STP-NU-013

IMPROVEMENT OF ASME NH

FOR GRADE 91 NEGLIGIBLE CREEP AND CREEP-FATIGUE

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IMPROVEMENT OF ASME NH FOR GRADE 91 NEGLIGIBLE CREEP AND CREEP FATIGUE

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FOREWORD

This document is the result of work resulting from Cooperative Agreement DE-FC07-05ID14712 between the US 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.

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.

The American Society of Mechanical Engineers (ASME) is a not-for-profit professional organization 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.

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ABSTRACT

This report provides recommendations for improvement of ASME NH for Grade 91 in the areas of negligible creep and creep-fatigue.

The report is separated into the following four parts.

Part I Improvement of ASME NH for Grade 91 (Negligible Creep)

Examines the current approaches available to define negligible creep and checks their applicability to Grade 91 steel. The work is based on material data available in France and the U.S.

Part II Improvement of ASME NH for Grade 91 (Creep-Fatigue)

Compares Subsection NH and RCC-MR creep-fatigue procedures. Comparisons are performed on cases defined on the basis of experimental test results available from Japan, France and the U.S. on Grade 91 steel. Particular attention was paid to the definition of safety factors and creep-fatigue damage envelope. Improvements to existing procedures are recommended.

Part III Proposed Test Program to Assess Negligible Creep Conditions of Modified 9Cr-1Mo

Part III is aimed at defining tests necessary to validate negligible creep conditions for Mod 9Cr-1 Mo material.

Part IV Proposed Test Program to Validate Creep-Fatigue Procedures for Modified 9Cr-1Mo

Part IV completes the work performed in Part II which, on the basis of creep-fatigue tests results available from Japan, Europe and the US, compared creep-fatigue procedures of ASME Subsection NH and RCC-MR Subsection RB.

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PART 1
IMPROVEMENT OF ASME NH
FOR GRADE 91
(NEGLIGIBLE CREEP)

1 INTRODUCTION

In the frame of the AREVA HTR-VHTR design, it is recommended to operate the Reactor Pressure Vessel (RPV) in the negligible creep regime in order to avoid the implementation of a surveillance program covering the monitoring of the creep damage throughout the whole life of the reactor. Within the two options that are currently under consideration for the RPV material of ANTARES (AREVA New Technology based on Advanced gas cooled Reactor for Energy Supply), the high chromium-alloyed steel known as grade 91 in ASTM SA 336 standard has more creep properties documented and is also expected to allow more severe hot transients. The purpose of this report is to discuss the negligible creep conditions of this steel, also called Mod. 9Cr-1Mo. Mod. 9Cr-1Mo is a ferritic steel and not an austenitic stainless steel. Following ASME Boiler and Pressure Vessel (B&PV) Code, Section III for Class 1 nuclear components, additional rules of Subsection NH which take creep and creep/fatigue interaction effects into account should be used for applications above the limit of 371˚C (700˚F). Thus, the definition of the negligible creep conditions is of prime importance to enable the use of elevated core inlet temperatures during normal operating conditions (400˚C at least) and to accommodate transients of limited duration. In addition, the negligible creep criteria will need to take account of the 60 year design life of the reactor which corresponds to 4.2×10^5 hours of operation (based on 80% availability).