II-2121 Permitted Material Specifications

The staff finds paragraph HGB-II-2121 to be acceptable because it is technically equivalent to paragraph ASME Code III-1-NG, NG-2121, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except for a minor modification of HGB-II-2121(a) when it is compared to NB-2121(a). Paragraph HGB-II-2121 refers to several tables for allowable stress values for the various material classes (ferritic, austenitic, plus bolting materials for ferritic and austenitic materials). The allowable stresses are all based on the same criteria as the design stress intensity values S_m in the ASME Code, Section II, Part D, Table 2A, which are essentially the same criteria used to determine the time-independent allowable stress S_m for Class A components (see Section 3.7.3), but are extended to higher temperatures than covered by the ASME Code, Section II, Part D, Table 2A. Use of a time-independent allowable stress in Appendix HBB-II is acceptable because the rules of this appendix may only be used for core support components that meet the time and temperature criteria of Mandatory Appendix HBB-IV, which means that creep is insignificant for these components (see Section 3.23.1).

HGB-II-2121(a) is technically equivalent to NG-2121(a) except for the addition of Table HGB-II-2121-4, which is for ASME Code II-D, bolting materials, and except for the last sentence. The addition of Table HGB-II-2121-4 is appropriate for ASME Code III-5-HGB because it defines design stress intensity values for bolting materials up to the continuous use temperature for ASME Code III-1 applications. The staff finds the last sentence acceptable because it solely states that core support structure materials at elevated service should also conform to the material specifications identified in the tables of Article HGB.

The staff finds Table HGB-II-2121-1 to be acceptable as shown. Table HGB-II-2121-1 provides the design stress intensity values for ferritic steels at elevated temperatures in core support structure applications. From Tables HGB-II-3229-1 and HGB-II-3229-4, the yield and ultimate strength, respectively, from 400 degrees C to 538 degrees C (750 degrees F to 1,000 degrees F) for these materials are shown to come from II-D, Table Y-1 and Table U, respectively. II-D is an appropriate reference for ASME Code material properties that have factors of safety built in, producing ASME Code values that are lower than what is found in an applicant's Certified Material Test Report or Certificate of Conformance. For the temperatures of 565 degrees C and 593 degrees C (1,050 degrees F and 1,100 degrees F), Table HGB-II-3229-1 shows the yield strength values for 2¼/Cr-1Mo, and Table HBB-3225-1 shows the ultimate strength. Note that the 1¼Cr-½Mo-Si nominal composition only has design stress intensity values up to 482 degrees C and 400 degrees C (900 degrees F and 750 degrees F) for forgings and plate, respectively. Using the yield and ultimate strength and following the criteria in ASME Code, Section II, Part D, Mandatory Appendix 2, 2-110, the design stress intensity at temperature for materials of construction from Tables 2A and 2B can be determined.

The values in Table HGB-II-2121-1 (U.S. Customary Units) are shown to be similar to what is produced following the provisions from ASME Code, Section II, Part D, Mandatory Appendix 2, as shown below. Discrepancies between values following this methodology and Table HGB-II-2121-1 can be attributed to rounding errors and using values listed in Section II, Part D, Certificate of Conformance, because the actual ASME Code committee data could not be acquired.

Table 3-8 compares Table HGB-II-2121-1 to the Section II, Part D, methodology.

Table 3-8 Table HGB-II-2121-1 Comparison of Design Stress Intensities to Section II, Part D Methodology

Design Stress Intensity [ksi] (Table HGB-II-2121-1 Comparison to Sec. II Part D Methodology)										
Nominal Composition	Product	Spec. No.	Type/ Grade	Class/ Condition/ Temper	Min Tensile Strength (ksi)	Min. Yield Strength (ksi)	750 °F		800 °F	
							Sec. II Part D Methodology	HGB-2121-1	Sec. II Part D Methodology	HGB-2121-1
1 1/4Cr– 1/2Mo–Si	Forgings	SA–182	F11	2	70	40	19.7	19.7	19.2	19.2
1 1/4Cr– 1/2Mo–Si	Plate	SA–387	11	2	75	45	22.1	22.2		
2 1/4Cr–1Mo	Wld. pipe	SA–691	2 1/4CR	…	60	30	17.9	17.9	17.7	17.9
2 1/4Cr–1Mo	Smls. tube	SA–213	T22	…	60	30	17.9	17.9	17.7	17.9
2 1/4Cr–1Mo	Smls. pipe	SA–335	P22	…	60	30	17.9	17.9	17.7	17.9
2 1/4Cr–1Mo	Forgings	SA–336	F22	1	60	30	17.9	17.9	17.7	17.9
2 1/4Cr–1Mo	Forged pipe	SA–369	FP22	…	60	30	17.9	17.9	17.7	17.9
2 1/4Cr–1Mo	Forgings	SA–182	F22	1	60	30	17.9	17.9	17.7	17.9
2 1/4Cr–1Mo	Smls. & wld. ftgs.	SA–234	WP22	1	60	30	17.9	17.9	17.7	17.9
2 1/4Cr–1Mo	Plate	SA–387	22	1	60	30	17.9	17.9	17.7	17.9
2 1/4Cr–1Mo	Cast pipe	SA–426	CP22	…	70	40	21.5	21.6	20.9	21.0

Design Stress Intensity [ksi] (Table HGB-II-2121-1 Comparison to Sec. II Part D Methodology)										
Nominal Composition	Product	Spec. No.	Type/ Grade	Class/ Condition/ Temper	Min Tensile Strength (ksi)	Min. Yield Strength (ksi)	850 °F		900 °F	
							Sec. II Part D Methodology	HGB-2121-1	Sec. II Part D Methodology	HGB-2121-1
1 1/4Cr– 1/2Mo–Si	Forgings	SA–182	F11	2	70	40	18.7	18.7	18.1	18.1
1 1/4Cr– 1/2Mo–Si	Plate	SA–387	11	2	75	45				
2 1/4Cr–1Mo	Wld. pipe	SA–691	2 1/4CR	…	60	30	17.5	17.6	17.1	17.2
2 1/4Cr–1Mo	Smls. tube	SA–213	T22	…	60	30	17.5	17.6	17.1	17.2
2 1/4Cr–1Mo	Smls. pipe	SA–335	P22	…	60	30	17.5	17.6	17.1	17.2
2 1/4Cr–1Mo	Forgings	SA–336	F22	1	60	30	17.5	17.6	17.1	17.2
2 1/4Cr–1Mo	Forged pipe	SA–369	FP22	…	60	30	17.5	17.6	17.1	17.2
2 1/4Cr–1Mo	Forgings	SA–182	F22	1	60	30	17.5	17.6	17.1	17.2
2 1/4Cr–1Mo	Smls. & wld. ftgs.	SA–234	WP22	1	60	30	17.5	17.6	17.1	17.2
2 1/4Cr–1Mo	Plate	SA–387	22	1	60	30	17.5	17.6	17.1	17.2
2 1/4Cr–1Mo	Cast pipe	SA–426	CP22	…	70	40	20.0	20.0	19.0	18.9

Table 3-8 Table HGB-II-2121-1 Comparison of Design Stress Intensities to Section II, Part D Methodology (cont.)

Design Stress Intensity [ksi] (Table HGB-II-2121-1 Comparison to Sec. II Part D Methodology)										
Nominal Composition	Product	Spec. No.	Type/ Grade	Class/ Condition/ Temper	Min Tensile Strength (ksi)	Min. Yield Strength (ksi)	950 °F		1000 °F	
							Sec. II Part D Methodology	HGB-2121-1	Sec. II Part D Methodology	HGB-2121-1
1 1/4Cr– 1/2Mo–Si	Forgings	SA–182	F11	2	70	40				
1 1/4Cr– 1/2Mo–Si	Plate	SA–387	11	2	75	45				
2 1/4Cr–1Mo	Wld. pipe	SA–691	2 1/4CR	…	60	30	16.5	16.7	15.8	15.9
2 1/4Cr–1Mo	Smls. tube	SA–213	T22	…	60	30	16.5	16.7	15.8	15.9
2 1/4Cr–1Mo	Smls. pipe	SA–335	P22	…	60	30	16.5	16.7	15.8	15.9
2 1/4Cr–1Mo	Forgings	SA–336	F22	1	60	30	16.5	16.7	15.8	15.9
2 1/4Cr–1Mo	Forged pipe	SA–369	FP22	…	60	30	16.5	16.7	15.8	15.9
2 1/4Cr–1Mo	Forgings	SA–182	F22	1	60	30	16.5	16.7	15.8	15.9
2 1/4Cr–1Mo	Smls. & wld. ftgs.	SA–234	WP22	1	60	30	16.5	16.7	15.8	15.9
2 1/4Cr–1Mo	Plate	SA–387	22	1	60	30	16.5	16.7	15.8	15.9
2 1/4Cr–1Mo	Cast pipe	SA–426	CP22	…	70	40	17.6	17.6	16.0	16.0

Design Stress Intensity [ksi] (Table HGB-II-2121-1 Comparison to Sec. II Part D Methodology)										
Nominal Composition	Product	Spec. No.	Type/ Grade	Class/ Condition/ Temper	Min Tensile Strength (ksi)	Min. Yield Strength (ksi)	1050 °F		1100 °F	
							Sec. II Part D Methodology	HGB-2121-1	Sec. II Part D Methodology	HGB-2121-1
1 1/4Cr– 1/2Mo–Si	Forgings	SA–182	F11	2	70	40				
1 1/4Cr– 1/2Mo–Si	Plate	SA–387	11	2	75	45				
2 1/4Cr–1Mo	Wld. pipe	SA–691	2 1/4CR	…	60	30	14.9	14.9	13.7	13.9
2 1/4Cr–1Mo	Smls. tube	SA–213	T22	…	60	30	14.9	14.9	13.7	13.9
2 1/4Cr–1Mo	Smls. pipe	SA–335	P22	…	60	30	14.9	14.9	13.7	13.9
2 1/4Cr–1Mo	Forgings	SA–336	F22	1	60	30	14.9	14.9	13.7	13.9
2 1/4Cr–1Mo	Forged pipe	SA–369	FP22	…	60	30	14.9	14.9	13.7	13.9
2 1/4Cr–1Mo	Forgings	SA–182	F22	1	60	30	14.9	14.9	13.7	13.9
2 1/4Cr–1Mo	Smls. & wld. ftgs.	SA–234	WP22	1	60	30	14.9	14.9	13.7	13.9
2 1/4Cr–1Mo	Plate	SA–387	22	1	60	30	14.9	14.9	13.7	13.9
2 1/4Cr–1Mo	Cast pipe	SA–426	CP22	…	70	40	16.4	14.5	14.6	12.7

The staff finds Table HGB-II-2121-2 to be acceptable as shown. Table HGB-II-2121-2 provides the design stress intensity values for ferritic steels at elevated temperatures in threaded structural fastener applications. From Tables HGB-II-3229-2 and HGB-II-3229-5, the yield and ultimate strength, respectively, from 400 degrees C to 538 degrees C (750 degrees F to 1,000 degrees F) for these materials are shown to come from Section II, Part D, Table Y-1 and Table U, respectively. Section II, Part D, is an appropriate reference for ASME Code material properties that have factors of safety built in, producing ASME Code values that are lower than those found in an applicant’s Certified Material Test Report or Certificate of Conformance. Note that the 2¼Cr-1Mo nominal composition only has design stress intensity values up to 482 degrees C (900 degrees F). Using the yield and ultimate strength, and following the criteria in Section II, Part D, Mandatory Appendix 2, 2-130, the design stress intensity at temperature for bolting materials from Section II, Part D, Table 4, can be determined. The values in Table HGB-II-2121-2 (U.S. Customary Units) are shown to be approximately equal to or lower than those produced using the provisions from ASME Code, Section II, Part D, Mandatory Appendix 2, as shown in Table 3-9. Discrepancies between values following this methodology and Table HGB-II-2121-2 can be attributed to rounding errors and using values listed in ASME Code, Section II, Part D, because the actual ASME Code committee data could not be acquired.

Table 3-9 Table HGB-II-2121-2 Comparison of Design Stress Intensities to Section II, Part D Methodology

Design Stress Intensity [ksi] (Table HGB-II-2121-2 Comparison to Sec. II Part D Methodology)								750 °F		800 °F	
Nominal Composition	Product Form	Spec. No.	Type/ Grade	Class/ Condition/ Temper	Size/ Thickness [in.]	Min. Tensile Strength [ksi]	Min. Yield Strength [ksi]	Sec. II Part D Methodology	HGB-2121-2	Sec. II Part D Methodology	HGB-2121-2
1Cr– 1/2Mo–V	Bolting	SA–540	B21	5	2 < t ≤ 8	115	100	26.6	24.1	25.5	22.8
1Cr– 1/2Mo–V	Bolting	SA–540	B21	2	≤4	155	140	32.5	33.8	34.3	31.9
1Cr– 1/2Mo–V	Bolting	SA–540	B21	3	≤6	145	130	30.5	31.4	32.1	29.6
1Cr– 1/2Mo–V	Bolting	SA–540	B21	4	≤6	135	120	28.3	29.0	29.9	27.4
1Cr– 1/2Mo–V	Bolting	SA–540	B21	5	≤2	120	105	25.2	25.3	26.6	23.9
1Cr– 1/2Mo–V	Bolting	SA–193	B16	…	≤2 1/2	125	105	28.4	25.3	31.3	23.9
1Cr– 1/2Mo–V	Bolting	SA–193	B16	…	2 1/2 < t ≤ 4	110	95	23.1	22.9	24.4	21.7
1Cr– 1/2Mo–V	Bolting	SA–193	B16	…	4 < t ≤ 7	100	85	21.0	20.5	22.2	19.4
2 1/4Cr–1Mo	Forgings	SA–336	F22	1	…	60	30	17.9	17.9	17.7	17.9

Design Stress Intensity [ksi] (Table HGB-II-2121-2 Comparison to Sec. II Part D Methodology)								850 °F		900 °F	
Nominal Composition	Product Form	Spec. No.	Type/ Grade	Class/ Condition/ Temper	Size/ Thickness [in.]	Min. Tensile Strength [ksi]	Min. Yield Strength [ksi]	Sec. II Part D Methodology	HGB-2121-2	Sec. II Part D Methodology	HGB-2121-2
1Cr– 1/2Mo–V	Bolting	SA–540	B21	5	2 < t ≤ 8	115	100	24.3	21.1	22.9	19.4
1Cr– 1/2Mo–V	Bolting	SA–540	B21	2	≤4	155	140	32.7	29.5	30.9	27.1
1Cr– 1/2Mo–V	Bolting	SA–540	B21	3	≤6	145	130	30.6	27.4	28.9	25.2
1Cr– 1/2Mo–V	Bolting	SA–540	B21	4	≤6	135	120	28.5	25.3	26.9	23.2
1Cr– 1/2Mo–V	Bolting	SA–540	B21	5	≤2	120	105	25.4	22.1	23.9	20.3
1Cr– 1/2Mo–V	Bolting	SA–193	B16	…	≤2 1/2	125	105	31.3	22.1	24.9	20.3
1Cr– 1/2Mo–V	Bolting	SA–193	B16	…	2 1/2 < t ≤ 4	110	95	23.3	20.0	22.1	18.4
1Cr– 1/2Mo–V	Bolting	SA–193	B16	…	4 < t ≤ 7	100	85	21.2	17.9	20.1	16.5
2 1/4Cr–1Mo	Forgings	SA–336	F22	1	…	60	30	17.5	17.6	17.1	17.2

Design Stress Intensity [ksi] (Table HGB-II-2121-2 Comparison to Sec. II Part D Methodology)								950 °F		1000 °F	
Nominal Composition	Product Form	Spec. No.	Type/ Grade	Class/ Condition/ Temper	Size/ Thickness [in.]	Min. Tensile Strength [ksi]	Min. Yield Strength [ksi]	Sec. II Part D Methodology	HGB-2121-2	Sec. II Part D Methodology	HGB-2121-2
1Cr– 1/2Mo–V	Bolting	SA–540	B21	5	2 < t ≤ 8	115	100	21.8	17.1	20.4	14.9
1Cr– 1/2Mo–V	Bolting	SA–540	B21	2	≤4	155	140	29.3	23.9	27.5	20.8
1Cr– 1/2Mo–V	Bolting	SA–540	B21	3	≤6	145	130	27.4	22.2	25.7	19.3
1Cr– 1/2Mo–V	Bolting	SA–540	B21	4	≤6	135	120	25.6	20.5	24.0	17.8
1Cr– 1/2Mo–V	Bolting	SA–540	B21	5	≤2	120	105	22.7	18.0	21.3	15.6
1Cr– 1/2Mo–V	Bolting	SA–193	B16	…	≤2 1/2	125	105	23.7	18.0	22.2	15.6
1Cr– 1/2Mo–V	Bolting	SA–193	B16	…	2 1/2 < t ≤ 4	110	95	20.8	16.2	19.4	14.1
1Cr– 1/2Mo–V	Bolting	SA–193	B16	…	4 < t ≤ 7	100	85	18.9	14.5	17.6	12.6
2 1/4Cr–1Mo	Forgings	SA–336	F22	1	…	60	30				

The staff finds Tables HGB-II-2121-3 and HGB-II-2121-4 to be acceptable as shown. Tables HGB-II-2121-3 and HGB-II-2121-4 show the design stress intensity values for austenitic and high nickel alloys at elevated temperatures in core support structure and threaded structural fastener applications. From Tables HGB-II-3229-3 and HGB-II-3229-6, the yield and ultimate strength, respectively, from 454 degrees C to 538 degrees C (850 degrees F to 1,000 degrees F) for these materials are shown to come from ASME Code, Section II, Part D, Table Y-1 and Table U, respectively. ASME Code, Section II, Part D, is an appropriate reference for ASME Code material properties that have factors of safety built in, producing ASME Code values that are lower than those found in an applicant's Certified Material Test Report or Certificate of Conformance. The temperatures of 566 degrees C and 593 degrees C (1,050 degrees F and 1,100 degrees F) for 316 SS and of 566 degrees C (1,050 degrees F), 593 degrees C (1,100 degrees F), 621 degrees C (1,150 degrees F), and 649 degrees C (1,200 degrees F) for Alloy 800H use the yield and tensile strength values found in Tables HGB-II-3229-3 and HGB-II-3229-6, respectively, and are not found in Section II, Part D. Using the yield and ultimate strength, and following the criteria in ASME Code, Section II, Part D, Mandatory Appendix 2, 2-110, the design stress intensity at temperature for materials of construction from Tables 2A and 2B can be determined. The values in Tables HGB-II-2121-3 (U.S. Customary Units) and HGB-II-2121-4 (U.S. Customary Units) are shown to be similar to those produced using the provisions from ASME Code, Section II, Part D, as shown in Table 3-10. Discrepancies between values following this methodology and Tables HGB-II-2121-3 and HGB-II-2121-4 can be attributed to rounding errors and using values listed in ASME Code, Section II, Part D, because the actual ASME Code committee data could not be acquired.

Note:
The material 304 SS only has design stress intensity values up to 537.8 degrees C (1,000 degrees F). The values in Table HGB-II-2121-4 follow this methodology because the materials of construction are not materials found in ASME Code, Section II, Part D, Table 4.

The comparison table of the ASME Code, Section II, Part D, methodology to Tables HGB-II-2121-3 and HGB-II-2121-4 has been truncated and does not include every line because the allowable stress intensities are the same within any given material composition with the same yield and tensile strength.

Table 3-10 Comparison of Tables HGB-II-2121-3 and HGB-II-2121-4 Design Stress Intensities to Section II, Part D, Methodology

Design Stress Intensity[ksi]										
Nominal Composition	Min. Tensile Strength [ksi]	Min. Yield Strength [ksi]	850 °F		900 °F		950 °F		1000 °F	
			Sec. II Part D Methodology	HGB-2121-3 and HGB-2121-4	Sec. II Part D Methodology	HGB-2121-3 and HGB-2121-4	Sec. II Part D Methodology	HGB-2121-3 and HGB-2121-4	Sec. II Part D Methodology	HGB-2121-3 and HGB-2121-4
18Cr–8Ni	75	30	14.9	14.8	14.6	14.6	14.3	14.3	14.0	14.0
18Cr–8Ni	70	30	14.9	14.8	14.6	14.6	14.3	14.3	14.0	14.0
16Cr–12Ni–2Mo	75	30	15.8	15.7	15.6	15.6	15.4	15.5	15.3	15.4
16Cr–12Ni–2Mo	70	30	15.8	15.7	15.6	15.6	15.4	15.5	15.3	15.4
33Ni–42Fe–21Cr	65	25	14.8	15.1	14.5	14.8	14.2	14.6	14.0	14.4

Design Stress Intensity [ksi]										
Nominal Composition	Min. Tensile Strength [ksi]	Min. Yield Strength [ksi]	1050 °F		1100 °F		1150 °F		1200 °F	
			Sec. II Part D Methodology	HGB-2121-3 and HGB-2121-4	Sec. II Part D Methodology	HGB-2121-3 and HGB-2121-4	Sec. II Part D Methodology	HGB-2121-3 and HGB-2121-4	Sec. II Part D Methodology	HGB-2121-3 and HGB-2121-4
18Cr–8Ni	75	30								
18Cr–8Ni	70	30								
16Cr–12Ni–2Mo	75	30	15.0	15.1	14.9	14.8				
16Cr–12Ni–2Mo	70	30	15.0	15.1	14.9	14.8				
33Ni–42Fe–21Cr	65	25	14.2	14.3	14.0	14.1	14.0	13.9	13.8	13.8

HGB-II-2400

HGB-II-2430

HGB-II-2433

HGB-II-2433.2 Acceptance Standards

The staff finds subparagraph HGB-II-2433.2 to be acceptable because it is technically equivalent to paragraph HBB-2433. Section 3.6.2 of this NUREG states the reasons why HBB-2433 is acceptable and HGB-II-2433.2 is acceptable for the same reasons.

3.21.3 Article HGB-II-3000 Design

HGB-II-3100

The staff finds paragraph HGB-II-3100 to be acceptable because it calls for the applicant to use the rules of ASME Code III-1-NG, NG-3000, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a, except as modified by Article HGB-II-3000. The exceptions are evaluated below for elevated temperature.

HGB-II-3110

HGB-II-3112

HGB-II-3112.4 Design Stress Intensity Values

The staff finds subparagraph HGB-II-3112.4 to be acceptable because it is technically equivalent, except for the higher metal temperatures, to subparagraph NG-3112.4, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a, without conditions. The higher temperatures use the values of Tables HGB-II-2121-1 through HGB-2121-4. Section 3.21.2 of this NUREG (immediately above) states the reasons why Tables HGB-II-2121-1 through HGB-2121-4 are acceptable and HGB-II-3112.4 is acceptable for the same reasons.

HGB-II-3130

HGB-II-3132 Reinforcement for Openings

The staff finds paragraph HGB-II-3132 to be acceptable because the first sentence is technically equivalent to paragraph NG-3132, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a, without conditions. The remaining text indicates that area replacement rules for Class A components may only be used for internal pressure loadings and that other loadings should be accounted for by additional engineering analysis.

