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NEW MATERIALS FOR ASME SUBSECTION NH

Prepared by:

Kazuhiko Suzuki and Tai Asayama

Japan Atomic Energy Agency

Robert W. Swindeman

Cromtech Inc

Douglas L. Marriott

Stress Engineering Services Inc

ASME STANDARDS TECHNOLOGY, LLC

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

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 11 titled “New Materials for ASME Subsection NH.”

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

When selecting candidate materials, their resistance to environmental degradation caused by exposure to an HTGR helium atmosphere is a key factor. Improving the resistance of commercially available Nickel base super alloys to corrosive oxidation in low oxidizing potential atmospheres such as HTGR-He was discussed in Part I of this report, with reference to, for example, the improved Hastelloy X resulting in Hastelloy XR. With regard to the operating temperature, the required primary helium coolant temperature in the SI process (or IS process) was identified as being 950°C at the reactor outlet.

Review of the available information on Hastelloy XR and Inconel 617 as candidate materials was made in Part I of this report, and several critical issues discussed. Information on Inconel 617 is from a Japanese project. Those issues were identified with help from the author's experiences in developing the HTTR high temperature structural design guide. Some R&D needed to obtain approval for Subsection NH construction was then pointed out.

With estimating the strength characteristics, the design creep rupture strength was identified as being 14MPa for Hastelloy XR, even in the HTGR-He atmosphere. The OSDP (Orr-Sherby-Dorn Parameter) method was applied to Hastelloy XR as an extrapolation technique to gain creep rupture strength values, primarily because of scarcity of data on the longer rupture life region.

In Part II of this report, the bounding conditions were briefly summarized for the Next Generation Nuclear Plant (NGNP) that is the leading candidate in the Department of Energy Generation IV reactor program. Metallic materials essential to the successful development and proof of concept for the NGNP were identified. The literature bearing on the materials technology for high-temperature gas-cooled reactors was reviewed with emphasis on the needs identified for the NGNP. Several materials were identified for a more thorough study of their databases and behavioral features relative to the requirements ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NH.

Material properties required for the design and construction of components meeting the rules of ASME Section III Subsection NH (ASME III-NH) were reviewed in Part II. An overview of the data available for candidate "new materials" for the Next Generation Nuclear Plant (NGNP) was undertaken with respect to meeting the needs for incorporation of the materials into ASME III-NH. These materials included alloy 617, alloy 230 and alloy 556 for service to 800°C and above. For service below 800°C, an "enhanced strength" stainless steel typical of a new group of such steels was included. Although not a new material, alloy 800H was included in the review. The data needs identified in the National Laboratories testing plans for the NGNP were considered. In these plans, emphasis was placed on alloy 617 which is the leading candidate for the high-temperature metallic components in the NGNP for components operating above 800°C. It was found that the plans were very comprehensive and identified the data needs for both incorporation of a new alloy into ASME III-NH and the complementary database needed for the application of the Code. A comparison of the strength of several candidate alloys approved for ASME Section I or Section VIII, Division 1 construction was made and this comparison supported the selection of alloy 617 as the leading candidate on the basis of strength. With respect to compact heat exchangers, some concerns about the behavioral features of these alloys as fine-grained strip products were developed, and some comparisons were made between candidate alloys developed for high-temperature recuperators.