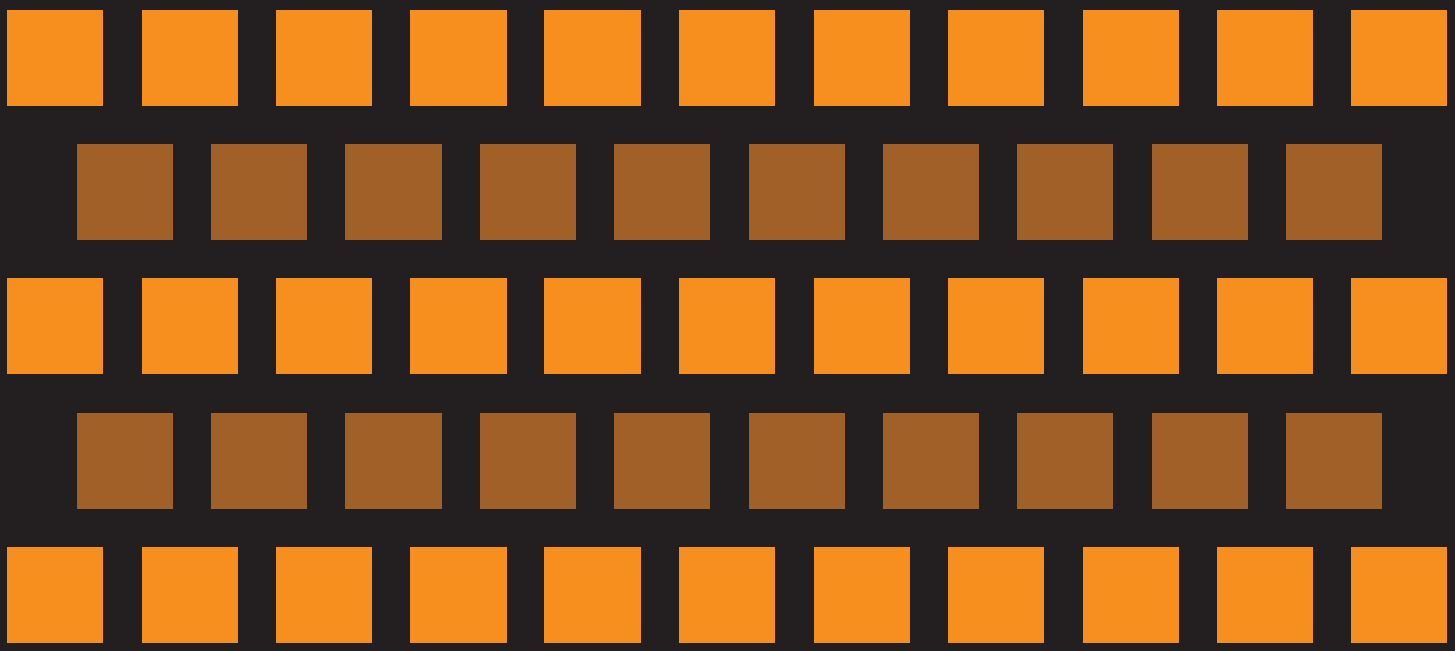
STP-NU-063

CORRECT AND EXTEND ALLOWABLE STRESS VALUES FOR 304 AND 316 STAINLESS STEEL



ASME STANDARDS TECHNOLOGY, LLC

STP-NU-063

CORRECT AND EXTEND ALLOWABLE STRESS VALUES FOR 304 AND 316 STAINLESS STEEL

Prepared by:

Mainak Sengupta
James E. Nestell

MPR Associates, Inc.

ASME STANDARDS TECHNOLOGY, LLC

Date of Issuance: June 28, 2013

This report was prepared as an account of work sponsored by the U.S. Department of Energy (DOE) through the ASME Standards Technology, LLC (ASME ST-LLC).

ASME Standards Technology, LLC
Two Park Avenue, New York, NY 10016-5990

ISBN No. 978-0-7918-6906-2

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FOREWORD

This document is the result of work resulting from Cooperative Agreement DE-NE0000288 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 14a titled "Correct and Extend Allowable Stress Values for 304 and 316 Stainless Steel."