HGB-II-3133 External Pressure Difference

The staff finds paragraph HGB-II-3133 to be acceptable because it calls for the applicant to follow the rules of paragraph NG-3133, which the NRC approved for ASME Code III-1 use in 10 CFR 50.55a, or to follow HGB-II-3133.7 (evaluated immediately below) when the rules of NG-3133 are not applicable due to the nature of the load or geometry.

HGB-II-3133.7 Alternate Rules for Buckling Loadings Due to External Pressure

The staff finds subparagraph HGB-II-3133.7 to be acceptable because it calls for the applicant to use the design factors of Appendix HGB-III to demonstrate compliance with paragraph NG-3133. Appendix HGB-III is acceptable for the reasons set forth in Section 3.22 of this NUREG, and HGB-II-3133.7 is acceptable for the same reasons.

HGB-II-3200

The staff compared each provision of HGB-II-3200 identified below to the corresponding provision of NG-3200. The staff has determined that each provision of HGB-II-3200 that is technically equivalent to the corresponding provision in NG-3200 is acceptable because the NRC has approved the provisions of NG-3200 through incorporation by reference into 10 CFR 50.55a. For the same reason, the staff has determined that each provision of HGB-II-3200 that provides for an applicant or licensee to follow the corresponding provision in NG-3200 is acceptable. Below, the staff notes the technical equivalence between the provisions of HGB-II and NG-3200 and does not repeat this rationale for each provision of HGB-II-3200. Below, the staff also evaluates the provisions of HGB-II-3200 that are new compared to NG-3200 or differ from NG-3200 (the discussions below may or may not include a statement to this effect).

HGB-II-3210

HGB-II-3211 Requirements for Acceptability

The staff finds paragraph HGB-II-3211 to be acceptable because it is technically equivalent, except for additional information in HGB-II-3211(a), to paragraph NG-3211, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a, without conditions.

The staff finds subparagraph HGB-II-3211(a) to be acceptable because the first sentence is technically equivalent to subparagraph NG-3211(a). The additional information in HGB-II-3211(a) is acceptable because it calls for the applicant to use the S_m values from Tables HGB-II-2121-1 through HGB-II-2121-4 (which the staff approved as documented above) and states that the requirements of ASME Code III-1-NG, NG-2190, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a with conditions, apply to austenitic materials that are solution annealed during fabrication and that experience elevated temperatures.

The staff finds subparagraph HGB-II-3211(b) to be acceptable because it is technically equivalent to subparagraph NG-3211(b).

The staff finds subparagraph HGB-II-3211(c) to be acceptable because it is technically equivalent to subparagraph NG-3211(c).

The staff finds subparagraph HGB-II-3211(d) to be acceptable because it is technically equivalent to subparagraph NG-3211(d).

HGB-II-3220

The staff finds paragraph HGB-II-3220 to be acceptable. This paragraph calls for the applicant to follow the rules of ASME Code III-1-NG, NG-3220, which the NRC approved through incorporation by reference into 10 CFR 50.55a without conditions, with a modification to

Note (7) of Table NG-3221-1 that adds text calling for the applicant to refer to Tables HGB-II-3222.4-1 through HGB-II-3222.4-4 in this Appendix for elevated temperature applications, which are evaluated immediately below.

HGB-II-3222

HGB-II-3222.4 Analysis for Cyclic Operation

The staff finds subparagraph HGB-II-3222.4 to be acceptable as written because it is technically equivalent, with slight modifications, to subparagraph NG-3222.4, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. The modifications allow the applicant to extend III-A Mandatory Appendix I with Tables HGB-II-3222.4-1 through HGB-II-3222.4-4 for elevated temperature use.

The staff finds Tables HGB-II-3222.4-1 through HGB-II-3222.4-4 for elevated temperature use to be acceptable as written. These four tables are technically equivalent to Figures HBB-T-1420-1A through HBB-T-1420-1D, except that the HGB-II tables present cycles versus stress and the HBB-T figures present cycles versus strain. The staff reviewed the conversion from stress to strain and confirmed the acceptability of the approach. Section 3.9 of this NUREG states the reasons why Figures HBB-T-1420-1A through HBB-T-1420-1D are acceptable and Tables HGB-II-3222.4-1 through HGB-II-322.4-4 are acceptable for the same reasons.

The staff finds HGB-II-3222.4(a) and (b) to be acceptable as written because they are technically equivalent to NG-3222.4(a) and (b), which the NRC has approved through incorporation by reference into 10 CFR 50.55a without conditions.

The staff finds HGB-II-3222.4(c) to be acceptable as written because it is technically equivalent, except for the last two sentences, to NG-3222.4(c) , which the NRC has approved through incorporation by reference into 10 CFR 50.55a without conditions. The last two sentences of HGB II 3222.4(c) are considered acceptable because they allow the applicant to extend III-A Mandatory Appendix I with Tables HGB-II-3222.4-1 through HGB-II-3222.4-4 for elevated temperature use, as described immediately above.

The staff finds HGB-II-3222.4(d) to be acceptable as written because it is technically equivalent to NG-3222.4(d), which the NRC has approved through incorporation by reference into 10 CFR 50.55a without conditions, but with modifications for elevated temperature use, as described immediately above.

HGB-II-3222.4(d)(1) is technically equivalent to NG-3222.4(d)(1), which the NRC has approved through incorporation by reference into 10 CFR 50.55a without conditions.

HGB-II-3222.4(d)(2) is technically equivalent to NG-3222.4(d)(2), which the NRC has approved through incorporation by reference into 10 CFR 50.55a without conditions, but with additional information allowing the applicant to extend III-A Mandatory Appendix I with Tables HGB-II-3222.4-1 through HGB-II-3222.4-4 for elevated temperature use as described above.

HGB-II-3222.4(d)(2)(-a) and (-b) are technically equivalent to NG-3222.4(d)(2)(-a) and (-b).

HGB-II-3222.4(d)(3) is technically equivalent to NG-3222.4(d)(3).

HGB-II-3222.4(d)(3)(-a) is technically equivalent to NG-3222.4(d)(3)(-a).

HGB-II-3222.4(d)(3)(-b) is technically equivalent to NG-3222.4(d)(3)(-b).

HGB-II-3222.4(d)(4) is technically equivalent to NG-3222.4(d)(4), with additional information allowing the applicant to extend III-A Mandatory Appendix I with Tables HGB-II-3222.4-1 through HGB-II-3222.4-4 for elevated temperature use.

HGB-II-3222.4(d)(4)(-a) is technically equivalent to NG-3222.4(d)(4)(-a).

HGB-II-3222.4(d)(4)(-b) is technically equivalent to NG-3222.4(d)(4)(-b).

The staff finds HGB-II-3222.4(e) to be acceptable as written because it is technically equivalent to NG-3222.4(e), with modifications for elevated temperature use.

HGB-II-3222.4(e)(1) is technically equivalent to NG-3222.4(e)(1).

HGB-II-3222.4(e)(2) is technically equivalent to NG-3222.4(e)(2).

HGB-II-3222.4(e)(3) is technically equivalent to NG-3222.4(e)(3), with additional information allowing the applicant to extend III-A Mandatory Appendix I with Tables HGB-II-3222.4-1 through HGB-II-3222.4-4 for elevated temperature use.

HGB-II-3222.4(e)(4) is technically equivalent to NG-3222.4(e)(4), with additional information allowing the applicant to extend III-A Mandatory Appendix I with Tables HGB-II-3222.4-1 through HGB-II-3222.4-4 for elevated temperature use.

HGB-II-3222.4(e)(5) is technically equivalent to NG-3222.4(e)(5).

HGB-II-3224

The staff finds paragraph HGB-II-3224 to be acceptable as written. This paragraph directs the applicant to follow the rules of ASME Code III-1-NG, NG-3224.1, which the NRC has approved through incorporation by reference in 10 CFR 50.55a without conditions, with a modification to Note (8) of Table NG-3224-1 that adds text directing the applicant to refer to Tables HGB-II-3229-4 through HGB-II-3229-6 in this Appendix for elevated temperature applications and is discussed below.

HGB-II-3224.1 Stress Intensity Limits

The staff finds subparagraph HGB-II-3224.1 and its subsubparagraphs to be acceptable as written because they are technically equivalent, with slight modifications, to subparagraph NG-3224.1 and its subsubparagraphs, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions. The modifications specify the conditions, when all present, that may produce invalid and unconservative results when the Stress Ratio Analysis method is used. The modifications are acceptable because they specify the limits of use for the Stress Ratio Analysis method.

The staff finds HGB-II-3224.1(a) to be acceptable as written because it is technically equivalent to NG-3224.1(a). Note that HGB-II-3224.1(a)(2) erroneously states NG-3221.3 when it should be NG-3221.2.

The staff finds HGB-II-3224.1(b) to be acceptable as written because it is technically equivalent to NG-3224.1(b).

The staff finds HGB-II-3224.1(c) to be acceptable as written because it is technically equivalent to NG-3224.1(c).

The staff finds HGB-II-3224.1(d) to be acceptable as written because it is technically equivalent to NG-3224.1(d), with additional information. Note that HGB-II-3224.1(d) erroneously states NG-3213.23 when it should be NG-3213.22. The additional information specify conditions, when all present, that may produce invalid and unconservative results when the Stress Ratio Analysis method is used. These conditions are (-a) a low yield-strength-to-ultimate-tensile-strength ratio, (-b) a high uniform elongation value, and (-c) a cross section that can distort under load in a manner that reduces the moment of inertia or that increases the loading on the structure. The additional information is acceptable because it specifies the limits of use for the Stress Ratio Analysis method.

The staff finds HGB-II-3224.1(e) to be acceptable as written because it is technically equivalent to NG-3224.1(e).

HGB-II-3228

HGB-II-3228.3 Simplified Elastic-Plastic Analysis

The staff finds subparagraph HGB-II-3228.3 to be acceptable as written because it is technically equivalent to subparagraph NG-3228.3, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, except for the permitted materials table and NG 3228.3(e). The permitted materials and the exclusion of NG-3228.3(e) are acceptable because the materials listed are specific materials for ASME Code III-5-HGB use instead of general materials and because NG-3228.3(e) states the ASME Code III-1 temperature limits are not to be exceeded.

HGB-II-3229 Design Stress Values

The staff finds paragraph HGB-II-3229 to be acceptable for the reasons set forth below. The first paragraph of HGB-II-3229 is technically equivalent to paragraph NG-3229, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions, with additional information allowing the applicant to extend ASME Code III-A Mandatory Appendix I with Tables HGB-II-3222.4-1 through HGB-II-3222.4-4 for elevated temperature use. The second paragraph of HGB-II-3229 identifies the correct Division 5 provisions for the design stress intensity values for HGB-II use and is therefore acceptable. The staff's review of the design stress intensity values is in Section 3.21.2.

For ferritic steels at elevated temperatures in core support applications, Tables HGB-II-3229-1 and HGB-II-3229-4 contain the yield and ultimate strength, respectively. These values are shown to come from II-D, Table Y-1 and Table U, respectively. II-D is an appropriate reference for ASME Code material properties that have factors of safety built in, producing ASME Code values that are lower than what is found in an applicant's Certified Material Test Report or Certificate of Conformance.

For ferritic steels at elevated temperatures in threaded structural fastener applications, the yield and ultimate strength values are contained in Tables HGB-II-3229-2 and HGB-II-3229-5. These values are shown to come from Section II, Part D, Table Y-1 and Table U, respectively. Section II, Part D, is an appropriate reference for ASME Code material properties that have factors of safety built in, producing ASME Code values that are lower than those found in an applicant's Certified Material Test Report or Certificate of Conformance.

For austenitic and high-nickel alloys, Tables HGB-II-3229-3 and HGB-II-3229-6 contain the yield and ultimate strength, respectively. These values are shown to come from ASME Code, Section II, Part D, Table Y1 and Table U, respectively. ASME Code, Section II, Part D, is an appropriate reference for ASME Code material properties that have factors of safety built in, producing ASME Code values that are lower than those found in an applicant's Certified Material Test Report or Certificate of Conformance. The temperatures of 566 degrees C and 593 degrees C (1,050 degrees F and 1,100 degrees F) for 316 SS and of 593 degrees C (1,050 degrees F), 593 degrees C (1,100 degrees F), 621 degrees C (1,150 degrees F), and 649 degrees C (1,200 degrees F) for Alloy 800H use the yield and tensile strength values found in Tables HGB-II-3229-3 and HGB-II-3229-6, respectively, and are not found in Section II, Part D.

Table HGB-II-3229-3, with regard to yield strength values versus temperature for austenitic and high nickel alloy, is technically equivalent to Table HBB-I-14.5, with minor truncation errors within 2 percent. The staff has determined that the S_y values in Table HBB-I-14.5 are acceptable for the reasons stated in Section 3.7.5 of this NUREG, and it is conservative to use the same S_y values for Class A materials for core supports because the material properties are the same. Therefore, the staff finds the values in Table HGB-II-3229-3 to be acceptable.

Table HGB-II-3229-6, with regard to tensile strength values versus temperature for austenitic and high nickel alloy, is technically equivalent to Table HBB-3225-1, with minor differences within 4 percent. The staff found the S_u values in Table HBB-3225-1 acceptable for the reasons stated in Section 3.7.6 of this NUREG, and it is conservative to use the S_u values for Class A materials for core supports because the material properties are the same.

The staff finds Tables HGB-II-3229-1 through HGB-II-3229-6 for elevated temperature use to be acceptable because the tensile and yield strength values in these tables are either essentially the same as those in the ASME Code, Section II-D or are the same as the values for Class A materials, as described above.

HGB-II-3230

HGB-II-3231 Design Conditions

The staff finds paragraph HGB-II-3231 and its subparagraphs to be acceptable as written because they are technically equivalent to paragraph NG-3231 and its subparagraphs, which the NRC has approved through incorporation by reference in 10 CFR 50.55a without conditions, with additional information for elevated temperature use. For the reasons set forth below, the additional information is acceptable.

The staff finds subparagraph HGB-II-3231(a) to be acceptable because it is technically equivalent to NG-3231(a), with additional information on extending the values to elevated temperature use with the tables in this Appendix, which are evaluated above.

The staff finds subparagraph HGB-II-3231(b) to be acceptable as written because it is technically equivalent to NG-3231(b).

The staff finds subparagraph HGB-II-3231(c) to be acceptable as written because it adds a note that calls for the N Certificate Holder to account for plastic strain associated with S_m limits for materials where Note 4 of Table HGB-II-2121-4 applies in evaluating the adequacy of threaded structural fasteners. This is an acceptable, additional provision not found in NG-3231.

3.21.4 Article HGB-II-4000 Fabrication and Installation Requirements

HGB-II-4100

The staff finds paragraph HGB-II-4100 to be acceptable as written because it calls for the applicant to use the rules of ASME Code III-1-NG, NG-4000, which the NRC approved for III-1 use through incorporation by reference in 10 CFR 50.55a without conditions, except as modified by Article HGB-II-4000, as discussed below.

HGB-II-4200

HGB-II-4230

HGB-II-4233 Alignment Requirements When Component Inside Surface Is Inaccessible

The staff finds paragraph HGB-II-4233 to be acceptable as written because it is technically equivalent to paragraph HGB-4233, and HGB-4233 is technically equivalent to NB-4233(a) and NB-4233(b), which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a, without conditions. It is an acceptable approach to use the Class 1 pressure-retaining components construction code for Class A core support structures since these provisions are not temperature dependent. Reference changes have been made in HGB-4233 when compared to NB-4233 for use with ASME Code III-5-HGB. HGB-4233(a) references "NG-4232," while NB-4233(a) references "NB-4232"; and HGB-4233(b) references "NG-4232," while NB-4233(a) references "NB-4232," all of which are the correct references for the identified provisions.

3.21.5 Article HGB-II-5000 Examination Requirements

The staff finds Article HGB-II-5000 to be acceptable as written because it calls for the applicant to use the rules of ASME Code III-1-NG, which the NRC has previously approved through incorporation by reference in 10 CFR 50.55a without conditions.

3.22 Mandatory Appendix HGB-III Buckling and Instability

3.22.1 Article HGB-III-1000 General Requirements

HGB-III-1000(a) states that the rules of this Appendix provide additional limits that are applicable to all specified Design and Service Loadings.

HGB-III-1000(b) states that Article HGB-III-2000 distinguishes between load-controlled buckling and strain-controlled buckling. Additionally, it defines the two types of buckling and indicates that avoiding strain-controlled buckling guards against failure from fatigue, excessive strain, and interaction with load-controlled instability. In some cases, relatively high (normally localized) strain is allowed under conditions that naturally limit total strain. Minor (localized) buckling or yielding is limited by the nature of the load and the design of the structure and so poses little risk. Therefore, the HGB-II-1000(b) provision for avoiding strain-controlled buckling is conservative and acceptable.

HGB-III-1000(c) states that when strain-controlled and load-controlled buckling interact, the Load Factors for load-controlled buckling are to be used for the combination of the two loads. This is conservative because the Load Factors for load-controlled buckling are larger and will guard against buckling in the interactive mode.

HGB-III-1000(d) states that the Load Factors applicable to load-controlled buckling shall be used for strain-controlled buckling when significant elastic followup may occur. Large strain concentrations due to elastic followup may occur when a small portion of the structure undergoes inelastic strains, while most of the structural system behaves in an elastic manner. This results when structural parts of different flexibility are in series and flexible portions are highly stressed. Therefore, it is conservative to use the Load Factors for load-controlled buckling to guard against buckling when significant elastic followup may occur.

HGB-III-1000(e) states that for load-controlled buckling, the effects of initial geometrical imperfections and tolerances shall be considered in the calculation of the instability load.

HGB-III-1000(f) states that for purely strain-controlled buckling, the effects of initial geometrical imperfections and tolerances need not be considered in the calculation of the instability strain. Comparison of inelastic buckling theory results to test data demonstrates that this provision is acceptable.

HGB-III-1000(g) states that the expected minimum stress-strain curve for the material at temperature shall be used.

HGB-III-1000(h) states that the limits of HGB-III-2000 or HGB-III-3000 shall be satisfied for the specified Design and Service Loadings.

The staff finds the general requirements of Article HGB-III-1000 to be acceptable because they impose additional limits to account for buckling or instability due to time-independent behavior, which is applicable to all specified Design and Service Loadings.

3.22.2 Article HGB-III-2000 Buckling Limits: Time-Independent Buckling

The staff finds Article HGB-III-2000 to be acceptable because the Load Factor for load-controlled buckling and the Strain Factor for strain-controlled buckling must be equal to or exceed the values in Table HGB-III-2000-1 for the specified Design and Service Loading to guard against time-independent buckling. This is conservative because the Load/Strain Factors add factors of safety to the design of the core support structure.

Table HGB-III-2000-1 is technically equivalent to Table HBB-T-1521-1 with additional Note (4). Note (4) states that the strain represents the average membrane strain through the thickness for clarification. The staff has determined that Table HBB-T-1521-1 is acceptable for Class A components for the reasons stated in Section 3.9.5 of this NUREG, with a condition. Class A and Core support structure use the same load factors and strain factors except that load factors for Level C and Level D of core support structure are slightly lower but still provide enough margin against buckling failure. Therefore, the staff finds Table HGB-III-2000-1 to be acceptable for the same reasons Table HBB-T-1521-1 is acceptable, with the following limitation:

- When an applicant or licensee uses the strain factors in Table HGB-III-2000-1 for time-independent buckling, the applicant or licensee should justify in the design report that (1) the buckling is purely strain-controlled and not combined with load-controlled buckling and (2) that significant elastic follow-up is not occurring.

3.22.3 Article HGB-III-3000 Alternative Procedures

The staff finds Article HGB-III-3000 to be acceptable as written because this provides an alternate procedure in lieu of HGB-III-2000. HGB-III-3000 states that an evaluation of stresses, strains, and deformations resulting from buckling may be used to demonstrate that the component has remained structurally and functionally integral with the specified loads multiplied by the applicable Load Factor. This Article also indicates that nonlinear, plastic, and initial imperfection effects shall be included. HGB-III-3000 is an alternative to the HGB-III-2000 method which demonstrates that the calculated load factor is not less than the load factor listed in HGB-III-2000. Further, the HGB-III-3000 method uses the load factor to amplify the design load to demonstrate that the component has remained structurally and functionally integral. Accordingly, HGB-III-3000 is acceptable.

3.23 Mandatory Appendix HGB-IV Time–Temperature Limits

3.23.1 Article HGB-IV-1000 Time–Temperature Limits

The staff finds Article HGB-IV-1000 to be acceptable as written as follows. The approach given in this Article is acceptable for a use-fraction and is a similar approach to that in HGB-3000. HGB-IV-1000 gives the applicant the ability to determine the maximum allowable time at temperature and states that this method cannot be used if the specified design lifetime exceeds 300,000 hours.

ASME Code Committee developed Figure HGB-IV-1000-1, “time at elevated temperature vs. metal temperature,” based on the allowable stress information and duration provided in Mandatory Appendix HBB-I-14. Figure HGB-IV-1000-1 correctly reflects the information in HBB-I-14. The NRC staff determined that Mandatory Appendix HBB-I-14 is acceptable for the reasons documented in Section 3.7 of this NUREG.

3.24 Subsection HH Class A Nonmetallic Core Support Structures, Subpart A Graphite Materials (HHA)

3.24.1 Article HHA-1000 Introduction

HHA-1100 Scope

HHA-1110 Aspects Covered

HHA-1110 provides a general description of the rules in the Subpart, which are applicable to GCCs and GCAs used within the reactor pressure vessels of high-temperature, graphite-moderated, fission reactors. The staff finds HHA-1110 to be acceptable because the scope of the Subpart is clearly defined and the staff believes that the general rule aspects give appropriate consideration to the integrity and functionality of the individual GCC and of the GCA.

HHA-1120 Environmental Effects and Limits

HHA-1120 identifies the typical environmental conditions that could affect GCCs, or the GCA, over the life of the plant and provides that appropriate design data be available for the graphite(s) used. This includes additional consideration of coolant interaction with graphite for reactor systems where the coolant used is not a gas.

The staff finds HHA-1120 to be acceptable because the staff believes that the general rule aspects give appropriate consideration to environmental conditions, such as irradiation and oxidation, that are known to affect GCCs. The staff also believes that it is appropriate to provide that coolant interaction with graphite be considered when applicable. Doing so facilitates the application of the rules in Subsection HH, Subpart A, to both gas-cooled and liquid-cooled reactor designs.

HHA-1200 Requirements

HHA-1210 General

The staff finds HHA-1210 to be acceptable because this subsubarticle provides no administrative or technical requirements other than those identified by reference to Subsection HA, Subpart B. Section 3.2 of this NUREG states the reasons why the staff approved Subsection HA, Subpart B and the staff approves HHA-1200 for the same reasons.

