STP-NU-037

OPERATING CONDITION ALLOWABLE STRESS VALUES IN ASME SECTION III SUBSECTION NH

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FOREWORD

This document is the result of work resulting from Cooperative Agreement DE-FC07-05ID14712 between the U.S. Department of Energy (DOE) and ASME Standards Technology, LLC (ASME ST-LLC) for the Generation IV (Gen IV) Reactor Materials Project. The objective of the project is to provide technical information necessary to update and expand appropriate ASME materials, construction and design codes for application in future Gen IV nuclear reactor systems that operate at elevated temperatures. The scope of work is divided into specific areas that are tied to the Generation IV Reactors Integrated Materials Technology Program Plan. This report is the result of work performed under Task 6 titled "Operating Condition Allowable Stress Values."

ASME ST-LLC has introduced the results of the project into the ASME volunteer standards committees developing new code rules for Generation IV nuclear reactors. The project deliverables are expected to become vital references for the committees and serve as important technical bases for new rules. These new rules will be developed under ASME's voluntary consensus process, which requires balance of interest, openness, consensus and due process. Through the course of the project, ASME ST-LLC has involved key stakeholders from industry and government to help ensure that the technical direction of the research supports the anticipated codes and standards needs. This directed approach and early stakeholder involvement is expected to result in consensus building that will ultimately expedite the standards development process as well as commercialization of the technology.

ASME has been involved in nuclear codes and standards since 1956. The Society created Section III of the Boiler and Pressure Vessel Code, which addresses nuclear reactor technology, in 1963. ASME Standards promote safety, reliability and component interchangeability in mechanical systems.

Established in 1880, the American Society of Mechanical Engineers (ASME) is a professional not-for-profit organization with more than 127,000 members promoting the art, science and practice of mechanical and multidisciplinary engineering and allied sciences. ASME develops codes and standards that enhance public safety, and provides lifelong learning and technical exchange opportunities benefiting the engineering and technology community. Visit www.asme.org for more information.

The ASME Standards Technology, LLC (ASME ST-LLC) is a not-for-profit Limited Liability Company, with ASME as the sole member, formed in 2004 to carry out work related to newly commercialized technology. The ASME ST-LLC mission includes meeting the needs of industry and government by providing new standards-related products and services, which advance the application of emerging and newly commercialized science and technology and providing the research and technology development needed to establish and maintain the technical relevance of codes and standards. Visit www.stllc.asme.org for more information.

ABSTRACT

Part I - Review of Current Operating Conditions Allowable Stresses in ASME Section III Subsection NH and Overview of the Availability of the Original and Augmented Databases Needed to Establish S_o, S_t, and S_r

The current operating condition allowable stresses provided in ASME Section III, Subsection NH were reviewed for consistency with the criteria used to establish the stress allowables and with the allowable stresses provided in ASME Section II, Part D. It was found that the S_o values in ASME III-NH were consistent with the S values in ASME II-D for the five materials of interest. However, it was found that $0.80S_r$ was less than S_o for some temperatures for four of the materials. Only value for alloy 800H appeared to be consistent with the criteria on which S_o values are established. With the intent of undertaking a more detailed evaluation of issues related to the allowable stresses in ASME III-NH, the availabilities of databases for the five materials were reviewed and augmented databases were assembled.

Part II and Part III - Assessment of the Databases Leading to the Establishment of Allowable Stresses in ASME Section III Subsection NH and Recommended Action for the Correction of Currently Listed Values for S_o, S_t and S_r

Based on a review of the current operating condition allowable stresses provided in ASME BPV Section III, Subsection NH and the finding of inconsistencies between the S values in ASME BPV Section II, Part D and the S_o values in ASME BPV III-NH for the five materials included in ASME BPV III-NH, expanded databases for stress-rupture, tertiary creep and time to 1% strain were assembled for use estimating and possibly revising the stress allowables in ASME BPV III-NH. A preliminary evaluation showed that, in spite of the substantially larger databases, the stress allowables S_t and S_r for some materials were within 5% of the existing values. It was judged that the existing values in ASME BPV III-NH for alloy 800H and 9Cr-1Mo-V steel were conservative and adequate for use in the temperature range of interest to the Generation IV reactor design. A number of issues were identified in using the databases to estimate the stresses based on tertiary creep and time to 1% strain criteria. Some actions were suggested to resolve the issues. The greatly expanded times for the databases were expected to help in extending allowable stresses to at least 500,000 hours.

PART I

Review of Current Operating Conditions Allowable Stresses in ASME Section III Subsection NH

and

Overview of the Availability of the Original and Augmented Databases Needed to Establish S_o, S_t and S_r

1 INTRODUCTION

In ASME Section II Part D, the criteria for setting S of wrought products above room temperature are provided in Appendix 1 Table I-100 and include:

(i) $S_T/3.5$, where S_T is the "specified minimum specified tensile strength at room temperature,"

(ii) $1.1S_TR_T/3.5$, where "R_T is the ratio of the average temperature dependent trend curve value of tensile strength to the room temperature tensile strength,"

(iii) $2S_Y/3$, where S_Y is the "specified minimum yield strength at room temperature,"

(iv) $2S_YR_Y/3$ or $0.9\ S_YR_Y$ where R_Y is the "ratio of the average temperature dependent trend curve value of yield strength to room temperature yield strength,"

(v) $F_{avg}S_{Ravg}$, where S_{Ravg} is the "average stress to cause rupture at the end of 100,000 hr" and F_{avg} is a "multiplier applied to S_{Ravg}" that has a value of 0.67 for temperatures of 1500°F and below,

(vi) $0.80S_{Rmin}$, where S_{Rmin} is the "minimum stress to cause rupture at the end of 100,000 hr" and

(vii) $1.0S_c$, where S_c is the "average stress to produce a creep rate of 0.01%/1,000 hr."

In ASME III-NH, the criteria for setting S_m, "the lowest stress intensity value at a given temperature among the time-independent strength properties" for wrought metal are provided in ASME Section II Part D Appendix 2 and Table 2-100(a). These include:

(i) $S_T/3$, where S_T is the "specified minimum specified tensile strength at room temperature,"

(ii) $1.1\ S_TR_T/3$, where "R_T is the ratio of the average temperature dependent trend curve value of tensile strength to the room temperature tensile strength,"

(iii) $2S_Y/3$, where S_Y is the "specified minimum yield strength at room temperature" and

(iv) $2S_YR_Y/3$ or $0.9\ S_YR_Y$ where R_Y is the "ratio of the average temperature dependent trend curve value of yield strength to room temperature yield strength."

The criteria for setting S_o, the "maximum allowable value of general primary membrane stress intensity to be used as a reference for stress calculation under Design Loadings" above room temperature, are identical to the criteria of ASME Section II-D Appendix 1 for wrought products and S_o is intended to be equivalent to S, "except for a few cases at lower temperatures" as defined in NH-3221. This exception sometimes appears as a lower value than S_m or greater value than S_t at the temperature where S_o transitions from the time-independent criteria to the time-dependent criteria.

The criteria in ASME III-NH for setting S_t, "the temperature and time-dependent stress intensity limit," include:

(i) "100% of the average stress required to obtain a total strain (elastic, plastic and creep) of 1%,"

(ii) "80% of the minimum stress to cause initiation of tertiary creep" and

(iii) "67% of the minimum stress to cause rupture."

The criteria for S_t, therefore, differ from the criteria for setting S and S_o in the sense that they need to cover a range of times from 1 to 300,000 hr, whereas S and S_o only pertain to 100,000 hr.