ASME ST-LLC has introduced the results of the project into the American Society of Mechanical Engineers (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 135,000 members and volunteers 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.

EXECUTIVE SUMMARY

This report was undertaken to correct the existing Subsection NH stress values and extend the time-dependent allowable stress values for 304 and 316 stainless steel to 500,000 hours. Extending the Code allowable stress values to 500,000 hours will allow Generation IV plant components to have a 60-year design life. The current stress values in the NH Code are based on an older and obsolete materials property database. The time-dependent data currently available in the public domain for 304 and 316 stainless steel is much larger and has been used for developing the new allowable stress values.

The allowable stress values that were corrected and extended are the time-dependent minimum stress-to-rupture strength (S_r), and stress intensity (S_t and S_{mt}) values. The values were developed using a Larson-Miller parameter analysis. The S_r and S_t values at long times and high temperatures are lower than the current Code values, and the long time, high temperature S_t values are controlled by the time-to-tertiary creep data. The upper limit on the S_t values was revised from "minimum stress to 1% strain" to "average stress to 1% strain". Therefore, the short time, low temperature stress values are higher than the current NH Code. Statistical analyses did not reveal any correlation between the time-to-tertiary creep and time-to-rupture.

1 INTRODUCTION

1.1 Purpose

This report presents revised allowable stress values for 304 and 316 stainless steel for inclusion in the ASME Boiler and Pressure Vessel Code (ASME BPV Code), Section III, Subsection NH – Components in Elevated Temperature Service.

1.2 Background

The U.S. Department of Energy (DOE) has established a program to develop next generation nuclear reactors. This program, known as Generation IV (Gen IV), addresses research and development (R&D) activities that are necessary to develop high efficiency, next generation nuclear power plants such as high temperature gas-cooled and liquid-cooled reactors. One of the challenges identified by this program was the development of necessary codes and standards to support the design and construction of Gen IV reactors. Therefore, a three-year collaborative effort was established between DOE and ASME to address technical issues related to codes and standards applicable to the Generation IV program.

A number of tasks were identified by ASME Standards Technology, LLC (ASME ST-LLC) as high priority items for Gen IV reactors. One of these tasks is Task 14a. The purpose of Task 14a is to correct and extend the allowable stress values for Type 304 and 316 stainless steels (SS) to 500,000 hours in ASME BPV Code, Section III, Subsection NH.

A precursor to this task was ASME ST-LLC Task 6 (STP-NU-037), which reviewed the current creep property databases for materials in NH for consistency, and for the feasibility of extending allowable stress values for a design life of 500,000 hours from 300,000 hours. Task 6 identified several deficiencies in time-independent properties of 304 and 316 SS. It was noted that the current stress allowable values for 304 and 316 SS in NH were developed using databases that were significantly smaller than the currently available database. In addition, the S_t values in NH were based on limited data for time-to-tertiary creep and time-to-1% creep strain, and would need to be revised.

MPR reviewed the final reports prepared for Task 6 and is aware of the statistical challenges associated with this task.

The time dependent stress allowable values, S_t (temperature and time dependent stress intensity) and S_r (expected minimum stress to rupture), the time independent, S_m (lowest stress intensity at a given temperature among time independent strength quantities) and S_{mt} (lower of the two stress intensity values, S_m and S_t) values were developed using augmented databases for 304 and 316 SS as a part of this task.

The time dependent stress values were developed using creep test data. The creep tests were conducted in various institutions and laboratories around the world. The primary sources of test data were American Society of Testing and Materials (ASTM), Oak Ridge National Laboratory (ORNL) and the National Institute of Material Science Japan (NIMS) among others.

1.3 Analysis Procedure

The allowable stress values for the two stainless steels were developed using Larson Miller Parameter (LMP) analysis. The LMP analysis is widely used to extend the creep properties to times and temperatures beyond the test data. Long-term creep data (greater than 100,000 hours or approximately 12 years) is difficult to develop as these tests are impractical. The LMP method provides a convenient method to extrapolate the stress values to times greater than 100,000 hours and