HHA-1220 Materials

HHA-1220 references the provisions for the selection and qualification of graphite materials in Article HHA-2000 and briefly describes the specific aspects covered therein. The staff finds HHA-1220 to be acceptable because the subsubarticle includes no administrative or technical requirements other than those identified by reference to HHA-2000, which the staff has reviewed and determined to be acceptable for the reasons stated in Section 3.24.2 of this report. For the same reasons, the staff has determined that HHA-1220 is acceptable.

HHA-1230 Design

HHA-1230 invokes the provisions for the design of GCCs and GCAs in Article HHA-3000. These provisions account for the effects of fast neutron irradiation, irradiation temperature, and oxidation on the appropriate mechanical and thermal properties dimensional changes and design and service loadings. HHA-1230 indicates that billet-to-billet variability material properties should be taken into account. HHA-1230 allows the use of probabilistic and deterministic design methodologies.

The staff finds HHA-1230 to be acceptable because the provisions identified and referenced in the subsubarticle are sufficient to provide a minimum acceptable standard for the design of GCCs and GCAs. The staff notes that HHA-1230 is general in nature and refers to HHA-3000 for specific design provisions. Section 3.24.3 of this report includes the staff's review of HHA-3000.

HHA-1240 Graphite Core Component Machining

HHA-1240 provides general provisions for machining GCCs, as given in Article HHA-4000, including provisions for machining, examination, testing, acceptance criteria for parts (i.e., graphite core components), and the qualification of personnel.

The staff finds HHA-1240 to be acceptable because the subsubarticle provides no administrative or technical requirements other than those identified by reference to HHA-4000, which the staff has reviewed and determined to be acceptable for the reasons stated in Section 3.24.4 of this NUREG. For the same reasons, the staff has determined that HHA-1240 is acceptable.

HHA-1250 Installation

HHA-1250 describes provisions for the installation of GCC and GCA, as given in Article HHA-5000. These include, but are not limited to, provisions for GCC storage, unpacking, examination, construction procedures, and reporting.

The staff finds HHA-1250 to be acceptable because the subsubarticle provides no administrative or technical provisions other than those identified by reference to HHA-5000, which the staff has reviewed and determined to be acceptable. This subsubarticle is general and refers to HHA-5000 for specific installation provisions. Section 3.24.5 of this NUREG state the reasons why the staff approved HHA-5000. For the same reasons, the staff approves HHA-1250.

HHA-1260 Responsibilities

HHA-1260 invokes Article HAB-3000 for the definition of responsibilities.

The staff finds HHA-1260 to be acceptable because this subsubarticle provides no administrative or technical provisions other than those identified by reference to Article HAB-3000, which provides specific rules for the responsibilities of Designers, the Graphite Manufacturing Organization, and the Graphite Component Installer, for example. Section 3.2.3 of this NUREG states the reasons why the staff approved HAB-3000. For the same reasons, the staff approves HHA-1260.

HHA-1300 Application of These Rules

HHA-1300 describes the scope of GCCs for which the rules in Subsection HH, Subpart A, are applicable. GCCs include fuel blocks, reflector blocks, shielding blocks, and any keys or dowels used to interconnect them. The rules also apply to the arrangement of GCCs that form the GCA. HHA-1300 specifically states that these rules do not extend to other components, such as fuel compacts and bushings.

The staff finds HHA-1300 to be acceptable because the scope of components for which the rules apply is clearly defined and does not exclude any components that the staff believes should be constructed in accordance with the rules of Subsection HH, Subpart A.

HHA-1400 Boundaries of Jurisdiction

The opening text in HHA-1400 refers to Figure HHA-1400-1, “Jurisdictional Boundary for Graphite Core Components and Assemblies—Circumferential Section View,” and Figure HHA-1400-2, “Jurisdictional Boundary for Graphite Core Components and Assemblies—Longitudinal Section View,” as aids in defining the boundaries of jurisdiction for HHA-1400.

The staff finds HHA-1400 to be acceptable because the opening text contains no administrative or technical provisions other than the reference to Figures HHA-1400-1 and HHA-1400-2, which the staff has reviewed and determined to be acceptable. The staff reviews Figures HHA-1400-1 and HHA-1400-2 below.

HHA-1410 Boundary Between Graphite Core Components and Core Support Structures

HHA-1410 defines the jurisdictional boundary between a GCC and the metallic core support structure, or the metallic/ceramic core restraints, as the surface of the GCC. Fasteners used to connect the GCC to the core support structures are part of the core support structure.

The staff finds HHA-1410 to be acceptable because the staff agreed that it is appropriate to define the jurisdictional boundary as the surface of the GCC. Defining the jurisdictional boundary in this manner ensures that each GCC will be constructed in accordance with the rules Subsection HH, Subpart A, which do not apply to metallic core support structures or metallic/ceramic core restraints. Doing so is also in agreement with the rules in HHA-1300, as well as the figures referenced in HHA-1400.

HHA-1420 Boundary Between Graphite Core Components and Fuel Pebbles or Compacts

HHA-1420 defines the jurisdictional boundary between GCCs and fuel pebbles or compacts as the surfaces of the GCC. Fasteners used to secure fuel compacts to the GCCs are considered as part of the fuel compacts and therefore outside the jurisdictional boundary.

The staff finds HHA-1420 to be acceptable because the staff agrees that it is appropriate and reasonable to define the jurisdictional boundary as the surface of the GCC. Defining the jurisdictional boundary in this manner ensures that each GCC will be constructed in accordance with the rules Subsection HH, Subpart A, which do not apply to fuel pebbles or compacts. Doing so is also in agreement with the rules provided in HHA-1300, as well as the figures referenced in HHA-1400.

Figure HHA-1400-1 Jurisdictional Boundary for Graphite Core Components and Assemblies—Circumferential Section View

HHA-1400-1 is a graphical representation of the jurisdictional boundary between a GCC and GCAs and other core components. The figure provides a circumferential section view of both the prismatic type core and pebble bed core designs. Figure HHA-1400-1 is intended as an aid, and the Designer should provide particular pictorial representations that are appropriate to the specific design.

The staff finds Figure HHA-1400-1 to be acceptable because it is a useful tool for defining the boundaries of jurisdiction for Subsection HH, Subpart A. The staff notes that Figure HHA-1400-1 is provided as an aid and that HAB-3220 specifies the underlying provision for the Owner to establish the GCC and GCA boundaries for a particular design.

Figure HHA-1400-2 Jurisdictional Boundary for Graphite Core Components and Assemblies—Longitudinal Section View

HHA-1400-2 is a graphical representation of the jurisdictional boundary between a GCC and GCAs and other core components. The figure is a longitudinal section view of both the prismatic type core and pebble bed core designs.

The staff finds Figure HHA-1400-2 to be acceptable because it is a useful tool for defining the boundaries of jurisdiction for Subsection HH, Subpart A. The staff notes that Figure HHA-1400-2 is provided as an aid and that HAB-3220 specifies the underlying provisions for the Owner to establish the GCC and GCA boundaries for a particular design.

HHA-1430 Other Boundaries

HHA-1430 states that the Design Specification shall define other boundaries. The staff finds HHA-1430 to be acceptable because it is appropriate and reasonable to call for the Design Specification to define other boundaries.

3.24.2 Article HHA-2000 Materials

HHA-2100 General Requirements

HHA-2110 Material for Graphite Core Components

HHA-2111 Permitted Material Specifications

HHA-2111 calls for GCC material to conform to the material specification(s) given in Mandatory Appendix HHA-I and to all of the applicable special provisions in HHA-2000. The specifications referenced in Mandatory Appendix HHA-I provide minimum standards that the Designer may supplement.

The staff finds HHA-2111 to be acceptable because the paragraph provides a minimum acceptable standard for GCC material specifications. The staff also agrees that it is appropriate and reasonable for the rules to allow the Designer to supplement those minimum standards in Mandatory Appendix HHA-I as necessary to ensure that the GCC will be suitable for its intended use. Doing so facilitates the broader applicability of the ASME Code rules.

HHA-2112 Special Requirements Conflicting with Permitted Specifications

HHA-2112 explains that special provisions in HHA-2000 supersede those in the permitted material specifications whenever the two are in conflict. This paragraph also states that examinations, inspections, tests, or treatments called for by both the special provisions and the material specifications need only be performed once to satisfy both sets of provisions.

The staff finds HHA-2112 to be acceptable because it clearly defines the hierarchy between HHA-2000 and the permitted material specifications and it appropriately clarifies the number of times that an examination, inspection, test, or treatment would need to be conducted to satisfy both sets of provisions.

HHA-2120 Certification of Material

HHA-2120 provides that all material used for the construction or installation of GCCs or GCAs be certified in accordance with HAB-3861 and HAB-3862. The subsubarticle also provides that copies of all Certified Material Test Reports (CMTRs) applicable to material used in GCAs or GCCs be furnished with the material.

The staff finds HHA-2120 to be acceptable because it is an appropriate practice to certify materials used for the construction of nuclear plant components and to furnish applicable certification records, such as CMTRs, with the material. The staff has also reviewed HAB-3861 and HAB-3862 and found them to be acceptable. Section 3.2.3 of this NUREG evaluates and documents the staff's review of HAB-3861 and HAB-3862.

HHA-2121 Application of the Rules of This Subpart

HHA-2121 provides that the Material Manufacturer's CMTRs certify that all provisions of the material specification and of HHA-2000 have been met. The paragraph also identifies specific information to be included in CMTRs.

The staff finds HHA-2121 to be acceptable because the provisions specified are sufficient to provide a minimum acceptable standard for the content of CMTRs provided by the Material Manufacturer.

During the review, the staff commented to the ASME Working Group for Nonmetallic Design and Materials that the 2017 Edition of the ASME Code III-5, does not define the terms "charge" and "graphitization charge." The Working Group is still developing its formal response to the comment but has informed the staff that it agrees and is making plans to address it. The staff determined that HHA-2121 is acceptable despite the open comment because, until the open comment is resolved, the staff can verify the definition and use of the terms on a case-by-case basis, if needed, as part of the licensing process. As such, the staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-2122 Exclusion of Small Products

HHA-2122 specifies that no graphite components shall be excluded from certification.

The staff finds HHA-2122 to be acceptable because it ensures that all graphite components will be constructed from certified material. The staff notes that the anticipated scenario is that small products would be fabricated from parts cut out, or otherwise machined, from a larger billet of certified material. In this case, the staff believes that the CMTR of the originally certified graphite billet would be sufficient evidence of certification of the small product.

HHA-2130 Deterioration of Materials During Service

HHA-2130 indicates that materials provided to meet the plant operating conditions given in the Design Specification shall be evaluated for their adequacy considering a deterioration in service.

The staff finds HHA-2130 to be acceptable because it is appropriate and reasonable to evaluate the adequacy of the material against known environmental conditions that could degrade or modify its physical and mechanical properties during service.

HHA-2131 Design Specification

HHA-2131 states that the Design Specification shall define the provisions for materials qualification and envelope the anticipated ranges of irradiation, temperature, and oxidation.

The staff finds HHA-2131 to be acceptable because the provisions in this paragraph are sufficient to provide a minimum acceptable standard for the content of a Design Specification as it relates to graphite material qualification.

HHA-2132 Qualification of Materials

HHA-2132 specifies that the qualification of materials shall be in accordance with HHA-2200.

The staff has determined HHA-2132 to be acceptable because the paragraph includes no administrative or technical provisions other than those identified by reference to HHA-2200, which the staff has reviewed and determined to be acceptable. The staff's review of HHA-2200 is provided below.

HHA-2140 Material Identification

HHA-2141 Billet Marking

HHA-2141 calls for material identification marking on each graphite billet and specifies the necessary information.

The staff finds HHA-2141 to be acceptable because it provides an appropriate means to facilitate material identification and traceability. The staff notes that calling for the marking to include the axis of forming enables the tracing of potential variations in properties on orthogonal directions of the billet to identify evidence of anisotropy in properties.

HHA-2142 Method of Marking

HHA-2142 provides that graphite billets be marked by any method that will not result in harmful contamination, functional degradation, or sharp discontinuities.

The staff finds HHA-2142 to be acceptable because it is good practice to avoid unnecessarily introducing harmful contamination, functional degradation, or sharp discontinuities into the graphite material.

HHA-2143 Transfer of Marking When Materials Are Cut or Machined

HHA-2143 provides that billet markings be transferred to finished GCCs and billet sections using methods described in HHA-2142.

The staff finds HHA-2143 to be acceptable because this paragraph facilitates the traceability of material back to the original billet. Such bookkeeping is necessary to ensure that a link can be made between the properties of the original billet and those of the components machined from the billet. This information is also important to have when assessing the effects of deterioration factors that modify the physical and mechanical properties of the component, as provided by HHA-2130.

HHA-2200 Material Properties for Design

HHA-2200 calls for the Designer to determine the graphite properties used for design and to publish those properties in the Material Data Sheet (MDS). The subarticle also provides general standards for the content of the MDS, which includes the material properties of graphite in the as-manufactured, irradiated, and oxidized conditions.

The staff finds HHA-2200 to be acceptable because the rules in the subarticle are sufficient to provide a minimum acceptable standard for the material properties to be included in the MDS. Because HHA-2200 provides that all graphite properties used for design be published in the MDS, it is appropriate and reasonable to allow the Designer to provide additional property data as needed. Doing so facilitates the application of the ASME Code rules to unforeseen design scenarios. Finally, the staff notes that HHA-2200 is general in nature and refers to various subsubarticles and Appendices for more specific provisions, all of which the staff has reviewed and determined to be acceptable. The applicable sections of this NUREG include the staff's review of the referenced subsubarticles and Appendices.

HHA-2210 As-Manufactured Material Properties

HHA-2210 provides that the MDS include the properties defined in Mandatory Appendix HHA-II. The subsubarticle also provides that the temperature range for the property measurements envelope the temperature range as defined in HHA-2131(b).

The staff finds HHA-2210 to be acceptable because the provisions of the subsubarticle are provided by reference to other portions of ASME Section III, Division 5, that the staff finds to be acceptable. Specifically, HHA-2210 refers to Mandatory Appendix HHA-II for material properties, and to the Design Specification, in accordance with HHA-2131(b), for the temperature range necessary for measuring the properties. The staff reviews HHA-2131 and Mandatory Appendix HHA-II above and in Section 3.26, respectively.

HHA-2220 Irradiated Material Properties

HHA-2220 calls for the MDS to include properties specified in Mandatory Appendix HHA-II and lists properties for which fast neutron irradiation effects should be determined. The damage dose and temperature range for the measurements of the material properties should be appropriately enveloped.

The staff finds HHA-2220 to be acceptable because the staff agrees that the scope of irradiated material properties is appropriate and because the other provisions in the subsubarticle are provided by reference to other sections of the ASME Code that the staff finds to be acceptable. The staff notes that HHA-2220 refers to Mandatory Appendix HHA-II for irradiated material properties and to the Design Specification, in accordance with HHA-2131(a), for the dose and temperature ranges necessary for measuring the properties. The staff reviews HHA-2131 and Mandatory Appendix HHA-II above and in Section 3.26, respectively.

During the review, the staff commented to the ASME Working Group for Nonmetallic Design and Materials that although HHA-2220(a)(2) identifies the creep coefficient as a singular term, there is typically more than one creep coefficient (e.g., primary, secondary, tertiary). Also, the staff commented that since very few data are available, consideration should be given to the effect of creep strain on the coefficient of thermal expansion and maybe the modulus. The Working Group is still developing its formal response but has informed the staff that it agrees with the comments and is making plans to address them. The staff determined that HHA-2220 is acceptable despite the open comments because the staff believes that the ASME Code appropriately addresses unforeseen design scenarios, such as the need to define multiple creep coefficients or the need to account for creep strain on the coefficient of thermal expansion or modulus. Specifically, HHA-2200 gives the Designer the flexibility to provide additional property data as needed while also providing that all graphite properties used for design be published in the MDS. In addition, the staff can obtain all of the design-specific information, including any justification of irradiated material properties used, on a case-by-case basis, if needed, as part of the licensing process. On this basis, these items do not bar endorsement of HHA-2220, and the staff considers these comments as items for future work with ASME and will continue to track their resolution through participation in the applicable ASME Code committees.

HHA-2230 Oxidized Material Properties

HHA-2230 calls for the MDS to include the properties defined in Mandatory Appendix HHA-II and lists properties for which the effects of oxidation should be determined.

The staff finds HHA-2230 to be acceptable because the staff agrees that the scope of oxidized material properties is appropriate and because the other provisions in the subsubarticle are provided by reference to other sections of the ASME Code that the staff finds acceptable. The staff notes that HHA-2230 refers to Mandatory Appendix HHA-II for oxidized material properties and to the Design Specification, in accordance with HHA-2131(c), for the oxidative environment and weight loss range necessary for measuring the properties. The staff reviews HHA-2131 and Mandatory Appendix HHA-II above and in Section 3.26, respectively.

During the review, the staff commented to the ASME Working Group for Graphite Core Components on rules to address the effect of oxidation on compressive strength for as-manufactured or irradiated graphite, which may be important to consider in graphite core supports. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. Although HHA-2230 does not mention compressive strength, HHA-2230 was determined to be acceptable despite this open comment because the staff believes that the ASME Code appropriately addresses the scenario where the oxidation effect on compressive strength would be significant enough to consider in the design of a GCC. Specifically, HHA-2200 gives the Designer the flexibility to provide additional property data as needed, while also providing that all graphite properties used for design be published in the MDS. In addition, the staff can obtain all the design-specific information, including any justification of oxidized material properties used, if needed, from the applicant as part of the licensing process. On this basis, these items do not bar endorsement of

HHA-2230, and the staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-2300 Sampling

HHA-2310 General Requirements

HHA-2310 provides that the Material Manufacturer sample the graphite according to the material specifications.

The staff finds HHA-2310 to be acceptable because the staff believes that it is appropriate and reasonable to conduct sampling in accordance with the material specification. HHA-2111, which references Mandatory Appendix HHA-I, includes rules for permitted material specifications. In addition, both ASTM standards referenced in Mandatory Appendix HHA-I provide for developing a statistical sampling plan.

HHA-2400 Material Manufacturer's Quality System Program

HHA-2400 provides that the Material Manufacturer's Quality System Program be in accordance with HAB-3800.

The staff finds HHA-2400 to be acceptable because the paragraph provides no specific provisions other than those identified by reference to HAB-3800, which the staff reviewed and finds to be acceptable. Section 3.2.3 of this NUREG includes the staff's review of HAB-3800.

HHA-2500 Examination and Repair of Graphite Core Component Material

HHA-2510 Examination

HHA-2510 provides that examinations be in accordance with the material specifications.

The staff finds HHA-2510 to be acceptable because it is appropriate and reasonable to conduct examinations in accordance with the material specification. The staff notes that HHA-2111, which references Mandatory Appendix HHA-I, includes rules for permitted material specifications. In addition, both ASTM standards referenced in Mandatory Appendix HHA-I provide examination provisions for graphite billets.

HHA-2520 Repair

HHA-2520 calls for repair by repurification or re-graphitization for graphite billets that fail purity or electrical resistivity standards and permits the use of undamaged portions of damaged or cracked billets for GCCs, provided that all other provisions of the material specification are met.

The staff finds HHA-2520 to be acceptable because regraphitization to achieve full graphitization is a demonstrated and proven graphite manufacturing method and is allowed by both of the ASTM standard material specifications accepted for use in Mandatory Appendix HHA-I. The staff also has determined that this subsubarticle provides a reasonable path for the use of undamaged portions of billets damaged or cracked in the production process.

HHA-2600 Packaging, Transportation, and Storage

HHA-2600 provides that the Construction Specification include provisions for packaging, transportation, and storage of graphite. The subarticle also lists information related to packaging, transportation, and storage that should also be included in the Construction Specification and provides that the packaging repeat the billet identification.

The staff finds HHA-2600 to be acceptable because the provisions in this subarticle are sufficient to provide a minimum acceptable standard for information to be included in the Construction Specification related to the packaging, transportation, and storage of graphite. The staff also believes that it is appropriate to call for the billet identification to be repeated on the packaging and that doing so would help to facilitate material traceability.

3.24.3 Article HHA-3000 Design

HHA-3100 General Design

HHA-3100 provides general rules for the design of GCCs and GCAs. The subarticle states that HHA-3200 addresses the design of GCCs and provides an overview of the following three design approaches contained therein: a simplified assessment in accordance with HHA-3220, a full assessment in accordance with HHA-3230, and design by test in accordance with HHA-3240. The subarticle also refers to HHA-3300 for specific provisions for the design of the GCA. Finally, HHA-3100 provides insights on the overall design approach taken and indicates that the Designer should evaluate the effects of cracking of individual GCCs during the design of the GCA and ensure that the assembly is damage tolerant.

The staff finds HHA-3100 to be acceptable because it is appropriate and reasonable for the designer to evaluate the effects of cracking on GCCs in the course of designing the GCA to ensure that the assembly is damage tolerant. All other provisions in the subarticle are provided by reference to subarticles HHA-3200 and HHA-3300, which the staff has reviewed and determined to be acceptable. The staff reviews HHA-3200 and HHA-3300 below.

During the review, the staff noted that the ASME Code does not define the term “damage tolerant” and that HHA-3100 has no technical provisions for quantifying and assessing damage tolerance. Upon further review, the staff determined that the phrase “damage tolerant” only appears once in the 2017 Edition of the ASME Code III-5, which indicates that the author may have used it as a descriptive term rather than one that was intended to be quantified. To obtain clarification on the intent of the phrase, the staff commented to the ASME Working Group for Graphite Core Components. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. The Working Group also indicated that the term was intended to describe a GCC that meets the functional design and safety provisions of the ASME Code. The staff finds HHA-3100 to be acceptable despite this comment because there is no objective evidence available that would cause the staff to believe that, if left uncorrected, the use of this subarticle would lead to a significant safety concern. Specifically, until the open comment is resolved, the staff can obtain the design-specific information used to demonstrate the damage tolerance of GCCs on a case-by-case basis, if needed, as part of the licensing process. Therefore, the staff has determined that this item does not bar endorsement of HHA-3100. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-3110 Graphite Core Components

HHA-3111 Classification of Graphite Core Components

HHA-3111 provides that GCCs be assigned to SRCs in the Design Specification and provides the criteria for assigning a GCC to a given SRC. HHA-3111 also assigns the responsibility for classifying GCCs to the Owner.

The staff finds HHA-3111 to be acceptable because it is in agreement with the longstanding ASME Code, Section III, approach of classifying components and applying the construction provisions commensurate with that classification. The staff also agrees that it is appropriate to assign the responsibility of classifying GCCs to the Owner.

HHA-3112 Enveloping Graphite Core Components

HHA-3112 permits GCCs and GCAs to be subdivided into groups of components that have similar functions, geometry, and environmental conditions for design analyses. The Designer is responsible for identifying and justifying the enveloping of GCCs.

The staff finds HHA-3112 to be acceptable because the approach to allowing the enveloping of GCCs in the manner described is reasonable, provided that it can be justified by the Designer.

HHA-3120 Loading Criteria

HHA-3121 General

HHA-3121 is general and states that the Design Specification provides the basis for the design, construction, and examination of GCC.

The staff finds HHA-3121 to be acceptable because it contains only general information on specific loading criteria, and the staff agrees with the emphasis placed on the Design Specification.

HHA-3122 Loadings

HHA-3122 identifies the loadings to be taken into account, at a minimum, in the design of GCCs and notes that some of the loadings listed may be loadings on the GCA that will be reduced to loads on the individual GCCs.

The staff finds HHA-3122 to be acceptable because the list of loadings in the paragraph is comprehensive and sufficient to provide a minimum acceptable standard for the loadings to be accounted for in the design of GCCs. The staff also agrees with the approach of allowing other design-specific loads to be considered in the analysis of stresses imposed on the GCC. This facilitates the broader application of the ASME Code rules.

HHA-3123 Design Loadings

HHA-3123 defines the Design Loadings as distributions of pressure, temperature, fast neutron flux, and various forces applicable to GCCs and refers to HHA-3123.1 through HHA-3123.4 for more specific information.

The staff finds HHA-3123 to be acceptable because the scope of Design Loadings identified and referenced in the paragraph is sufficient to provide a minimum acceptable standard for use in the design of GCCs and GCAs.

HHA-3123.1 Design Fast Flux Distribution

HHA-3123.1 defines the Design Fast Flux Distribution and provides that it be used to determine the enveloping fast neutron fluence over the design life of the GCC.

The staff finds HHA-3123.1 to be acceptable because the subparagraph clearly and appropriately defines the Design Fast Flux Distribution. The staff also agrees with the approach to determining the enveloping fast neutron fluence.

HHA-3123.2 Design Temperature Distribution

HHA-3123.2 defines the Design Temperature and provides that it be used with the Design Fast Flux and Design Mechanical Load for the completion of the design life assessment calculations. For GCAs, the assessment also considers nonlocal heating due to irradiation.

The staff finds HHA-3123.2 to be acceptable because the staff believes that the subparagraph appropriately defines the Design Temperature. The staff also agrees with the approach to completing the design life assessment calculations, including the additional consideration of nonlocal heating in assessing the temperature distribution within the GCA.

HHA-3123.3 Design Mechanical Load

HHA-3223.3 provides that mechanical loadings identified in the Design Specification be considered in conjunction with the Design Fast Flux Distribution and Design Temperature Distribution. This provision is limited to loadings that are sustained or that occur for prolong periods.

The staff finds HHA-3123.3 to be acceptable because it is appropriate and reasonable to consider various mechanical loadings in conjunction with fast flux and temperature distribution. The staff also agrees that it is appropriate for short duration loadings to be excluded from the rules of this subparagraph because short duration loadings, such as those associated with an accident scenario or plant transient, would be more appropriately classified as service loadings, which are covered by HHA-3124.

HHA-3123.4 Design Pressure Distribution

HHA-3132.4 provides that the Design Loads include the loads on GCCs due to sustained pressure differences during normal operation.

The staff finds HHA-3123.4 to be acceptable because it is appropriate to include loads due to the sustained pressure differences in the Design Loads, as called for by the subparagraph.

HHA-3124 Service Loadings

HHA-3124 provides that each Service Loading to which the GCC or GCA may be subjected be classified in accordance with HAB-2142 and Service Limits designated in the Design

Specification in such detail as to provide a complete basis for design, construction, and examination.

The staff finds HHA-3124 to be acceptable because the provisions for classifying Service Loadings in the paragraph are sufficient to set a minimum acceptable standard for use in the design of GCCs and GCAs. Section 3.2.2 of this NUREG includes the staff's review of HAB-2142.

HHA-3130 Nomenclature

HHA-3110 provides the nomenclature used in the Subpart.

The staff finds HHA-3130 to be acceptable because all of the terms in the subsubarticle are clearly defined.

HHA-3140 Special Considerations

HHA-3140 provides that assessments of GCC and GCA consider oxidation, irradiation, abrasion and erosion, fatigue, and buckling. The subsubarticle points to HHA-3141 and HHA-3143 for rules on oxidation, abrasion, and erosion, respectively, and notes that those paragraphs are specific to high-temperature gas reactors.

The staff finds HHA-3140 to be acceptable because it is appropriate and reasonable for a GCC design assessment to consider the various aspects mentioned in the subsubarticle.

HHA-3141 Oxidation

HHA-3141 provides that oxidation analysis be conducted to estimate the weight loss profiles of graphite structures and provides the specific provisions to be applied to the analysis in subparagraphs (a) through (d). The staff finds HHA-3141 to be acceptable based on the reasons provided below.

HHA-3141(a)

The staff finds HHA-3141(a) to be acceptable because the staff agrees with the approach that material be considered as oxidized if the weight loss is greater than 1 percent.

HHA-3141(b)

The staff finds HHA-3141(b) to be acceptable because it is appropriate for the oxidation analysis to account for reductions in strength as a function of weight loss.

During the review, the staff commented to the ASME Working Group for Graphite Core Components on HHA-3141(b) and the applicability of Figures HHA-3141-1 and HHA-3141-2. Specifically, the figures were created using data generated from previous graphite grades. Because previous graphite manufacturing processes produced inconsistent results, it cannot be assumed that oxidation data generated from previous grades are universally applicable to all future graphite grades. The Working Group is still developing its formal response to the comment but has informed the staff that it agrees with the comment and is making plans to address it. HHA-3141(b) was determined to be acceptable despite this comment because the subparagraph does not mandate the use of Figures HHA-3141-1 and HHA-3141-2 to determine strength reduction but rather provides them for informational use as an example of how strength decreases as a function of weight loss in graphite. The underlying provision in HHA-3141(b) is that the stress evaluation be made according to this relation. In this context, the term “relation” refers to the relationship between strength and weight loss caused by oxidation, which, as stated above, the staff believes is appropriate to account for in the oxidation analysis. Therefore, the staff has determined that this item does not bar endorsement of HHA-3100. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-3141(c)

The staff finds HHA-3141(c) to be acceptable because it is appropriate to place an upper limit on the amount of weight loss allowed in the oxidation analysis.

During the review, the staff commented to the ASME Working Group for Graphite Core Components on the amount of weight loss allowed by HHA-3141(c). Specifically, HHA-3141(c) could be interpreted to allow up to a 30-percent reduction in the cross-sectional geometry of a component with oxidation and doing so could be detrimental to maintaining the structural integrity of the GCCs. The Working Group is still developing its formal response to the comment but has informed the staff that it agrees and is making plans to address it. The staff determined that HHA-3141(c) is acceptable despite the open comment because the 30-percent limit in HHA-3141(c) does not relieve the Designer of the responsibility to ensure the integrity and functionality of the individual GCCs, and of the GCA, in its design, taking due account of irradiation and oxidation. However, the staff also notes that the limit may not be generically applicable to all high-temperature reactor designs and therefore is not endorsing the provisions of HHA-3141(c) that set the weight loss limit as 30 percent for geometry reduction in the oxidation analysis. As such, designers should determine the amount of weight loss above which the region should be regarded as completely removed from the structure and justify that the limit is adequate for the design specific oxidation analysis.

The staff finds HHA-3141(d) to be acceptable because it is appropriate to exclude the degradation scenarios from the scope of the ASME Code provisions until such time as sufficient data are available to justify rules that would be provided. Doing so does not preclude the importance of ensuring that degradation scenarios do not occur in a specific design. Until the ASME Code includes such rules, the staff can obtain information to ensure that either the scenarios are not applicable to a given design or that the integrity and functionality of the GCCs and GCA will be maintained despite the scenarios, if needed, as part of the licensing process. Oxidation of graphite is a known area of continued work for ASME, and the staff will continue to track its progress through participation in the applicable ASME Code committees.

Figure HHA-3141-1 Dependence of Strength and Weight Loss in Uniformly Oxidized Graphite of Classes IIHP or INHP

Figure HHA-3141 shows the relationship between strength and weight loss in Class IIHP and Class INHP graphite and is referenced in HHA-3141(b).

The staff finds Figure HHA-3141-1 to be acceptable because the figure was provided for informational use only and does not present a new technical provision. The staff reviews HHA-3141(b) elsewhere in this section of this NUREG.

Figure HHA-3141-2 Dependence of Strength and Weight Loss and Uniformly Oxidized Graphite of Classes EIHP, ENHP, MIHP, MNHP

Figure HHA-3141-2 shows the relationship between strength and weight loss in EIHP, ENHP, MIHP, and MNHP graphite and is referenced in HHA-3141(b).

The staff finds Figure HHA-3141-2 to be acceptable because it was for informational use only and does not present a new technical provision. The staff reviews HHA-3141(b) elsewhere in this section of this NUREG.

HHA-3142 Irradiation Effects

The staff finds HHA-3142 to be acceptable, based on the staff's review of the associated subparagraphs described below.

HHA-3142.1 Irradiation Fluence Limits

HHA-3142.1 specifies the threshold limits to be used in determining how the effects of cumulative fast (E > 0.1 megaelectron volt (MeV)) neutron irradiation fluence should be considered for a given component. It also provides that material used in the core be limited to the temperature and dose range for which the material has been characterized.

The staff finds HHA-3142.1 to be acceptable because the staff agrees with the approach of classifying graphite components according to their projected fast fluence. The staff also believes that it is appropriate and reasonable to provide that the use of graphite material within the core be limited by the range of temperature and dose over which the irradiated material properties have been measured, as provided by HHA-2220.

During the review, the staff commented to the ASME Working Group for Graphite Components on the use of "E > 0.1 MeV" in HHA-3142.1 instead of equivalent DIDO nickel dose (EDND) or displacements per atom (dpa), which are used in HHA-3142.1(a) through HHA-3142.1(c). The Working Group is still developing its formal response to the comment but has informed the staff that it agrees and that a code action to change the fluence to dpa in the 2021 Edition of the ASME Code III-5, has already been balloted. The staff determined that HHA-3142.1 is acceptable despite this comment because it is administrative in nature and has no impact on the technical requirements in HHA-3142.1.

HHA-3142.2 Stored (Wigner) Energy

HHA-3142.2 provides that stored (Wigner) energy be accounted for in irradiated graphite exposed to temperatures greater than 200 degrees C (392 degrees F).

The staff finds HHA-3142.2 acceptable because it is appropriate and reasonable to account for stored energy in the manner described in the subparagraph.

HHA-3142.3 Internal Stresses Due to Irradiation

HHA-3142.3 provides that the internal stresses of irradiated GCCs exceeding dose limits in HHA-3142.1(c) be calculated and that the calculation be completed by viscoelastic modeling.

The staff finds HHA-3142.3 to be acceptable because it is appropriate and reasonable to calculate internal stresses in irradiated GCCs and account for both the elastic and plastic behaviors of the material in the calculation.

HHA-3142.4 Graphite Cohesive Life Limit

HHA-3142.4 provides that the graphite cohesive life limit fluence be set to the fluence at which the material experiences a +10-percent linear dimensional change in the with-grain direction.

The staff finds HHA-3142.4 to be acceptable because the staff agrees with the approach of setting a fluence limit beyond which the material is considered to provide no contribution to the structural performance of the GCC. However, the staff also notes that a +10-percent linear dimensional change limit may not be generically applicable to all high-temperature reactor designs. Therefore, the staff is not endorsing the provisions of HHA-3142.4 that set the graphite cohesive life limit fluence to the fluence at which the material experiences a +10 percent linear dimensional change in the with-grain direction. Designers should determine the graphite cohesive life fluence limit beyond which the material is considered to provide no contribution to the structural performance of the GCC and justify that the limit is adequate for the GCC design.

HHA-3143 Abrasion and Erosion

HHA-3143 calls for abrasion to be evaluated if there is relative motion between GCCs, or between GCCs and other items such as interfacing components or fuel pebbles. The paragraph also calls for the evaluation of erosion in areas where the mean gas flow velocity exceeds 100 meters per second (330 feet per second).

The staff finds HHA-3143 to be acceptable because the staff agrees that it is appropriate and reasonable to evaluate abrasion and erosion of GCCs if the requisite conditions exist in a given design. However, the staff also notes that the mean gas flow velocity limit may not be generically applicable to all high-temperature, gas-cooled reactor designs. Therefore, the staff is not endorsing the provisions of HHA-3143 that set the mean gas flow velocity limit of 100 meters per second (330 feet per second) for evaluating the effects of erosion on the GCC design. Designers should determine the mean gas flow velocity limit above which an evaluation of erosion is necessary and justify that the limit is adequate for the GCC design.

During the review, the staff commented to the ASME Working Group for Nonmetallic Design and Materials on HHA-3143(b) and its potential applicability to molten salt reactors. The Working Group is still developing its formal response to the comment but has informed the staff that changes have been proposed to make HHA-3143 generic to all types of high-temperature reactors. The open comments do not impact the staff's disposition of HHA-3143 because, as stated in HHA-3140, the rules in HHA-3143 in the 2017 Edition are specific to high-temperature, gas-cooled reactors. As such, the staff has determined that this item does not bar endorsement of HHA-3100. The staff considers the open comment described above as items for future work with ASME and will continue to track their resolution through participation in the applicable ASME Code committees. In the meantime, the staff can obtain information on the necessity and threshold for evaluating the erosion of GCCs in a liquid-cooled graphite reactor design on a case-by-case basis, if needed, as part of the licensing process.

HHA-3144 Graphite Fatigue

HHA-3144 is shown as “in the course of preparation.” Therefore, the staff did not perform a review and is not endorsing HHA-3144, and the rest of the 2017 Edition of ASME Code III-5 remains valid without this provision.

HHA-3145 Compressive Loading

HHA-3145 provides that GCCs loaded under compression be analyzed against buckling failure and provides the equation for the design critical stress.

The staff finds HHA-3145 to be acceptable because it is appropriate and reasonable to analyze GCCs loaded in compression against buckling failure.

HHA-3200 Design by Analysis—Graphite Core Components

HHA-3210 Design Criteria for Graphite Core Components

HHA-3211 Requirements for Acceptability

HHA-3211 provides for the acceptability by analysis or design-by-test in subparagraphs(a) through (f).

The staff finds HHA-3211 to be acceptable because the provisions identified and referenced in this paragraph are sufficient to provide a minimum standard for the acceptability of the design of a GCC by analysis.

HHA-3212 General Design Requirements for the Graphite Core Components

HHA-3212 provides the general design provisions for individual GCCs in subparagraphs (a) through (h).

The staff finds HHA-3212 to be acceptable because the provisions identified in this paragraph are sufficient to provide a minimum acceptable standard for the general design provisions to be applied to an individual GCC. During the review, the staff noted that the use of the minimum fillet radius allowed by HHA-3212(h) may not be appropriate or acceptable for all design scenarios. NUMARK, 2020b indicates that the provisions for fillet radius based on maximum grain size may not be conservative for all grades of graphite. NUMARK, 2020b states that notch sensitivity studies on IM1-24 graphite by Brocklehurst and Kelly (1979) indicate a minimum fillet radius of 5 times the grain size may be insufficient to prevent a significant decrease of the bending strength of graphite. However, the minimum fillet radius allowed by HHA-3212(h) does not present a general safety concern to the staff because regardless of the graphite grade selected or the fillet radius used, ASME Code III-5 provides that the design of the GCC be such that the provisions of HHA-3200 are met.

Compliance with HHA-3200 ensures that the acceptability of a given GCC design is based on stress analyses that account for the entire volume of the GCC, including potential sites of stress concentration such as grooves, keyways, and dowel holes. In lieu of performing a stress analysis, design-by-test is allowed, and the associated rules in HHA-3240 for design-by-test also account for the geometry of the GCC.

HHA-3213 Basis for Determining Stresses

HHA-3213 provides the formula for determining the equivalent stress at a point within a graphite structure. This equivalent stress is compared directly to the results of a uniaxial strength test.

The staff finds HHA-3213 to be acceptable because the paragraph contains general information on the maximum deformation energy theory of failure used in the rules for combining stresses.

HHA-3214 Terms Relating to Stress Analysis

HHA-3214 states that the terms used in this Subpart relating to stress analysis are defined in subparagraphs HHA-3214.1 through HHA-3214.14: equivalent stress, peak equivalent stress, normal stress, shear stress, membrane stress, bending stress, combined stress, peak stress, load stress, internal stress, total stress, operational cycle, and Probability of Failure (POF).

The staff finds HHA-3214 to be acceptable because all terms in the associated subparagraphs are clearly defined and consistent with traditional and broadly accepted definitions.

HHA-3215 Stress Analysis

HHA-3215 calls for a detailed stress analysis to ensure that all GCCs meet the stress limitations of HHA-3220 or the POF limits of HHA-3230. The paragraph calls for the evaluation of all loads or effects on the GCC that cause loads of deformations. HHA-3215 also emphasizes that stress analysis models consider simultaneously applied loads and that attention be given to the boundary conditions applied to the stress analysis model.

The staff finds HHA-3215 to be acceptable because the rules provided are consistent with stress analyses used in the design of previous experimental and commercial power high-temperature reactors.

HHA-3215.1 General

HHA 3215.1 provides that the determination of stresses for assessment include (a) stresses resulting from loads acting simultaneously, (b) stress concentration effects, (c) linear elastic material properties with consideration given to viscoelastic properties for irradiated GCCs, and (d) the use of the dynamic elastic moduli.

The staff finds HHA-3215.1 to be acceptable because the scope of the general rules in the subparagraph is sufficient to provide a minimum acceptable standard for the determination of stresses to include in the stress analysis.

HHA-3215.2 Stress Analysis of Nonirradiated Graphite Core Components

HHA 3215.2 provides an elastic analysis of unirradiated GCCs and states that the analysis does not need to take into account the effects of irradiation damage on the material properties of graphite, with the exception of thermal conductivity.

The staff finds HHA-3215.2 to be acceptable because the staff agrees with this approach for performing a stress analysis on nonirradiated graphite. The special case for which the effect of neutron irradiation should be included to account for thermal conductivity in this subparagraph is consistent with the provision for irradiation fluence limits in HHA-3142.1, which the staff has reviewed and determined to be acceptable as stated above.

HHA-3215.3 Stress Analysis of Irradiated Graphite Core Components

HHA-3215.3 calls for a viscoelastic analysis of GCCs that takes into account the effects of irradiation damage. This analysis also accounts for irradiation-induced dimensional change in creep.

The staff finds HHA-3215.3 to be acceptable because the staff agrees with this approach for performing a stress analysis on irradiated graphite. The staff also believes that the responsibility for the accuracy and acceptability of analysis methods is appropriately assigned to the Designer.

HHA-3215.4 Stress Analysis of Oxidized Graphite Core Components

HHA-3215.4 calls for a stress analysis of oxidized graphite GCCs.

The staff finds HHA-3215.4 to be acceptable because it appropriately takes into consideration the potential effects of oxidation on the dimensions and material properties of the GCC during reactor operation.

HHA-3216 Derivation of Equivalent Stress

HHA-3216 provides a procedure for calculating the equivalent stress values.

The staff finds HHA-3216 to be acceptable because the procedure is consistent with generally accepted calculation procedures for deriving the equivalent stress values and which the NRC staff uses.

HHA-3217 Calculation of Probability of Failure

HHA-3217 provides a procedure for calculating the POF in subparagraphs (a) through (g).

The staff finds HHA-3217 to be acceptable because the procedure is consistent with the generally accepted engineering stress calculation and analysis practice, which the NRC staff uses.

HHA-3220 Stress Limits for Graphite Core Component—Simplified Assessment

As a simplified assessment, HHA-3220 calls for the peak equivalent stress (HHA-3214.2) calculated for the GCC to be compared to the allowable stress value, which is dependent on the target POF derived from the SRC of the GCC and the Service Level of the load. The subsubarticle also indicates that the simplified assessment is conservative and a full assessment, or design-by-test, may be completed to accept the GCC if the limit in the simplified assessment is not met.

The staff finds HHA-3220 to be acceptable because it is reasonable to allow a more conservative simplified assessment of a GCC to be conducted. The staff also agrees with the approach of allowing a full assessment, or design-by-test, to be used for acceptance of a GCC instead of the simplified assessment.

HHA-3221 Design Limits

HHA-3221 states that the equivalent stress limits that shall be satisfied for the Design Loadings stated in the Design Specifications are the two limits identified in the paragraph and the special stress limits in HHA-3226.

The staff finds HHA-3221 to be acceptable because the provisions identified and referenced in this paragraph are sufficient to provide a minimum acceptable standard for the stress limits for the Design Loadings.

HHA-3221.1 Combined Membrane Stress

HHA-3221.1 states that the design equivalent stress is derived from the average value across the thickness of the ligament or other section of the combined stresses produced by the Design Loadings. The allowable stresses depend upon the SRC of the GCC enumerated in subsubparagraphs (a) through (c).

The staff finds HHA-3221.1 to be acceptable because the procedure for determining the combined membrane stress limit is clearly defined, and the staff also agrees with the approach of assigning acceptability criteria commensurate with the SRC of the GCC.

During the review, the staff noted that the ASME Code does not define the term "internal stresses due to irradiation at the design lifetime," which appears in HHA-3221.1, HHA-3221.2, HHA-3222.1, HHA-3222.2, HHA-3224.1, HHA-3224.2, HHA-3225.1, and HHA-3225.2, and commented to the ASME Working Group for Nonmetallic Design and Materials. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. Given that rules are provided for determining internal stresses due to irradiation in HHA-3142.3, the applicable subparagraphs are determined to be acceptable despite this open comment because the definition of the term "internal stresses due to irradiation at the design lifetime" can be reasonably inferred from the ASME Code requirements as follows:

> **Internal stresses due to irradiation at the design lifetime**: the internal stresses due to irradiation, calculated in accordance with HHA-3142.3, using irradiation conditions (damage dose and temperature) consistent with the expected design life of the GCC.

In addition, there is no other objective evidence available that would cause the staff to believe that, if left uncorrected, the use of the aforementioned subparagraphs would lead to a significant safety concern. Specifically, the term "internal stresses due to irradiation at the design lifetime" is only used to describe the design allowable stress value, S_g, for SRC-2 components, which are not important to safety but are subject to environmental degradation. In addition, until the open comment is resolved, the staff can verify how internal stresses due to irradiation at the design lifetime are included in the determination of the allowable stress values on a case-by-case basis, if needed, by obtaining the design-specific information from the applicant as part of the licensing process. Therefore, the staff has determined that this item does not bar endorsement of HHA-3221.1. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-3221.2 Peak Equivalent Stress

HHA-3221.2 calls for evaluation of the peak equivalent stress produced by the Design Loadings, including all combined and peak stresses. The allowable stresses depend upon the SRC of the GCC enumerated in subsubparagraphs (a) through (c).

The staff finds HHA-3221.2 to be acceptable because the procedure for determining the peak equivalent stress is clearly defined, and the approach of assigning acceptability criteria commensurate with the SRC of the GCC is appropriate and reasonable.

During the review, the staff noted that the ASME Code does not define the term "internal stresses due to irradiation at the design lifetime," which appears in HHA-3221.1, HHA-3221.2, HHA-3222.1, HHA-3222.2, HHA-3224.1, HHA-3224.2, HHA-3225.1, and HHA-3225.2, and commented to the ASME Working Group for Nonmetallic Design and Materials. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. Given that rules are provided for determining internal stresses due to irradiation in HHA-3142.3, the applicable subparagraphs are determined to be acceptable despite this open comment because the definition of the term "internal stresses due to irradiation at the design lifetime" can be reasonably inferred from the ASME Code requirements as follows:

> **Internal stresses due to irradiation at the design lifetime**: the internal stresses due to irradiation, calculated in accordance with HHA-3142.3, using irradiation conditions (damage dose and temperature) consistent with the expected design life of the GCC.

In addition, there is no other objective evidence available that would cause the staff to believe that, if left uncorrected, the use of the aforementioned subparagraphs would lead to a significant safety concern. Specifically, the term "internal stresses due to irradiation at the design lifetime" is only used to describe the design allowable stress value, S_g, for SRC-2 components, which are not important to safety but are subject to environmental degradation. In addition, until the open comment is resolved, the staff can verify how internal stresses due to irradiation are included in the determination of the allowable stress values on a case-by-case basis, if needed, by obtaining the design-specific information from the applicant as part of the licensing process. Therefore, the staff has determined that this item does not bar endorsement of HHA-3221.2. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-3222 Level A Service Limits

HHA-3222 provides that the Level A Service Limits to be satisfied for the Service Level A Loadings for which the limits are designated in the Design Specifications be the three limits of this paragraph and the special stress limits in HHA-3226.

The staff finds HHA-3222 to be acceptable because the provisions identified and referenced in this paragraph are sufficient to provide a minimum acceptable standard for the stress limits for the Service Level A Loadings.

HHA-3222.1 Combined Membrane Stress

HHA-3222.1 defines the combined membrane stress as the equivalent stress derived from the average value across the thickness of a ligament or other section of the combined stresses produced by all Level A Service Loadings. The allowable stresses depend upon the SRC of the GCC, as enumerated in subsubparagraphs (a) through (c).

The staff finds HHA-3222.1 to be acceptable because the combined membrane stress is clearly defined and the approach of assigning acceptability criteria commensurate with the SRC of the GCC is appropriate and reasonable.

During the review, the staff noted that the ASME Code does not define the term "internal stresses due to irradiation at the design lifetime," which appears in HHA-3221.1, HHA-3221.2, HHA-3222.1, HHA-3222.2, HHA-3224.1, HHA-3224.2, HHA-3225.1, and HHA-3225.2, and commented to the ASME Working Group for Nonmetallic Design and Materials. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. Given that rules are provided for determining internal stresses due to irradiation in HHA-3142.3, the applicable subparagraphs are determined to be acceptable despite this open comment because the definition of the term "internal stresses due to irradiation at the design lifetime" can be reasonably inferred from the ASME Code requirements as follows:

> **Internal stresses due to irradiation at the design lifetime**: the internal stresses due to irradiation, calculated in accordance with HHA-3142.3, using irradiation conditions (damage dose and temperature) consistent with the expected design life of the GCC.

In addition, there is no other objective evidence available that would cause the staff to believe that, if left uncorrected, the use of the aforementioned subparagraphs would lead to a significant safety concern. Specifically, the term "internal stresses due to irradiation at the design lifetime" is only used to describe the design allowable stress value, S_g, for SRC-2 components, which are not important to safety but subject to environmental degradation. In addition, until the open comment is resolved, the staff can verify how internal stresses due to irradiation were included in the determination of the allowable stress values on a case-by-case basis, if needed, by obtaining the design-specific information from the applicant as part of the licensing process. Therefore, the staff has determined that this item does not bar endorsement of HHA-3222.1. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-3222.2 Peak Equivalent Stress

HHA-3222.2 provides that the peak equivalent service stress produced by Level A Service Loadings, including all combined and peak stresses, be evaluated. The allowable stresses depend upon the SRC of the GCC enumerated in subsubparagraphs (a) through (c).

The staff finds HHA-3222.2 to be acceptable because the procedure for determining the peak equivalent stress is clearly defined, and the approach of assigning acceptability criteria commensurate with the SRC of the GCC is appropriate and reasonable.

During the review, the staff noted that the ASME Code does not define the term "internal stresses due to irradiation at the design lifetime," which appears in HHA-3221.1, HHA-3221.2,

HHA-3222.1, HHA-3222.2, HHA-3224.1, HHA-3224.2, HHA-3225.1, and HHA-3225.2, and commented to the ASME Working Group for Nonmetallic Design and Materials. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. Given that rules are provided for determining internal stresses due to irradiation in HHA-3142.3, the applicable subparagraphs are determined to be acceptable despite this open comment because the definition of the term "internal stresses due to irradiation at the design lifetime" can be reasonably inferred from the ASME Code requirements as follows:

> **Internal stresses due to irradiation at the design lifetime**: the internal stresses due to irradiation, calculated in accordance with HHA-3142.3, using irradiation conditions (damage dose and temperature) consistent with the expected design life of the GCC.

In addition, there is no other objective evidence available that would cause the staff to believe that, if left uncorrected, the use of the aforementioned subparagraphs would lead to a significant safety concern. Specifically, the term "internal stresses due to irradiation at the design lifetime" is only used to describe the design allowable stress value, S_g, for SRC-2 components, which are not important to safety but are subject to environmental degradation. In addition, until the open comment is resolved, the staff can verify how internal stresses due to irradiation were included in the determination of the allowable stress values on a case-by-case basis, if needed, by obtaining the design-specific information from the applicant as part of the licensing process. Therefore, the staff has determined that this item does not bar endorsement of HHA-3222.2. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-3222.3 Deformation Limits

HHA-3222.3 indicates that deformation limits in the Design Specifications should be met.

The staff finds HHA-3222.3 to be acceptable because it is appropriate and reasonable for any deformation limits specified in the Design Specification be met.

During the review, the staff commented to ASME on the potential for defining two explicit deformation limits within the ASME Code. The first deformation limit would be related to acceptable deformation, which can be monitored, while the other limit would be related to the initiation of cracking in graphite. The Working Group responded to the comment with proposals for near-term and long-term actions to be considered. The staff has determined that this item does not bar endorsement of HHA-3222.3. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees. The acceptability of HHA-3222.3 is not affected by this comment because, as stated above, the ASME Code text is acceptable as written.

HHA-3223 Level B Service Limits

HHA-3223 provides that Level A Service Limits be applied to Level B Service Loadings and that deformation or other limits in the Design Specifications be met.

The staff finds HHA-3223 to be acceptable because the staff agrees with the conservative approach that Level A Service Limits apply to Level B Service Loadings. The provision that

GCCs meet the deformation or other limits in the Design Specification is also consistent with the approach taken in HHA-3222, which the staff finds acceptable.

HHA-3224 Level C Service Limits

HHA-3224 states that the Level C Service Limits to be satisfied for the Service Level C Loadings for which the limits are designated in the Design Specifications are the three limits of this paragraph and the special stress limits in HHA-3226.

The staff finds HHA-3224 to be acceptable because the provisions identified and referenced in this paragraph are sufficient to provide a minimum acceptable standard for the stress limits that shall be satisfied for the Service Level C Loadings.

HHA-3224.1 Combined Membrane Stress

HHA-3224.1 states that the combined membrane stress is derived from the average value across the thickness of a ligament or other section of the combined stresses produced by all the Level C Service Loadings. The allowable stresses depend upon the SRC of the GCC, as enumerated in subsubparagraphs (a) through (c).

The staff finds HHA-3224.1 to be acceptable because the procedure for determining the combined membrane stress limit is clearly defined, and the staff agrees with the approach of assigning acceptability criteria commensurate with the SRC of the GCC.

During the review, the staff noted that the ASME Code does not define the term “internal stresses due to irradiation at the design lifetime,” which appears in HHA-3221.1, HHA-3221.2, HHA-3222.1, HHA-3222.2, HHA-3224.1, HHA-3224.2, HHA-3225.1, and HHA-3225.2, and commented to the ASME Working Group for Nonmetallic Design and Materials. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. Given that rules are provided for determining internal stresses due to irradiation in HHA-3142.3, the applicable subparagraphs are determined to be acceptable despite this open comment because the definition of the term “internal stresses due to irradiation at the design lifetime” can be reasonably inferred from the ASME Code requirements as follows:

> **Internal stresses due to irradiation at the design lifetime**: the internal stresses due to irradiation, calculated in accordance with HHA-3142.3, using irradiation conditions (damage dose and temperature) consistent with the expected design life of the GCC.

In addition, there is no other objective evidence available that would cause the staff to believe that, if left uncorrected, the use of the aforementioned subparagraphs would lead to a significant safety concern. Specifically, the term “internal stresses due to irradiation at the design lifetime” is only used to describe the design allowable stress value, S_g, for SRC-2 components, which are not important to safety but are subject to environmental degradation. In addition, until the open comment is resolved, the staff can verify how internal stresses due to irradiation were included in the determination of the allowable stress values on a case-by-case basis, if needed, by obtaining the design-specific information from the applicant as part of the licensing process. Therefore, the staff has determined that this item does not bar endorsement of HHA-3224.1. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-3224.2 Peak Equivalent Stress

HHA-3224.2 calls for the evaluation of the peak equivalent service stress produced by Level C Service Loadings, including all combined and peak stresses. The allowable stresses depend upon the SRC of the GCC, enumerated in subsubparagraphs (a) through (c).

The staff finds HHA-3224.2 to be acceptable because the procedure for determining the peak equivalent stress is clearly defined, and the approach of assigning acceptability criteria commensurate with the SRC of the GCC is appropriate and reasonable.

During the review, the staff noted that the ASME Code does not define the term "internal stresses due to irradiation at the design lifetime," which appears in HHA-3221.1, HHA-3221.2, HHA-3222.1, HHA-3222.2, HHA-3224.1, HHA-3224.2, HHA-3225.1, and HHA-3225.2, and commented to the ASME Working Group for Nonmetallic Design and Materials. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. Given that rules are provided for determining internal stresses due to irradiation in HHA-3142.3, the applicable subparagraphs are determined to be acceptable despite this open comment because the definition of the term "internal stresses due to irradiation at the design lifetime" can be reasonably inferred from the ASME Code requirements as follows:

> **Internal stresses due to irradiation at the design lifetime**: the internal stresses due to irradiation, calculated in accordance with HHA-3142.3, using irradiation conditions (damage dose and temperature) consistent with the expected design life of the GCC.

In addition, there is no other objective evidence available that would cause the staff to believe that, if left uncorrected, the use of the aforementioned subparagraphs would lead to a significant safety concern. Specifically, the term "internal stresses due to irradiation at the design lifetime" is only used to describe the design allowable stress value, S_g, for SRC-2 components, which are not important to safety but are subject to environmental degradation. In addition, until the open comment is resolved, the staff can verify how internal stresses due to irradiation were included in the determination of the allowable stress values on a case-by-case basis, if needed, by obtaining the design-specific information from the applicant as part of the licensing process. Therefore, the staff has determined that this item does not bar endorsement of HHA-3224.2. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-3224.3 Deformation Limits

HHA-3224.3 indicates that any deformation limits in the Design Specifications should be met.

The staff finds HHA-3224.3 to be acceptable because it is appropriate and reasonable that any deformation limits specified in the Design Specification be met.

During the review, the staff provided a comment to ASME on the potential for defining two explicit deformation limits within the ASME Code. The first limit would be related to acceptable deformation, which can be monitored, while the other limit would be related to the initiation of cracking in graphite. The Working Group responded to the comment with proposals for near-term and long-term actions to be considered. The staff has determined that this item does not bar endorsement of HHA-3224.3. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees. The acceptability of HHA-3224.3 is not impacted by this comment because, as stated above, the ASME Code text is acceptable as written.

HHA-3225 Level D Service Limits

HHA-3225 states that the Level D Service Limits to be satisfied for the Level D Loadings for which these limits are designated in the Design Specification are the three limits of this paragraph and the special stress limits in HHA-3226. In addition, when applicable, the calculated stresses should not exceed twice the stress limits given in HHA-3226, as applied to Level A Service Limits.

The staff finds HHA-3225 to be acceptable because the provisions identified and referenced in this paragraph are sufficient to provide a minimum acceptable standard for the stress limits that shall be satisfied for the Service Level D Loadings.

HHA-3225.1 Combined Membrane Stress

HHA-3225.1 states that the combined membrane stress is the equivalent stress derived from the average value across the thickness of the ligament of the combined stresses produced by all Service Level D Loadings. The allowable stresses depend upon the SRC of the GCC, as enumerated in subsubparagraphs (a) through (c).

The staff finds HHA-3224.1 to be acceptable because the procedure for determining the combined membrane stress limit is clearly defined, and the approach of assigning acceptability criteria commensurate with the SRC of the GCC is appropriate and reasonable.

During the review, the staff noted that the ASME Code does not define the term “internal stresses due to irradiation at the design lifetime,” which appears in HHA-3221.1, HHA-3221.2, HHA-3222.1, HHA-3222.2, HHA-3224.1, HHA-3224.2, HHA-3225.1, and HHA-3225.2, and commented to the ASME Working Group for Nonmetallic Design and Materials. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. Given that rules are provided for determining internal stresses due to irradiation in HHA-3142.3, the applicable subparagraphs are determined to be acceptable despite this open comment because the definition of the term “internal stresses due to irradiation at the design lifetime” can be reasonably inferred from the ASME Code requirements as follows:

> **Internal stresses due to irradiation at the design lifetime**: the internal stresses due to irradiation, calculated in accordance with HHA-3142.3, using irradiation conditions (damage dose and temperature) consistent with the expected design life of the GCC.

In addition, there is no other objective evidence available that would cause the staff to believe that, if left uncorrected, the use of the aforementioned subparagraphs would lead to a significant safety concern. Specifically, the term “internal stresses due to irradiation at the design lifetime” is only used to describe the design allowable stress value, S_g, for SRC-2 components, which are not important to safety but are subject to environmental degradation. In addition, until the open comment is resolved, the staff can verify how internal stresses due to irradiation were included in the determination of the allowable stress values on a case-by-case basis, if needed, by obtaining the design-specific information from the applicant as part of the licensing process.

Therefore, the staff has determined that this item does not bar endorsement of HHA-3225.1. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-3225.2 Peak Equivalent Stress

HHA-3225.2 calls for the evaluation of the peak equivalent service stress produced by Level D Service Loadings, including all combined and peak stresses. The allowable stresses depend upon the SRC of the GCC, enumerated in subsubparagraphs (a) through (c).

The staff finds HHA-3225.2 to be acceptable because the procedure for determining the peak equivalent stress is clearly defined, and the approach of assigning acceptability criteria commensurate with the SRC of the GCC is appropriate and reasonable.

During the review, the staff noted that the ASME Code does not define the term "internal stresses due to irradiation at the design lifetime," which appears in HHA-3221.1, HHA-3221.2, HHA-3222.1, HHA-3222.2, HHA-3224.1, HHA-3224.2, HHA-3225.1, and HHA-3225.2, and commented to the ASME Working Group for Nonmetallic Design and Materials. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. Given that rules are provided for determining internal stresses due to irradiation in HHA-3142.3, the applicable subparagraphs are determined to be acceptable despite this open comment because the definition of the term "internal stresses due to irradiation at the design lifetime" can be reasonably inferred from the ASME Code requirements as follows:

> **Internal stresses due to irradiation at the design lifetime**: the internal stresses due to irradiation, calculated in accordance with HHA-3142.3, using irradiation conditions (damage dose and temperature) consistent with the expected design life of the GCC.

In addition, there is no other objective evidence available that would cause the staff to believe that, if left uncorrected, the use of the aforementioned subparagraphs would lead to a significant safety concern. Specifically, the term "internal stresses due to irradiation at the design lifetime" is only used to describe the design allowable stress value, S_g, for SRC-2 components, which are not important to safety but are subject to environmental degradation. In addition, until the open comment is resolved, the staff can verify how internal stresses due to irradiation were included in the determination of the allowable stress values on a case-by-case basis, if needed, by obtaining the design-specific information from the applicant as part of the licensing process. Therefore, the staff has determined that this item does not bar endorsement of HHA-3225.2. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees.

HHA-3225.3 Deformation Limits

HHA-3225.3 provides that deformation limits in the Design Specifications be met.

The staff finds HHA-3225.3 to be acceptable because it is appropriate and reasonable that any deformation limits specified in the Design Specification be met.

During the review, the staff provided a comment to ASME on the potential for defining two explicit deformation limits within the ASME Code. The first deformation limit would be related to acceptable deformation, which can be monitored, while the other limited would be related to the initiation of cracking in graphite. The Working Group responded to the comment with proposals for near-term and long-term actions to be considered. The staff has determined that this item does not bar endorsement of HHA-3225.3. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees. The acceptability of HHA-3225.3 is not affected by this comment because, as stated above, the ASME Code text is acceptable as written.

HHA-3226 Special Stress Limits

HHA-3226 provides for deviations from the basic stress limits to cover special Design or Service Loadings and provides that the rules of this paragraph take precedence in cases of a conflict with the basic stress limits.

The staff finds HHA-3226 to be acceptable because it is appropriate to provide rules to cover special Design or Service Loading scenarios, and the rules appropriately establish a hierarchy of provisions in case of a conflict with the basic stress limits.

HHA-3226.1 Bearing Stresses

HHA-3226.1 states that the average bearing stress over the contact area shall be less than the applicable design equivalent stress value multiplied by the ratio of compressive to tensile strength. The subparagraph also refers to HHA-3222.1, HHA-3224.1, and HHA-3225.1 for S_g values.

The staff finds HHA-3226.1 to be acceptable because it clearly defines the applicability of bearing stresses in design considerations.

HHA-3227 Design Equivalent Stress Values and Material Properties

HHA-3227 specifies that the MDSs give the design equivalent stress values and contain all of the other graphite material properties used for design.

The staff finds HHA-3227 to be acceptable because the location of the stress values and graphite properties of interest is clearly defined.

HHA-3230 Probability of Failure Limits for Graphite Core Components—Full Assessment

HHA-3230 provides that a full assessment POF (HHA-3214.14) calculated for the GCC be compared directly to an allowable value. The target POF values are derived from the SRC of the GCC and the Design or Service Level of the Loading. The material values are calculated from the MDS generated for the specific grade.

The staff finds HHA-3230 to be acceptable because the approach to developing the full assessment is clearly defined and appropriate for determining POF limits.

HHA-3231 Design Limits

HHA-3231 states that the POF limits for satisfying the Design Loadings are the limits of this paragraph, its subparagraphs, and the special limits of HHA-3236.

The staff has determined HHA-3231 to be acceptable because the provisions identified and referenced in this paragraph are sufficient to provide a minimum acceptable standard for the POF limits that shall be satisfied for the Design Loadings.

HHA-3231.1 Probability of Failure Resulting from Combined Stress

HHA-3231.1 states that the POF derived from the combined equivalent stress in the GCC, including peak stress, shall be calculated. The allowable POFs depend on the three SRCs of the GCC, as listed in subsubparagraphs (a) through (c).

The staff finds HHA-3231.1 to be acceptable because the approach of assigning acceptability criteria commensurate with the SRC of the GCC is appropriate and reasonable. The staff reviewed the procedure for calculating the POF described in HHA-3217 and determined it to be acceptable. The staff's review of HHA-3217 is provided above.

HHA-3232 Level A Service Limits

HHA-3232 states the Level A Service Limits shall be satisfied by the limits of this paragraph and HHA-3236.

The staff finds HHA-3232 to be acceptable because the provisions identified and referenced in this paragraph are sufficient to provide a minimum acceptable standard for the POF Limits for the Level A Service Loadings.

HHA-3232.1 Probability of Failure Resulting from Combined Stress

HHA-3232.1 states that the POF derived from the combined equivalent stress, which includes peak stress, throughout the GCC shall be calculated. The allowable POFs depend on the SRC of the GCC.

The staff finds HHA-3232.1 to be acceptable because the approach of assigning acceptability criteria commensurate with the SRC of the GCC is appropriate and reasonable. The staff reviewed the procedure for calculating the POF described in HHA-3217 and determined it to be acceptable. The staff's review of HHA-3217 is provided above.

HHA-3232.2 Deformation Limits

HHA-3232.2 states that deformation limits in the Design Specifications shall be met.

The staff finds HHA-3232.2 to be acceptable because it is appropriate and reasonable that any deformation limits specified in the Design Specification be met.

During the review, the staff commented to ASME on the potential for defining two explicit deformation limits within the ASME Code. The first deformation limit would be related to acceptable deformation, which can be monitored, while the other limit would be related to the initiation of cracking in graphite. The Working Group responded to the comment with proposals for near-term and long-term actions to be considered. The staff has determined that this item does not bar endorsement of HHA-3232.2. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees. The acceptability of HHA-3232.2 is not affected by this comment because, as stated above, the ASME Code text is acceptable as written.

HHA-3233 Level B Service Limits

HHA-3233 provides that Level A Service Limits be applied to Level B Service Loadings and that deformation or other limits in the Design Specifications be met.

The staff finds HHA-3233(a) to be acceptable because the staff agrees with the conservative approach of applying Level A Service Limits to Level B Service Loadings. The provisions that GCCs meet the deformation or other limits in the Design Specification is also consistent with the approach taken in other ASME Code paragraphs, which the staff determined to be acceptable, e.g., above in this section.

HHA-3234 Level C Service Limits

HHA-3234 states that the Level C Service Limits to be satisfied for the Service Level C Loadings for which the limits are designated in the Design Specifications are the two limits of this paragraph and the special stress limits in HHA-3236.

The staff finds HHA-3234 to be acceptable because the provisions identified and referenced in this paragraph are sufficient to provide a minimum acceptable standard for the POF limits for the Service Level C Loadings.

HHA-3234.1 Probability of Failure Resulting from Combined Stress

HHA-3234.1 states that the POF derived from the combined equivalent stress throughout the entire GCC shall be calculated. The allowable POFs depend on the SRCs listed in subsubparagraphs (a) through (c).

The staff finds HHA-3234.1 to be acceptable because the staff agrees with the approach of assigning acceptability criteria commensurate with the SRC of the GCC. The staff reviewed the procedure for calculating the POF described in HHA-3217 and determined it to be acceptable. The staff's review of HHA-3217 is provided above.

HHA-3234.2 Deformation Limits

HHA-3234.2 states that any deformation limits in the Design Specifications shall be met.

The staff finds HHA-3434.2 to be acceptable because it is appropriate and reasonable that any deformation limits specified in the Design Specification be met.

During the review, the staff commented to ASME on the potential for defining two explicit deformation limits within the ASME Code. The first deformation limit would be related to acceptable deformation, which can be monitored, while the other limit would be related to the initiation of cracking in graphite. The Working Group responded to the comment with proposals for near-term and long-term actions. The staff has determined that this item does not bar endorsement of HHA-3234.2. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees. The acceptability of HHA-3234.2 is not affected by this comment because, as stated above, the ASME Code text is acceptable as written.

HHA-3235 Level D Service Limits

HHA-3235 states that the Level D Service Limits to be satisfied for the Level D Loadings for which these limits are designated in the Design Specification are the limits of this paragraph and the special stress limits in HHA-3236. In addition, when applicable, the calculated stresses should not exceed twice the stress limits given in HHA-3236, as applied for Level A Service Limits.

The staff finds HHA-3235 to be acceptable because the provisions identified and referenced in this paragraph are sufficient to provide a minimum acceptable standard for the POF limits for the Service Level D Loadings.

HHA-3235.1 Probability of Failure Resulting from Combined Stress

The POF derived from the combined equivalent stress throughout the GCC should be calculated. The allowable POF depends on the SRC of the GCC, as listed in subsubparagraphs (a) through (c).

The staff finds HHA-3225.1 to be acceptable because the staff agrees with the approach of assigning acceptability criteria commensurate with the SRC of the GCC. The staff reviewed the procedure for calculating the POF described in HHA-3217 and determined it to be acceptable. The staff's review of HHA-3217 is provided above.

HHA-3235.2 Deformation Limits

HHA-3235.2 states the deformation limits prescribed by the Design Specifications shall be met.

The staff finds HHA-3235.2 to be acceptable because it is appropriate and reasonable that any deformation limits specified in the Design Specification be met.

During the review, the staff commented to ASME on the potential for defining two explicit deformation limits within the ASME Code. The first deformation limit would be related to acceptable deformation, which can be monitored, while the other limit would be related to the initiation of cracking in graphite. The Working Group responded to the comment with proposals for near-term and long-term actions. The staff has determined that this item does not bar endorsement of HHA-3221.2. The staff considers this comment as an item for future work with ASME and will continue to track its resolution through participation in the applicable ASME Code committees. The acceptability of HHA-3235.2 is not affected by this comment because, as stated above, the ASME Code text is acceptable as written.

HHA-3236 Special Stress Limits

HHA-3236 calls for the applicant to use the provisions of HHA-3226 to determine any special stress limits.

The staff finds HHA-3236 to be acceptable because it calls for the use of HHA-3226, which the staff has reviewed and determined to be acceptable for the reasons set forth above. HHA-3236 is acceptable for the same reasons.

HHA-3237 Design Stress Values and Material Properties

HHA-3237 states the POF calculation is based on the statistical material parameters describing the material reliability curve. These material parameters are given in the MTSs in accordance with HHA-2200.

The staff finds HHA-3237 to be acceptable because the staff believes that the description of the Probability of Failure calculation is appropriate and consistent with other portions of ASME Section III, Division 5, such as Mandatory Appendix HHA-III-3000, which contains the requirements for deriving the materials reliability curve. HHA-3237 also refers to HHA-2200, which the staff has reviewed and determined to be acceptable. Section 3.24.2 of this NUREG includes the staff's review of HHA-2200.

HHA-3240 Experimental Limits—Design-by-Test

HHA-3240 indicates that it is acceptable to meet this Article based on component testing. This is referred to as design-by-test.

The staff finds HHA-3240 to be acceptable because it is reasonable to allow testing to be used as a means of verifying compliance with the design provisions of HHA-3000.

HHA-3241 General

HHA-3241 states general provisions for design-by-test in subparagraphs (a) through (d).

The staff finds HHA-3241 to be acceptable because the scope of general provisions identified and referenced in this paragraph is sufficient to provide a minimum acceptable standard for design-by-test.

HHA-3242 Experimental Proof of Strength and Demonstration of Probability of Failure

HHA-3242 consists of three subsubparagraphs, (a) through (c). HHA-3242(a) provides that the Probability of Failure (POF) of a GCC under the specified loadings be less than the allowable POF defined in HHA-3000. HHA-3242(b) allows extrapolation to the GCC POF values by using a statistical analysis of the test results. HHA-3242(c) calls for the test loadings to represent or envelope all appropriate Design and Service Loadings.

The staff finds HHA-3242 to be acceptable because the provisions ensure that the Code allowable POF values will be met when design-by-testing of GCCs is used.

HHA-3242.1 Design Limits, Level A and Level B Service Limits

HHA-3242.1 states that HHA-3232 defines the POF limits to be met by the test for Design, Level A, and Level B Service Loadings.

The staff finds HHA-3242.1 to be acceptable because the paragraph ensures that the appropriate and applicable POF limits are met.

HHA-3242.2 Level C and Level D Service Limits

HHA-3242.2 consists of two subsubparagraphs, (a) and (b). HHA-3242(a) identifies the POF limits to be met for Level C and Level D Service Loadings. If the testing of a prototype can show that the specified loads do not exceed 60 percent of the maximum load or load combination used in the test, then HHA-3242(b) permits that testing to be used as an alternative to the Level C and Level D Service Limits.

The staff finds HHA-3242.2 to be acceptable because the paragraph ensures that the appropriate and applicable POF limits are met. The staff also believes that the allowed alternative is reasonable to achieve the same goal and, therefore, acceptable.

HHA-3243 Experimental Proof of Strength, Service Load Rating

HHA-3243 states that, when using design-by-test, the Service Load Rating shall be greater than the envelope of the Service Load under consideration. HHA-3243 also provides an equation defining the Service Load Rating.

The staff finds HHA-3243 to be acceptable because the technical contents of the paragraph are reasonable and ensure the testing is valid for its purpose.

HHA-3300 Requirements for Design of the Graphite Core Assembly

The opening text in HHA-3300 defines the scope of the subarticle and indicates that the provisions therein are an extension to the provisions of the Design Specification. The text also indicates that minimum standards for GCA functions be documented in the Design Specification and assessed as part of the design process.

The staff finds the opening text of HHA-3000 to be acceptable because the scope of the subarticle is clearly defined and the approach of specifying the minimum standards for GCA functions in the Design Specification is appropriate and reasonable.

HHA-3310 General Requirements

HHA-3310 provides that the GCA be designed such that the GCCs that comprise the GCA meet the provisions of HHA-3100 and HHA-3200.

The staff finds HHA-3310 to be acceptable because the staff agrees with the approach to maintain the design of the GCCs in the design of the GCA. The staff reviews HHA-3100 and HHA-3200 elsewhere in this section of this NUREG.

HHA-3320 Design Considerations

HHA-3321 Design and Service Loadings

HHA-3321 states that the provisions of HHA-3120 apply.

The staff finds HHA-3321 to be acceptable because it calls for the application of HHA-3120, which the staff has reviewed and determined to be acceptable for the reasons stated above in this section of this NUREG. HHA-3321 is acceptable for the same reasons.

HHA-3322 Special Considerations

HHA-3322 states that the provisions of HHA-3140 apply.

The staff finds HHA-3322 to be acceptable because it calls for the application of HHA-3140, which the staff has reviewed and determined to be acceptable for the reasons stated above in this section of this NUREG. HHA-3322 is acceptable for the same reasons.

HHA-3323 General Design Rules

HHA-3323 states that the provisions of HHA-3212 apply, except when they conflict with HHA-3300. In the case of a conflict, HHA-3300 governs the design of the GCA.

The staff finds HHA-3323 to be acceptable because HHA-3323 clearly defines the hierarchy of provisions between HHA-3212 and HHA-3300. HHA-3323 also calls for the application of HHA-3212, which the staff has reviewed and determined to be acceptable for the reasons stated above in this section of this NUREG. To the extent HHA-3323 applies HHA-3212, HHA-3323 is acceptable for the same reasons.

HHA-3330 Design of the Graphite Core Assembly

HHA-3330 lists the general criteria for the design of the GCA in paragraphs (a) through (i). These criteria include the arrangement of the GCC and considerations for inspection, repair, and removal of the GCC after shutdown.

The staff finds HHA-3330, paragraphs (a) through (f), and paragraph (i) to be acceptable because the provisions are sufficient to provide a minimum acceptable standard for the design of GCAs. However, the staff is not endorsing the provisions of HHA-3330(g) because requirements for inservice inspection are outside of the scope of ASME Code III-5, Subsection HH, Subpart A. The scope of the rules in Subsection HH, Subpart A, is clearly defined in HAB-1100 and HHA-1100, both of which do not include provisions for inservice inspection.

Table HHA-3221-1 Design Allowable Probability of Failure

Table HHA-3221-1 summarizes the POF limits and is referenced in several places.

The staff finds Table HHA-3221-1 to be acceptable because the information in the table is a summary of provisions in HHA-3000, all of which the staff has reviewed and determined to be acceptable as set forth in this section of this NUREG.

Figure HHA-3221-1 Design Allowable Stresses Flowchart for SRC-1 Graphite Core Component

Figure HHA-3221-1 provides a flowchart of the design allowable stress limits and is referenced in several places in HHA-3000.

The staff finds Figure HHA-3221-1 to be acceptable because the information in the figure summarizes the provisions in HHA-3000, all of which the staff has reviewed and determined to be acceptable as set forth in this section of this NUREG.

3.24.4 Article HHA-4000 Machining, Examination, and Testing

HHA-4100 General Requirements

HHA-4110 Introduction

HHA-4110 provides that GCCs be machined, examined, and tested in accordance with the provisions of HHA-4000 and those described in the Construction Specification. The party responsible for GCC machining should be a G Certificate Holder or a G Quality System Certificate Holder.

The staff finds HHA-4110 to be acceptable because the provisions identified and referenced in the subsubarticle are sufficient to provide a minimum acceptable standard for the machining, examination, and testing of GCCs.

HHA-4120 Certification of Materials and Machining by the Graphite Core Component Manufacturer

HHA-4121 Means of Certification

HHA-4121 calls for the GCC manufacturer to complete a G-2 Data Report to certify that the materials used comply with the material specification and that the machining, examination, and testing of all GCCs comply with the provisions listed therein.

The staff finds HHA-4121 to be acceptable because it is appropriate and reasonable to call for the completion of the G-2 Data Report, in accordance with Article HAB-8000, as the vehicle for certification. Doing so provides documented evidence that all applicable material, machining, examination, and testing provisions have been met. Section 3.2.7 of this report includes the staff's review of HAB-8000.

HHA-4122 Certification of Examinations and Tests

HHA-4122 calls for the GCC manufacturer to prepare and distribute certified reports of the examination and tests that it performs, in accordance with Table HAB-3255-1.

The staff finds HHA-4122 to be acceptable because the preparation of examination and test reports will assure that the results of examinations and tests performed by the manufacturer will be documented and readily available to show conformance with the provisions of this article. Also, the staff has reviewed Table HAB-3255-1 and determined that it is acceptable. Section 3.2.3 of this report includes the staff's review of Table HAB-3255-1.

HHA-4123 Identification of Materials and Machined Graphite Core Components

HHA-4123.1 Materials

HHA-4123.1 calls for the rejection of material that is not clearly marked in accordance with HHA-2140. The lack of clear markings in accordance with HHA-2140 raises doubt about the provenance and quality of the material. Accordingly, the staff finds HHA-4123.1 to be acceptable because it is reasonable and appropriate to reject material that is not clearly marked in accordance with HHA-2140, which the staff has reviewed and determined to be acceptable. Section 3.24.2 of this report documents the staff's review of HHA-2140.

HHA-4123.2 Machined Graphite Core Components

HHA-4123.2 consists of subsubparagraphs (a) through (e), which provide provisions for the marking of GCCs.

The staff finds HHA-4123.2 to be acceptable because the provisions adequately facilitate material identification and traceability.

HHA-4130 Joining

HHA-4130 calls for graphite items that need joining to be done so mechanically. The staff finds HHA-4130 to be acceptable because it provides for graphite items to be joined only by mechanical means. Other means of joining, such as chemical bonding, may not be feasible for high-temperature reactor applications and could result in unacceptable contamination or damage to the graphite.

HHA-4200 Machining, Examination, and Testing

HHA-4210 Procedures, Qualification, and Evaluation

HHA-4211 General Requirements

HHA-4211 calls for nondestructive examinations to be performed by qualified personnel and that the results of examinations be evaluated in accordance with applicable acceptance standards. The staff finds HHA-4211 to be acceptable because calling for qualified personnel to perform the NDE of graphite components is one measure for ensuring that the NDE is correctly performed. The staff notes that this provision is equivalent to other provisions of the ASME Code approved by the NRC through incorporation by reference in 10 CFR 50.55a.

HHA-4212 Nondestructive Examination Procedures

HHA-4212 calls for all NDEs to be performed in accordance with detailed written procedures. The paragraph also provides that measures be taken to ensure that the GCC is not contaminated during examination.

The staff finds HHA-4212 to be acceptable because performing NDE of graphite components in accordance with written procedures is one measure to ensure that the NDE is correctly performed. HHA-4212 is also equivalent to other provisions of the ASME Code approved by the NRC through incorporation by reference in 10 CFR 50.55a. The provision to avoid contaminating the GCC during examination is in conformance with Section 8.1 in ASTM D7219-08, “Standard Specification for Isotropic and Near-isotropic Nuclear Graphites” (ASTM, 2008a) and Section 7.1 in ASTM D7301-08, “Standard Specification for Nuclear Graphite Suitable for Components Subjected to Low Neutron Irradiation Dose” (ASTM, 2008b). This provision is necessary to ensure that NDE of GCC does not adversely affect the material properties of the GCC. Accordingly, this provision is acceptable to the staff.

HHA-4213 Qualifications of Examination Personnel

HHA-4213 calls for all personnel performing NDEs under this Article to be qualified on the basis of education, training, and examination in accordance with the organization’s Quality System Program.

The staff finds HHA-4213 to be acceptable because the activities HHA-4213 calls for are effective in qualifying NDE personnel to perform their assigned duties, which is one measure for ensuring that NDE is correctly performed. HHA-4213 is also equivalent to other provisions of the ASME Code approved by the NRC through incorporation by reference in 10 CFR 50.55a. HAB-3820 contains detailed provisions for the qualification of examination personnel, which the NRC staff finds acceptable for the reasons stated in Section 3.2.3 of this NUREG.

HHA-4220 Graphite Core Component Machining

HHA-4221 General

HHA-4221 calls for all GCC to be machined and finished according to shop drawings and documented procedures. HHA-4221 explicitly provides that GCC be protected from contamination and handling damage.

The staff finds HHA-4221 to be acceptable because calling for machining and finishing GCC according to shop drawings and document procedures is one measure for assuring that GCC will be correctly fabricated in accordance with design specifications. The provision to protect GCC from contamination and handling damage is necessary GCC material and structural properties are not adversely affected during fabrication. Accordingly, this provision is acceptable to the staff.

HHA-4222 Machining Facilities and Tools

HHA-4222 provides detailed provisions for machining facilities and tools in subparagraphs (a) through (h) that are intended to avoid graphite contamination and damage. HHA-4222 refers to Table HHA-4222-1, “Prohibited and Controlled Substances,” for substances that should either be avoided or minimized when machining.

The staff finds HHA-4222 to be acceptable because the rules identified and referenced in this paragraph are reasonable and sufficient to provide a minimum acceptable standard for machining facility and tool cleanliness that, if implemented, would avoid contamination of the graphite.

The staff notes that ASTM D7219-08 recommends that the supplier provide chemical impurity data on the nuclear graphite and limits on key impurities agreed upon between the supplier and the purchaser.

HHA-4223 Receiving Inspection

HHA-4223 states provisions for the receiving inspection to be conducted on material before releasing it for GCC machining.

The staff finds HHA-4223 to be acceptable because conduction a receipt inspection on material before using is one method for ensuring GCC is fabricated from material that meets design specifications.

HHA-4224 Other Processing Steps

HHA-4224 provides that procedures detail the measures in place to ensure material traceability during the machining of GCC. The staff finds HHA-4224 to be acceptable because it establishes one method for ensuring GCC is fabricated from material that meets design specification.

HHA-4230 Graphite Core Component Examination

HHA-4231 General

HHA-4231 provides that machined GCC be examined in compliance with the rules in this Article. The G Certificate Holder or the G Quality System Certificate Holder performs the examinations.

The staff finds HHA-4231 to be acceptable because the provisions identified and referenced in the paragraph are sufficient to provide a minimum acceptable standard for GCC examination, including the type of entity that must perform these examinations.

HHA-4232 Dimensional Examination

HHA-4232 provides the dimensions of all machined and finished GCC to be examined. Any GCC with one or more dimensions out of tolerance is rejected unless corrective machining is performed.

The staff finds HHA-4232 to be acceptable because the dimensional examination ensures that machined and finished GCCs will conform with shop drawings and the Construction Specification.

HHA-4233 Examination for Material Defects and Damage

HHA-4233.1 Requirements

HHA-4233.1 calls for the visual examination of each GCC following machining for material defects and for damage sustained during handling.

The staff finds HHA-4233.1 to be acceptable because it is appropriate and reasonable to examine GCCs for flaws, defects, or other damage following machining or handling. Doing so facilitates the detection and appropriate disposition of defects and damage before placement of the GCC in service.

HHA-4233.2 Material Defects/Flaws

HHA-4233.2 defines the classification of material defects and flaws and calls for comparison of observed defects against the appropriate acceptance criteria. The subparagraph also references Nonmandatory Appendix HHA-D for guidance on defects and flaws in graphite and their acceptability. The staff notes that Nonmandatory Appendix HHA-D is in the course of preparation.

The staff finds HHA-4233.2 to be acceptable because it is appropriate and reasonable to classify defects and flaws and compare them against appropriate acceptance criteria. Doing so facilitates the appropriate disposition of defects and damage before placement of the GCC in service. The NRC staff endorses HHA-4233.2 despite the fact that Nonmandatory Appendix HHA-D is still in preparation. HHA-D is not necessary to implement HHA-4233.2, but merely provides additional guidance on defects and flaws in graphite.

HHA-4233.3 Damage

HHA-4233.3 states that damage experience during handling shall be compared against acceptance criteria in HHA-4233.4.

The staff finds HHA-4233.3 to be acceptable because it is appropriate and reasonable to compare damage experienced during handling against appropriate acceptance criteria. Doing so facilitates the appropriate disposition of damage sustained during handling before placement of the GCC in service.

HHA-4233.4 Acceptance Criteria

HHA-4233.4 provides that the acceptance criteria for material defects, and damage incurred during handling, be defined by the Designer in the Construction Specification. The subparagraph also provides specific details on the information needed to define acceptance criteria for surface cracks, other surface defects and flaws or damage, and subsurface defects and flaws.

The staff finds HHA-4233.4 to be acceptable because it is appropriate and reasonable for the Construction Specification to provide the acceptance criteria. In addition, the staff believes that the responsibility for defining the acceptance criteria has been appropriately assigned to the Designer, who prepares the Construction Specification and certifies that all provisions therein have been met.

HHA-4233.5 Repair of Defects and Flaws

HHA-4233.5 states that only cracks that are visible at the surface, with the depth not exceeding 2.0 millimeters (0.079 inch), shall be subject to repair.

The staff determined that the overall approach to dispositioning defects and flaws in HHA-4233.5 is reasonable. However, the staff could not determine whether the provision for a crack to be dressed to a depth not exceeding 2 millimeters (0.079 inch) was generically applicable to all graphite grades and GCC designs. As a result, the staff commented to the ASME Working Group for Nonmetallic Design and Materials on the issue. Specifically, given the broad applicability of Subsection HH, Subpart A, to currently existing graphite grades, as well as those that may be developed in the future, the staff believes that the maximum repair depth allowed in HHA-4233.5 should be evaluated on a case-by-case basis to justify that it is adequate for the graphite grades and component sizes used in the design. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. Therefore, the staff is not endorsing the provisions of HHA-4233.5 that set a maximum allowed repair depth of 2 millimeters (0.079 inch). Designers should determine a maximum allowed repair depth and justify that it is adequate for the GCC design, including consideration of the size of the component and the graphite grade(s) used.

HHA-4240 Graphite Core Component Testing

HHA-4241 General

HHA-4241 calls for the Designer to identify in the Construction Specification all provisions necessary to carry out load testing of machined GCCs before final acceptance. The paragraph also calls for either a proof load test or an internal pressure test.

The staff finds HHA-4241 to be acceptable because the provisions in the paragraph are sufficient to represent a minimum acceptable standard for testing before final acceptance of the GCC.

HHA-4242 Graphite Core Component Testing

HHA-4242 indicates that the Construction Specification shall define a GCC that needs testing, either individually or as part of the subassembly. The paragraph also calls for the Construction Specification to specify the modes of loading to be applied as well as the maximum test load or pressure.

The staff finds HHA-4242 to be acceptable because the provision ensures that the Construction Specification will document all testing necessary before the final acceptance of the GCC. The staff notes that preparing the Construction Specification, as well as certifying that all provisions therein have been met, is the responsibility of the Designer.

HHA-4243 Post-Test Examination of Graphite Core Components

HHA-4243 states the G Certificate Holder shall examine all GCC-defined damage that resulted from testing. The criteria given in the Construction Specification determine the acceptability of damage.

The staff finds HHA-4243 to be acceptable because it is appropriate and reasonable to examine GCCs after testing. The staff also agrees with the approach for the Construction Specification to provide details on the necessary examination techniques and acceptance criteria. Doing so facilitates the detection and appropriate disposition of damage sustained during testing before placement of the GCC in service.

HHA-4244 Trial Assembly

HHA-4244 indicates that the Designer shall define the provision for trial assembly of portions of the GCA in the Construction Specification.

The staff finds HHA-4244 to be acceptable because the provisions specified in the paragraph are sufficient to represent a minimum acceptable standard for what is needed for the trial assembly of portions of the GCA.

HHA-4250 Graphite Core Component Packaging

HHA-4250 lists the minimum packing and storage procedures to include in the Construction Specification in subparagraphs (a) through (e). The subparagraphs ensure GCCs are properly packaged to prevent damage and contamination. Additionally, each package is appropriately marked and documented.

The staff finds HHA-4250 to be acceptable because the provisions specified in the subsubarticle are sufficient to provide a minimum acceptable standard for the packaging and storage of GCCs. The staff also believes that the provisions therein facilitate the prevention of unwanted contamination and damage, as well as material traceability.

Table HHA-4222-1 Prohibited and Controlled Substances

Table HHA-4222-1 identifies prohibited substances, which may not be used or introduced into the graphite during machining, and controlled substances, the use of which should be minimized in the processing of materials to limit any contamination.

The staff finds Table HHA-4222-1 to be acceptable because it clearly identifies specific chemical elements that should not be introduced into graphite during machining, handling, and other operations. It also clearly identifies chemical elements for which potential contamination of graphite should be controlled.

3.24.5 Article HHA-5000 Installation and Examination

The opening text in Article HHA-5000 describes the scope of the Article. The staff finds the opening text in HHA-5000 to be acceptable because the scope of the Article is clearly defined.

HHA-5100 General Requirements

HHA-5110 Introduction

HHA-5110 describes the general process to be followed, from machining of a GCC to the installation of the GCA, and references the applicable ASME Code provisions. Additionally, HHA-5110 states that these activities shall be performed by a G Certificate Holder or a G Quality System Certificate Holder, as described in Article HAB-3000.

The staff finds HHA-5110 to be acceptable because it provides general information on the provisions specified in other portions of ASME Code III-5, which the staff has reviewed and determined to be acceptable. Specifically, the staff reviews the HAB-3000, HHA-4000, and the specific provisions in HHA-5000 in their respective sections of this NUREG.

HHA-5200 Storage, Unpacking, and Examination

HHA-5210 Storage and Unpackaging

HHA-5210 lists the minimum standards for storage, unpackaging, and examination of GCCs at the site in subparagraphs (a) through (f) and refers to HHA-4250 for the minimum standards for packaging and storage before transportation to the site.

The staff finds HHA-5210 to be acceptable because the provisions specified in the subsubarticle are sufficient to provide a minimum acceptable standard for the storage, unpackaging, and examination of GCCs at the site. Also, the provisions of HHA-5210 adequately facilitate the prevention of unwanted damage or contamination; the performance of a receipt inspection; and appropriate disposition of discrepancies, defects, and damage before installation of the GCC.

HHA-5220 Examination of Graphite Core Components

HHA-5221 General Requirements

HHA-5221 provides that individuals qualified as called for by Article HHA-5000 perform the examination of GCCs after unpacking and that examination results be evaluated using the acceptance standards defined in Article HHA-5000.

The staff finds HHA-5221 to be acceptable because the performance of examinations by qualified personnel and the evaluation of examination results against applicable acceptance standards is an effective part of ensuring that GCCs are undamaged as received or that any damage is identified and dispositioned. This approach is also consistent with other provisions of the ASME Code currently approved by the NRC through incorporation by reference in 10 CFR 50.55a.

HHA-5222 Examination Procedures

HHA-5222 calls for the execution of all examinations performed under this Article in accordance with detailed written procedures and that those procedures be available to the Graphite Inspector upon request.

The staff finds HHA-5222 to be acceptable because performing all examinations in accordance with written procedures is an effective part of ensuring that GCCs are undamaged or that any damage is identified and dispositioned. This provision is also consistent with other provisions of the ASME Code currently approved by the NRC through incorporation by reference in 10 CFR 50.55a.

HHA-5223 Qualifications of Examination Personnel

The staff finds HHA-5223 to be acceptable because the provisions helps to ensure that examinations of GCCs are correctly performed, which ensures that GCCs are undamaged or that damage is identified and dispositioned. In addition, HHA-5223 is consistent with other provisions of the ASME Code currently approved by the NRC through incorporation by reference in 10 CFR 50.55a.

HHA-5300 Installation

HHA-5310 Documentation

HHA-5311 Construction Procedures

HHA 5311 provides that construction procedures include the information specified in subparagraphs (a) through (k).

The staff finds HHA-5311 to be acceptable because the scope of information called for by the paragraph is sufficient to provide a minimum acceptable standard for the content of construction procedures. The staff notes that HHA-5311 also references HAB-3451, which the staff has reviewed and approved for the reasons stated in Section 3.2.3 of this NUREG.

HHA-5400 Examination During Installation

HHA-5400 provides that, during installation, a G certificate Holder complete examinations after each layer of the GCC has been installed in the GCA.

The staff finds HHA-5400 to be acceptable because this approach will ensure that the GCCs are installed in the correct location and orientation and that the GCA will remain within the specified tolerances.

HHA-5500 Examination Post-Installation

HHA-5500 calls for the G Certificate Holder to examine the GCA and any interfacing metallic items or structures to ensure that they have been installed correctly according to construction procedures and field drawings, that they are within specified tolerances, and that no foreign bodies are present. The subarticle also includes provisions for the results of the examinations.

The staff finds HHA-5500 to be acceptable because it is appropriate and reasonable to examine the GCA after installation. The staff also believes that the provisions specified in this subarticle are sufficient to provide a minimum acceptable standard for what is necessary during a postinstallation examination of a GCA.

3.24.6 Article HHA-8000 Nameplates, Stamping, and Reports

HHA-8100 Requirements

HHA-8100 indicates that GCCs and the GCA shall meet the applicable provisions of Article HAB-8000. The staff finds HHA-8100 to be acceptable because it applies HAB-8000, which the staff has reviewed and determined to be acceptable for reasons stated in Section 3.2.7 of this NUREG.

3.25 <u>Mandatory Appendix HHA-I Graphite Material Specifications</u>

3.25.1 Article HHA-I-1000 Introduction

HHA-I-1100 Scope

HHA-I-1100 defines the scope of the Mandatory Appendix. The staff has determined that the scope of the Mandatory Appendix is clearly defined and is, therefore, acceptable.

HHA-I-1110 Material Specifications

HHA-I-1110 provides the accepted material specifications by reference to ASTM D7219-08 and ASTM D7301-08.

The staff finds HHA-I-1110 to be acceptable because the material specifications are provided by reference to consensus standards developed by a nationally recognized consensus standard body. Use of consensus standards in this manner is acceptable because it is consistent with the established NRC policy as described in NRC MD 6.5. The staff finds ASTM D7219-08 and ASTM D7301-08 acceptable as applied to HHA-I-1110 because the specifications adequately cover the classification, processing, and properties of nuclear grade graphite billets of sufficient size for nuclear reactor designers.

3.26 Mandatory Appendix HHA-II Requirements for Preparation of a Material Data Sheet

3.26.1 Article HHA-II-1000 Introduction

HHA-II-1000 provides a general description of the rules in the Mandatory Appendix in paragraphs (a) through (h).

The staff finds HHA-II-1000 to be acceptable because the provisions identified and referenced in that Article are sufficient to provide a minimum acceptable standard for the preparation of an MDS.

3.26.2 Article HHA-II-2000 Material Data Sheet Forms

HHA-II-2000 provides the MDS form in SI Units (MDS-1) and U.S. Customary units (MDS-2) and calls for completion of the form for each graphite grade used to construct the GCA.

The staff finds HHA-II-2000 to be acceptable because forms MDS-1 and MDS-2 are consistent with the provisions of HHA-2000, and the scope of material properties identified in the forms is adequate to provide a minimum acceptable standard for information necessary to facilitate the design of GCCs. The staff notes that the information in the MDS forms is not all inclusive, and additional material property data may be needed for some design scenarios. For example, the MDS forms do not have a place for permeability, which may be a property of interest in liquid-cooled graphite reactors. However, the staff believes that the ASME Code appropriately addresses this scenario in HHA-2000 by both allowing the Designer the flexibility to provide additional property data as needed and calling for publication in the MDS of all graphite properties used for design.

Form MDS-1 Material Data Sheet (SI Units)

Form MDS-1 lists material properties to be measured for each GCC and included with the Design Report. Material properties are to be reported in SI units.

The staff determined that MDS-1 is acceptable, based on the staff's review of HHA-II-2000, which is provided above.

Form MDS-2 Material Data Sheet (U.S. Customary)

Form MDS-2 lists material properties to be measured for each GCC and included with the Design Report. Material properties are to be reported in U.S. Customary units.

The staff determined that MDS-2 is acceptable, based on the staff's review of HHA-II-2000, which is provided above.

Table HHA-II-2000-1 Notes on Material Data Sheet, Forms MDS-1 and MDS-2

Table HHA-II-2000-1 contains annotated notes that define the parameters in the MDS and how they are to be determined. The staff has determined that Table HHA-II-2000-1 is acceptable because it provides clarifications and definitions for the items in Forms MDS-1 and MDS-2.

3.26.3 Article HHA-II-3000 Detailed Requirements for Derivation of the Material Data Sheet—As-Manufactured Properties

Article HHA-II-3000 contains equations for determining the material reliability parameters and the design allowable stress values.

The staff finds HHA-II-3000 to be acceptable because the procedures provided and calculation methods used to derive the as-manufactured material properties are reasonable and consistent with widely accepted calculation methods (e.g., calculation methods that have been in general use in engineering and science for several decades, including at the NRC).

During the review, the staff noted that Figures HHA-II-3100-1 and HHA-II-3100-2 could be more legible. These figures are for informational purposes only. The staff commented to the ASME Working Group for Nonmetallic Design and Materials on this issue. The Working Group is still developing its formal response but has informed the staff that it agrees with the comment and is making plans to address it. The acceptability of HHA-II-3000 is not affected by this comment because it is administrative in nature.

3.26.4 Article HHA-II-4000 Detailed Requirements for Derivation of the Material Data Sheet—Irradiated Material Properties

HHA-II-4100 provides general rules to be followed for the derivation of irradiated material properties in subparagraphs (a) through (e).

The staff finds HHA-II-4000 to be acceptable because the provisions specified in the Article are sufficient to provide a minimum acceptable standard for the derivation of irradiated material properties to include in the MDS.

3.27 Mandatory Appendix HHA-III Requirements for Generation of Design Data for Graphite Grades

3.27.1 Article HHA-III-1000 Scope

Article HHA-III-1000 defines the scope of the Appendix. The Article also notes that it is the policy of the ASME Committee to only adopt graphite specifications that have been adopted by ASTM and by other recognized national or international organizations. Finally, HHA-III-1000 indicates that changes to the graphite grade will call for the generation of new design data.

The staff finds HHA-III-1000 to be acceptable because the scope of the Mandatory Appendix is clearly defined, and it is appropriate and reasonable to generate new design data when the graphite grade is changed.

3.27.2 Article HHA-III-2000 General Requirements

HHA-II-2000 provides general provisions for graphite design data in subparagraphs (a) through (c).

The staff finds HHA-III-2000 to be acceptable because the general provisions identified in this Article are sufficient to provide a minimum acceptable standard for generating graphite design data. The staff notes that HHA-II-2000 references HAB-4000 as an option for Quality Assurance Program measures.

3.27.3 Article HHA-III-3000 Properties To Be Determined

The opening text of HHA-III-3000 calls for the Designer to generate adequate data for the design values in the MDS with consideration of the heterogeneity of graphite in the statistical nature of the data. HHA-III-3000(a) calls for the use of test standards specified in ASTM C781-08, "Standard Practice for Testing Graphite Materials for Gas-Cooled Nuclear Reactor Components" (ASTM, 2008c), and Article HHA-III-3000(b) provides the test procedure to be filed with the material test data when a test standard does not exist or has to be customized.

The staff finds the opening text in HHA-III-3000 to be acceptable because the staff agrees with the approach to call for the Designer to generate adequate data based on testing performed in accordance with a recognized consensus standard. The staff finds ASTM C781-08 acceptable as applied to HHA-III-3000 because the practice references a comprehensive list of test methods (17 ASTM standards) for testing graphite and boronated graphite materials, and using these test methods will yield valid test results. The staff also agrees that it is appropriate and reasonable to retain the test procedure with the material data if a test standard does not exist or has to be customized.

HHA-III-3100 As-Manufactured Graphite

HHA-III-3100 provides that the mechanical, physical, and thermal properties specified in subparagraphs (a) through (j) be determined for as-manufactured graphite. The subarticle also specifies the maximum temperature increments for which temperature-dependent properties are to be measured and provides that they be measured from room temperature to at least the maximum intended use temperature. HHA-III-3100 states that the temperature dependence of only one strength parameter need be determined. Other strength parameters can be assumed to change the same relative fraction.

The staff finds HHA-III-3100 to be acceptable because the scope of material properties defined by this subarticle is sufficient to provide a minimum acceptable standard for the necessary properties to be determined for as-manufactured graphite. The staff also believes that the provisions associated with the measurement of temperature-dependent properties are appropriate and reasonable.

HHA-III-3200 Oxidized Graphite

Subarticle HHA-III-3200 provides that the properties specified in subparagraphs (a) through (c) be determined for oxidized graphite.

The staff finds HHA-III-3200 to be acceptable because the scope of material properties defined by this subarticle is sufficient to provide a minimum acceptable standard for the properties to be determined for oxidized graphite. Given that oxidation of graphite is a known area of continued work for ASME, the staff understands that the list of necessary properties is not all inclusive and that additional oxidized material properties may be needed for some design scenarios. However, the staff has determined that the ASME Code appropriately addresses this scenario in HHA-2000 by both allowing the Designer the flexibility to provide additional property data as needed and providing that all graphite properties used for design be published in the MDS.

HHA-III-3300 Irradiated Graphite

Subarticle HHA-III-3300 provides that the properties specified in subparagraphs (a) through (f) be determined for irradiated graphite. The subarticle also provides that the test data represent and envelope the irradiation conditions in service. It also defines the maximum temperature increment in which data may be collected. Measurements that do not envelope the maximum use temperature are permissible to measure changes in properties with irradiation without annealing irradiation-induced damage.

The staff finds HHA-III-3300 to be acceptable because the scope of material properties defined by HHA-III-3300 is sufficient to provide a minimum acceptable standard for the properties to be determined for irradiated graphite. Given that irradiation of graphite is a known area of continued work for ASME, the staff understands that the list of properties is not all inclusive and that additional irradiated material properties may be needed for some design scenarios. However, the staff has determined that the ASME Code appropriately addresses this scenario in HHA-2000 by both allowing the Designer the flexibility to provide additional property data as needed and providing that all graphite properties used for design be published in the MDS.

3.27.4 Article HHA-III-4000 Requirement for Representative Data

The staff finds HHA-III-4000 acceptable because the staff has determined subarticles HHA-III-4100 and HHA-III-4200 to be acceptable as documented below.

HHA-III-4100 As-Manufactured Graphite

Subarticle HHA-III-4100 provides that as-manufactured material property data be obtained from at least three charges, consisting of a minimum of four billets per charge, and includes more specific sampling provisions for graphite formed by extruding, molding, and isomolding.

The staff finds HHA-III-4100 to be acceptable because the provisions specified are sufficient to provide a minimum acceptable standard for the test specimen sample needed to generate representative data for as-manufactured graphite.

HHA-III-4200 Irradiated or Oxidized Graphite

HHA-III-4200 states that irradiated or oxidized material property data shall be obtained from material that is representative of the material used for the generation of the irradiated or oxidized material design data. The subarticle also assigns responsibility for the determination and justification of representative data to the Designer.

The staff finds the second paragraph of HHA-III-4200 to be acceptable because the responsibility for the determination and justification of representative data is appropriately assigned to the Designer. However, the staff could not determine the acceptability of the first sentence in HHA-III-4200 because the staff could not determine the meaning or intent of the provision. As a result, the staff commented to the ASME Working Group for Nonmetallic Design and Materials to obtain the clarification needed. The Working Group is still developing its formal response. Therefore, the NRC staff endorses HHA-III-4200 with the following exception: Irradiated or oxidized material property data used to populate the Material Data Sheet should come from testing performed on material that is representative of production billet specimens exposed to environmental conditions that are consistent with the qualification envelope defined in the Design Specification.

3.27.5 Article HHA-III-5000 Use of Historical Data

Article HHA-III-5000 indicates that historical data shall meet the provisions of Appendix HHA-III and be for the same graphite grade. Testing is necessary to demonstrate historical data are applicable to current production material.

The staff finds HHA-III-5000 to be acceptable because it is reasonable to allow the use of previous test data generated for the same graphite grade. The staff also agrees that it is appropriate and reasonable to perform testing to demonstrate that the historical data are applicable to the current production material. Doing so provides assurance that credit for historical data is taken only when it is justifiable to do so.

3.28 Nonmandatory Appendix HHA-A Graphite as a Structural Material

Nonmandatory Appendix HHA-A provides information intended to familiarize the reader with graphite as a structural material for nuclear reactors. It provides insights on various steps of the manufacturing process in subsubarticles HHA-A-1100 through HHA-A-1150 and on the importance of grain orientation in HHA-A-1160.

The staff finds Nonmandatory Appendix HHA-A to be acceptable because the information contained therein is intended for educational purposes. Specifically, the Nonmandatory Appendix contains no administrative or technical provisions for the construction of GCCs or the GCA but rather provides history and insights on graphite that would be useful to the uninformed reader. HHA-A is not necessary, and the rest of the 2017 Edition of ASME Code III-5 remains valid without this appendix. Accordingly, the NRC staff finds that Nonmandatory Appendix HHA-A does not contain information for the NRC to endorse.

3.29 Nonmandatory Appendix HHA-B Environmental Effects in Graphite

Nonmandatory Appendix HHA-B provides information intended to familiarize the reader with environmental effects in graphite used for nuclear reactors. The environmental effects covered in the Nonmandatory Appendix are radiation damage, gas coolant-graphite interactions (oxidation), and salt-coolant interactions.

The staff finds Nonmandatory Appendix HHA-B to be acceptable because the information contained therein is intended for educational purposes. Specifically, the Nonmandatory Appendix contains no administrative or technical provisions for the construction of GCCs or the GCA but rather provides insights on the environmental effects discussed in the cited references. HHA-B is not necessary, and the rest of the 2017 Edition of ASME Code III-5 remains valid without this appendix. Accordingly, the NRC staff finds that Nonmandatory Appendix HHA-B does not contain information for the NRC to endorse.

3.30 Nonmandatory Appendix HHA-D Guidance on Defects and Flaws in Graphite

The staff is unable to make a finding on the acceptability of Nonmandatory Appendix HHA-D at this time because this Appendix is in the course of preparation. HHA-D is not necessary, and the rest of the 2017 Edition of ASME Code III-5 remains valid without this appendix. Accordingly, the NRC staff finds that Nonmandatory Appendix HHA-D does not contain information for the NRC to endorse.

4 TECHNICAL REVIEW OF CODE CASES N-861 AND N-862

ASME asked the NRC to review two Code Cases, N-861, "Satisfaction of Strain Limits for Division 5 Class A Components at Elevated Temperature Service Using Elastic-Perfectly Plastic Analysis," and N-862, "Calculation of Creep-Fatigue for Division 5 Class A Components at Elevated Temperature Service Using Elastic-Perfectly Plastic Analysis."

4.1 Code Case N-861, Satisfaction of Strain Limits for Division 5 Class A Components at Elevated Temperature Service Using Elastic-Perfectly Plastic Analysis

Code Case N-861 provides an alternative method for evaluating strain limits to comply with ASME Code III-5-HBB, HBB-T-1320 (satisfaction of strain limits using elastic analysis), and HBB-T-1330 (satisfaction of strain limits using simplified inelastic analysis). This Code Case is termed a simplified method because it does not require the use of comprehensive full inelastic constitutive equations that account for both time-independent plasticity and time-dependent creep. This elastic-perfectly plastic (EPP) simplified analysis method also demonstrates compliance with code strain and stress limits without the use of stress classification procedures. Strain limits for 304 SS and 316H SS, as approved for use in ASME Code III-5, Table HBB-I-14.1(a), may be satisfied when performed in accordance with the requirements of this Code Case.

Code Case N-861 permits the use of EPP finite element analysis to show compliance with strain limits and ratcheting. As described in NUMARK, 2020c, the four-step method of the Code Case implements the EPP method and will result in conservative predictions. The staff has reviewed NUMARK, 2020c and agrees with these conclusions. Validation problems performed to date have shown that EPP analysis always produces conservative results, as cited in NUMARK, 2020c. The staff finds the EPP analysis methods found in Code Case N-861 conform to the previously studied EPP analysis. Therefore, the staff finds Code Case N-861 acceptable, with additional discussion of selected items discussed below.

4.1.1 Article 1 General Requirements

This article provides conservative predictions based on the four-step method, with the exception of structures where geometrical nonlinearities exist. The staff finds the general provisions acceptable as written. As discussed above in Section 4.1, proper implementation of the four-step method ensures conservative predictions will result, except where nonlinearities, such as skeletal structures, exist because bounds cannot be established.

The four-step method, discussed in more detail in Article 4 and Appendix I to the Code Case, ensure conservative strain limits are predicted using the EPP methods. The four-step method uses a strain distribution based on the lower of the yield and the isochronous stress strain curve at temperature, which bounds the strain distribution caused by the actual creep at temperature. Verification and validation tests (analytical, numerical, and comparison with experiments) performed to date have shown conservative predictions result except for skeletal structures. Skeletal structures (e.g., a bar with a uniform axial load throughout) are currently precluded for use with the Code Case. For example, Jetter et al. (2017) investigated the "two bar" skeletal problem, where tests were conducted and test results were analyzed using Code Case N-861.

Nonconservative results were obtained for some of the design space. Further work is ongoing with regard to skeletal structures, but this is not yet complete (see Appendix for examples).

This design methodology is not applicable to skeletal structures nor to structures where geometrical nonlinearities exist (e.g., canopy or omega seals).

4.1.2 Article 2 Load Definition

The staff finds the load definitions to be acceptable because the composite load definitions defined in the Code Case ensure that conservative predictions of ratcheting will result.

The load definitions conform to ASME Code III-5, Mandatory Appendix HBB-T service loading methodology, which the staff found acceptable in Section 3.9 of this NUREG. The grouping of service cycles into composite cycles as in Code Case N-861, Appendix I, for assessment using this Code Case, will always provide conservative results for the reasons described in Carter, 2005.

4.1.3 Article 3 Numerical Model

The staff finds Article 3 conforms to the method for EPP analysis described in Section 4.1 of this NUREG.

The numerical model requirements are properly defined to encompass all details, including holes and fillets. Representative examples for application of the Code Case, including mesh requirements, can be found in NUMARK, 2020c, and references cited therein. Requirements for solution accuracy, however, are not specified. Modeler advice to ensure numerical convergence and solution accuracy during the analysis might be considered. For example, elastic-plastic finite element codes typically increase the increment size automatically based on convergence history as the solution marches along. Therefore, care must be taken to ensure that details in loading are not missed. The current requirement states that the “model must also be accurate for small details” and is not specific enough for finite element analysis. Recent work (NUMARK, 2020c and references cited therein) has identified possible issues with convergence using EPP methods due to numerical roundoff errors, as well.

4.1.4 Article 4 Requirements for Satisfaction of Strain Limits

Article 4 of the Code Case is consistent with HBB-T rules except that the strains are obtained from the numerical solution. The rules for defining the pseudo yield stress are consistent with the EPP method, as discussed in NUMARK, 2020c, ensuring conservatism for the reasons discussed above, in Section 4.1 of this NUREG. The iterative procedure described to determine the target strain is adequate and provides design safety using this Code Case.

The staff finds Article 4 conforms to the method for EPP analysis described in Section 4.1 of this NUREG. Therefore, the staff finds the satisfaction of strain limits for ratcheting analysis using the four-step procedure in this Article to be acceptable.

Additional validation cases for examples with weldments could be useful as this Code Case is extended to additional materials. This is not considered to be a safety-significant issue. The strain limit provisions for welding are consistent with HBB-T provisions (half the base metal limits), which the staff has determined to be acceptable for reasons stated in Section 3.9 of this

NUREG. Therefore, the staff finds the satisfaction of strain limits for weldments for ratcheting analysis using the four-step procedure in this Article to be acceptable.

4.1.5 Article 5 Weldments

Article 5 indicates that the additional considerations apply for the implementation of the strain limits for weldments, which are reviewed below.

Subarticle 5.1 Weld Region Model Boundaries

The staff finds the definition of the weld region boundaries to be acceptable as written for the following reasons. The various weld configurations in Code Case N-861 are the same as those in ASME Code III-5, HBB-4000, and the corresponding reference to NB-4000 are consistent with ASME Code weld configuration definitions. Also, the definition of the weld region boundaries in the Code Case is consistent with the provisions of HBB-T. The staff has determined that the weld configurations and definition of the weld region boundaries to be acceptable for reasons stated in Section 3.9 of this NUREG.

Subarticle 5.2 Requirements

The staff finds these requirements to be acceptable because the Code Case provisions are consistent with HBB-T-1714, which the staff has determined were acceptable in Section 3.9.6 of this NUREG.

Subarticle 5.3 Properties

The staff finds the properties in subarticle 5.3 of Code Case N-861 to be acceptable because assuming the thermal and physical properties of weldments and base metal to be the same for allowed permissible weld and base metal combinations is a generally accepted engineering practice. The staff notes that this subarticle refers to Table HBB-I-14.10 where it should refer to Table HBB-I-14.1(b). Therefore, the staff finds this subarticle acceptable with that clarification.

Subarticle 5.4 Dissimilar Metal Welds

This subarticle of the Code Case is a placeholder, there is no provision in the Code Case for dissimilar metal welds.

4.1.6 Mandatory Appendix I Ratcheting Analysis

This Appendix specifies details of the Code Case N-861 ratcheting analysis procedures in a series of steps. The goal is to bound the ratcheting strains using EPP analysis to provide a simple alternative to HBB. The Code Case N-861 analysis procedure is based on finite element solutions to satisfy ratcheting strain assessment requirements for code acceptance. As mentioned above, the four-step method ensures conservative results will be produced for structures that satisfy Code Case definitions. Moreover, validation cases examined to date (see NUMARK, 2020c and references cited therein) have all produced conservative results when compared to analytical solutions and experimental results. Notably, results from these validation cases are conservative compared to the HBB procedures. Appendix I details the procedures discussed above for this Code Case. The staff finds the EPP analysis methods found in Code Case N-861, Appendix I, conform to the previously studied EPP analysis, as cited in NUMARK, 2020c. Therefore, the staff finds Code Case N-861, Appendix I, acceptable.

4.2 Code Case N-862, Calculation of Creep-Fatigue for Division 5 Class A Components at Elevated Temperature Service Using Elastic-Perfectly Plastic Analysis

Code Case N-862 provides an alternative method for evaluating creep-fatigue damage to comply with ASME Code III-5, HBB-3252 and Nonmandatory Appendix HBB-T. This is termed a simplified method because it does not require the use of comprehensive full inelastic constitutive equations that account for both time-independent plasticity and time-dependent creep. The EPP method is significantly more straightforward to implement than the HBB methods. Code Case N-862 has been validated through comparison to several example cases using Nonmandatory Appendix HBB-T, as discussed in NUMARK, 2020c.

As described in NUMARK, 2020c, the four-step method of the Code Case implements the EPP method and will result in conservative predictions. The staff has reviewed NUMARK, 2020c and agrees with these conclusions. Validation problems performed to date have shown that EPP analysis always produces conservative results, as cited in NUMARK, 2020c. The staff finds the EPP analysis methods found in Code Case N-862 conform to the previously studied EPP analysis. Therefore, the staff finds Code Case N-862 acceptable, with additional discussion of selected items discussed below.

4.2.1 Article 1 General Requirements

The staff finds Article 1 to be acceptable because the Code Case procedures are consistent with HBB-T provisions which the NRC staff found acceptable above in Section 3.9, and the four-step method ensures conservative predictions. Code Case N-862 applies to Type 304 SS and 316 SS.

The staff concludes that the general requirements provisions ensure conservative predictions and are consistent with HBB-T code requirements based on the staff's review of the four-step method. The four-step method ensures conservative predictions of creep damage and "shakedown" when using EPP analyses following the procedures of the Code Case. The four-step method uses a strain distribution based on the lower of the yield and the isochronous stress strain curve at temperature, which bounds the strain distribution caused by the actual creep at temperature. "Shakedown" is a high-temperature design requirement that refers to the achievement of cyclic elastic or elastic-plastic behavior throughout the component with time and cycles. Under the provisions of the Code Case, the pseudo yield stress for the EPP analysis is chosen as a temperature-dependent minimum stress to rupture value to ensure shakedown occurs with guidance from Mandatory Appendix I. The Code Case procedure does not necessarily predict the actual component creep-fatigue life, but when the Code Case procedures are followed, they will ensure a conservative design basis for metallic components at high temperature.

4.2.2 Article 2 Load Definition

The staff finds the load definitions to be acceptable because the four-step method ensures that using the simplified composite load spectrum, which eliminates hold times, still results in conservative creep-fatigue life predictions. The NUMARK, 2020c validation study's references (i.e., Jetter et al. (2017), Sham et al. (2015)) refer to these cycles as "rapid cycles" to contrast with "hold cycles" in full inelastic analysis because all the complicated hold cycles need not be included. The elimination of hold times in the composite cycle(s) (or rapid cycles) permits practical solutions within a reasonable time, which is an advantage for designers.

Article 2 conforms to the HBB-3113 service load definitions for load Levels A, B, and C. The grouping of service cycles into composite cycles as in Appendix I to this Code Case, provides conservative results based on the staff's review of the four-step method, as discussed in Section 4.2 of this NUREG.

4.2.3 Article 3 Numerical Model

The staff finds Article 3 conforms to the method for EPP analysis described in Section 4.2 of this NUREG. The staff finds the numerical model requirements provisions to be acceptable with the exception of requirements for solution accuracy.

Code Case N-862 includes provisions that ensure the numerical model encompasses all details, including holes and fillets. The Code Case does not, however, include provisions for solution accuracy. Accuracy should be established for both the thermal and structural solution processes. Modeler advice to ensure numerical convergence during the analysis should be included (e.g., mesh convergence studies) for clarity. Recent work in "Report on an Assessment of the Application of EPP Results from the Strain Limit Evaluation Procedure to the Prediction of Cyclic Life Based on the SMT Methodology" (Jetter et al., 2017), has identified possible issues with convergence using EPP methods due to numerical roundoff errors. The modeler needs to ensure that the automatic time incrementation in modern finite element codes does not skip important load step features.

Despite the possible issues with convergence, designers are experienced finite element modelers who will take steps to avoid these issues. Therefore, the staff finds Article 3 to be acceptable.

4.2.4 Article 4 Calculation of Creep Damage

The staff finds the creep damage assessment using the four-step procedure in this Article to be acceptable for the following reasons. The staff notes that the calculation of creep damage in Article 4 uses the S_r values from Tables HBB-I-14.6A through HBB-I-14.6F. The staff identified exceptions and limitations on the use of these S_r values for some materials, including Type 304 and Type 316, as detailed in Section 3.7 of this NUREG. Users should comply with these exceptions and limitations when applying Article 4. The staff finds this Article to be acceptable because the Code Case uses the results of the EPP analysis to calculate the creep damage time fraction using the appropriate pseudo yield stress.

The Code Case provisions in Article 4 are consistent with the HBB provisions except the creep damage is obtained from the EPP numerical solution. The rules for defining the pseudo yield stress and, therefore, creep damage time fraction are consistent with the EPP method ensuring conservative assessments. The iterative procedure described to determine the pseudo yield stress ensures that shakedown will occur after the eventual proper choice of the trial time duration.

4.2.5 Article 5 Calculation of Fatigue Damage

The staff finds the satisfaction of strain limits for ratcheting analysis using the four-step procedure in this Article to be acceptable for the following reasons. The assessment of HBB-T determined that the linear damage creep-fatigue rules, with all appropriate safety factors, ensure conservative designs will result. Since the rules of HBB-T-1413, along with margins and safety factors, and the fatigue curves in HBB-T-1420 are used in the Code Case, conservative predictions are ensured using the EPP analysis procedure for the fatigue damage assessment.

The shakedown analysis with the Code Case EPP procedure is used to obtain the total strains (elastic plus plastic). The equivalent strain range is then determined using HBB-T-1413 (or HBB-T-1414, when principal strains do not rotate). The design fatigue curves of Figure HBB-T-1420-1 are then used to obtain the allowable cycles for each cycle type. Therefore, the procedure follows current Section III HBB rules, except the shakedown strains are determined from the EPP analysis. The four-step method ensures that the resulting strains are conservative and are, therefore, acceptable.

4.2.6 Article 6 Weldments

The staff finds the satisfaction of strain limits for weldments for shakedown analysis using this Article to be acceptable because it is consistent with the provisions for weldments in Nonmandatory Appendix HBB-T, which the NRC staff determined to be acceptable above in Section 3.9 of this NUREG.

Subarticle 6.2 Allowable Cycles

The staff finds this subarticle to be acceptable as written, since the allowable cycles in the weldments are reduced by one half, which introduces a conservative margin of 50 percent.

Subarticle 6.3 Requirements

The strain concentration factors for analysis of weld geometry of HBB-T-1714 are to be used for Code Case N-862. The staff finds this subarticle to be acceptable as written since it follows the HBB-T-1714 requirements directly, which have been approved by the staff above in Section 3.9.6 of this NUREG.

Subarticle 6.4 Properties

The staff finds subarticle 6.4 of Code Case N-862 to be acceptable because assuming the thermal and physical properties of weldments and base metal to be the same for allowed permissible weld and base metal combinations is a generally accepted engineering practice. The staff notes that this subarticle refers to Table HBB-I-14.10 where it should refer to Table HBB-I-14.1(b). Therefore, the staff finds this subarticle acceptable with that clarification.

Subarticle 6.5 Weld Region Model Boundaries

This subarticle is consistent with HBB-T procedures; therefore, the staff finds this acceptable based on its review of HBB-T-1714 in Section 3.9.6 of this NUREG.

Subarticle 6.6 Dissimilar Metal Welds

This subarticle of the Code Case is a placeholder, there is no provision in the Code Case for dissimilar metal welds.

4.2.7 Mandatory Appendix I Shakedown Analysis

Code Case N-862 represents a new alternative design method based on general analysis procedures with minimal rules that is consistent with current ASME Code requirements for HBB and HBB-T. This Appendix specifies the details of the Code Case N-862 shakedown analysis procedures in a series of steps. The staff finds the EPP analysis methods found in Code Case N-861, Appendix I, conform to the previously studied EPP analysis, as cited in NUMARK, 2020c. Therefore, the staff finds Code Case N-862, Appendix I, acceptable.

4.3 Summary

The staff finds Code Cases N-861 and N-862 to be acceptable, as discussed above. Conservative results are expected using these Code Cases are expected. Bounding theorems, mainly developed in the 1960s and 1970s before the widespread use of computational modeling, form the basis for the conservative nature of these Code Cases. They represent an alternative to satisfying the strain limits (N-861) and creep-fatigue damage (N-862) using EPP finite element modeling where the perfectly plastic "yield" stress is defined to account for creep damage. Validation tests, using both full inelastic computational modeling and new test data, have been performed that validate the conservative nature of these Code Cases. The staff notes that Code Case N-862 may be overly conservative in practice.

5 SUMMARY

Table 5-1, below, provides a summary of the staff's technical review of the 2017 Edition of ASME Code III-5, and identifies whether the section is accepted as written, accepted with exceptions and or limitations, or rejected. Any portions of ASME Code III-1 used as required or permited by ASME Code III-5 must follow any applicable conditions identified in 10 CFR 50.55a.

Table 5-1 Summary of Technical Review of 2017 Edition of ASME Code, Section III, Division 5

General Requirements, Low Temperature Metallic Components, and Supports:

ASME Code Section	Acceptance
General Requirements, Metallic Materials (Subsection HAA)	Accepted as written, except as identified below
HAA-1110, Scope	Accepted with exception/limitation
Class A Metallic Pressure Boundary Components, Low Temperature Service (HBA)	Accepted as written
Class B Metallic Pressure Boundary Components (HCA)	Accepted as written
Class A and Class B Metallic Supports, Low Temperature Service (HFA)	Accepted as written
Class A Metallic Core Support Structures, Low Temperature Service (HGA)	Accepted as written

Elevated Temperature Metallic Components:

ASME Code Section	Acceptance
Class A Metallic Pressure Boundary Components, Elevated Temperature Service (HBB)	
1000 Introduction	Accepted as written
2000 Material	Accepted as written
3000 Design	Accepted as written, except as identified below
HBB-3430, Pump Types	Accepted with exception/limitation
HBB-3600, Piping Design	Accepted with exception/limitation
HBB-3660, Design of Welds	Accepted with exception/limitation
4000 Fabrication and Installation	Accepted as written
5000 Examination	Accepted as written
6000 Testing	Accepted, except as indicated below
HBB-6212, Test Medium and Test Temperature	Accepted with exception/limitation
7000 Overpressure Protection	Accepted as written

Table 5-1 Summary of Technical Review of 2017 Edition of ASME Code, Section III, Division 5 (Cont.)

ASME Code Section	Acceptance
8000 Nameplates, Stamping with the Certification Mark, and Reports	Accepted as written
Mandatory Appendix HBB-I-14 Tables and Figures	Accepted with exceptions/limitations
Mandatory Appendix HBB-II Use of SA-533 Type B, Class 1 Plate and SA-508 Grade 3, Class 1 Forgings and Their Weldments for Limited Elevated Temperature Service	Accepted as written
Nonmandatory Appendix HBB-T Rules for Strain, Deformation, and Fatigue Limits at Elevated Temperatures	Accepted as written, except as identified below
HBB-T-1420, Limits Using Inelastic Analysis	Accepted with exception/limitation
HBB-T-1510, General Requirements	Accepted with exception/limitation
HBB-T-1520, Buckling Limits	Accepted with exception/limitation
HBB-T-1710, Special Strain Requirement at Welds	Accepted with exception/limitation
Nonmandatory Appendix HBB-U Guidelines for Restricted Material Specifications to Improve Performance in Certain Service Applications	Accepted as written
Nonmandatory Appendix HBB-Y Guidelines for Design Data Needs for New Materials	Not reviewed, not endorsed
Class B Metallic Pressure Boundary Components, Elevated Temperature Service (HCB)	
1000 Introduction	Accepted as written
2000 Material	Accepted as written
3000 Design	Accepted as written, except as identified below
HCB-3115, Design Report and Certification	Accepted with exception/limitation
HCB-3150, Limitations on Use	Accepted with exception/limitation
4000 Fabrication and Installation	Accepted with exception/limitation
5000 Examination	Accepted as written
6000 Testing	Accepted as written
7000 Overpressure Protection	Accepted as written
8000 Nameplates, Stamping with the Certification Mark, and Reports	Accepted as written
Mandatory Appendix HCB-I Stress Range Reduction Factor for Piping	Accepted as written
Mandatory Appendix HCB-II Allowable Stress Values for Class B Components	Accepted as written
Mandatory Appendix HCB-III Time–Temperature Limits for Creep and Stress-Rupture Effects	Accepted as written
Class A Metallic Core Support Structures, Elevated Temperature Service (HGB)	
1000 Introduction	Accepted as written

Table 5-1 Summary of Technical Review of 2017 Edition of ASME Code, Section III, Division 5 (Cont.)

ASME Code Section	Acceptance
2000 Material	Accepted as written
3000 Design	Accepted as written
4000 Fabrication and Installation	Accepted as written
5000 Examination	Accepted as written
8000 Nameplates, Stamping with the Certification Mark, and Reports	Accepted as written
Mandatory Appendix HGB-I Rules for Strain, Deformation, and Fatigue Limits at Elevated Temperatures	Accepted as written
Mandatory Appendix HGB-II Rules for Construction of Core Support Structures, Extended for Restricted Service at Elevated Temperature, without Explicit Consideration of Creep and Stress-Rupture	Accepted as written
Mandatory Appendix HGB-III Buckling and Instability	Accepted as written, except as identified below
HGB-III-2000 Buckling Limits: Time-Independent Buckling	Accepted with exception/limitation
Mandatory Appendix HGB-IV Time–Temperature Limits	Accepted as written

Graphite and Composites:

ASME Code Section	Acceptance
General Requirements, Graphite and Composite Materials (HAB)	
1000 Introduction	Accepted as written, except as identified below
HAB-1140, Use of Code Editions, Addenda, and Cases	Accepted with exception/limitation
2000 Classification of Graphite Core Components	Accepted as written
3000 Responsibilities and Duties	Accepted as written, except as identified below
HAB-3126, Subcontracted Calibration Services	Accepted with exception/limitation
HAB-3127, Subcontracted Testing Services	Accepted with exception/limitation
HAB-3220, Categories of the Owner's Responsibilities	Accepted with exception/limitation
HAB-3255, Certification of the Design Specifications	Accepted with exception/limitation
HAB-3352, Design Report	Accepted with exception/limitation
HAB-3360, Certification of the Construction Specification, Design Drawings, and Design Report	Accepted with exception/limitation
HAB-3842.2, Evaluation of the Qualified Material Organization's Program by GC Certificate Holders	Accepted with exception/limitation

Table 5-1 Summary of Technical Review of 2017 Edition of ASME Code, Section III, Division 5 (Cont.)

ASME Code Section	Acceptance
HAB-3853.1, Quality System Manual	Accepted with exception/limitation
HAB-3855.3, Approval and Control of Suppliers of Subcontracted Services	Accepted with exception/limitation
4000 Quality Assurance	Accepted as written, except as identified below
HAB-4130, Establishment and Implementation	Accepted with exception/limitation
HAB-4134.6, Document Control	Accepted with exception/limitation
HAB-4134.7, Control of Purchased Items and Services	Accepted with exception/limitation
5000 Authorized Inspection	Accepted as written, except as identified below
HAB-5125, Duties of Authorized Nuclear Inspector Supervisor (Graphite)	Accepted with exception/limitation
HAB-5230, Scope of Work, Design, Specifications, and Design Reports	Accepted with exception/limitation
HAB-5250, Qualification Records	Accepted with exception/limitation
HAB-5290, Data Reports and Construction Reports	Accepted with exception/limitation
7000 Reference Standards	Accepted as written, except as identified below
HAB-7100, General Requirements	Accepted with exception/limitation
8000 Certificates and Data Reports	Accepted as written, except as identified below
HAB-8161, Evaluation for a Certificate	Accepted with exception/limitation
HAB-8180, Renewal	Accepted with exception/limitation
9000 Glossary	Accepted as written
Mandatory Appendix HAB-I Certificate Holder’s Data Report Forms, Instructions, and Application Forms for Certificates of Authorization	Accepted as written
Class A Nonmetallic Core Components, Graphite Materials (HHA)	
1000 Introduction	Accepted as written
2000 Material	Accepted as written

Table 5-1 Summary of Technical Review of 2017 Edition of ASME Code, Section III, Division 5 (Cont.)

ASME Code Section	Acceptance
3000 Design	Accepted as written, except as identified below
HHA-3141, Oxidation	Accepted with exception/limitation
HHA-3142.4, Graphite Cohesive Life Limit	Accepted with exception/limitation
HHA-3143, Abrasion and Erosion	Accepted with exception/limitation
HHA-3330, Design of the Graphite Core Assembly	Accepted with exception/limitation
4000 Fabrication and Installation	Accepted as written, except as identified below
HHA-4233.5, Repair of Defects and Flaws	Accepted with exception/limitation
5000 Examination	Accepted as written
8000 Nameplates, Stamping with the Certification Mark, and Reports	Accepted as written
Mandatory Appendix HHA-I Graphite Material Specifications	Accepted as written
Mandatory Appendix HHA-II Requirements for Preparation of a Material Data Sheet	Accepted as written
Mandatory Appendix HHA-III Requirements for Generation of Design Data for Graphite Grades	Accepted as written, except as identified below
HHA-III-2000, General Requirements	Accepted with exception/limitation
HHA-III-4200, Irradiated or Oxidized Graphite	Accepted with exception/limitation

Code Cases

Code Case	Code Case Title	Acceptance
N-861	Satisfaction of Strain Limits for Division 5 Class A Components at Elevated Temperature Service Using Elastic-Perfectly Plastic Analysis	Accepted with exception/limitation
N-862	Calculation of Creep-Fatigue for Division 5 Class A Components at Elevated Temperature Service Using Elastic-Perfectly Plastic Analysis	Accepted with exception/limitation

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NRC FORM 335 (12-2010) NRCMD 3.7 — U.S. NUCLEAR REGULATORY COMMISSION	1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)
BIBLIOGRAPHIC DATA SHEET *(See instructions on the reverse)*	NUREG-2245
2. TITLE AND SUBTITLE Technical Review of the 2017 Edition of ASME Code, Section III, Division 5, "High Temperature Reactors"	3. DATE REPORT PUBLISHED MONTH: January YEAR: 2023 4. FIN OR GRANT NUMBER
5. AUTHOR(S) A. Yeshnik, J. Poehler, A. Tsirigotis, M. Gordon, A. Hull, E. Focht, S. Downey, M. Breach, K. Hsu, Y. Diaz-Castillo, R. Davis, R. Roche-Rivera, T. Lupold, J. Hoellman	6. TYPE OF REPORT Technical 7. PERIOD COVERED (Inclusive Dates)

8. PERFORMING ORGANIZATION - NAME AND ADDRESS (If NRC, provide Division, Office or Region, U. S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)

Division of Advanced Reactors and Non-Power Production and Utilization
Facilities Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

9. SPONSORING ORGANIZATION - NAME AND ADDRESS (If NRC, type "Same as above", if contractor, provide NRC Division, Office or Region, U. S. Nuclear Regulatory Commission, and mailing address.)

Same as above

10. SUPPLEMENTARY NOTES

J. Hoellman, Project Manager

11. ABSTRACT (200 words or less)

This NUREG documents the U.S. Nuclear Regulatory Commission (NRC) staff's technical evaluation of the 2017 Edition of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code), Section III, "Rules for Construction of Nuclear Facility Components," Division 5, "High Temperature Reactors," and select associated Code Cases for acceptability and endorsement. As of this writing, the absence of a code of construction endorsed by the NRC for nuclear reactors operating above 425 degrees Celsius (800 degrees Fahrenheit) is a significant obstacle for advanced non-light-water-reactor designs. Review of an elevated temperature code of construction during a licensing review of a new nuclear power plant would result in substantial cost and a longer schedule for the requested action. This report documents the NRC's technical review and findings that support its endorsement of ASME Code, Section III, Division 5.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)	13. AVAILABILITY STATEMENT
American Society of Mechanical Engineers (ASME) Section III, Division 5 High Temperature Reactors	unlimited
	14. SECURITY CLASSIFICATION *(This Page)* unclassified *(This Report)* unclassified
	15. NUMBER OF PAGES
	16. PRICE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555-0001

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NUREG-2245

Technical Review of the 2017 Edition of ASME Code, Section III, Division 5, "High Temperature Reactors"

January 2023