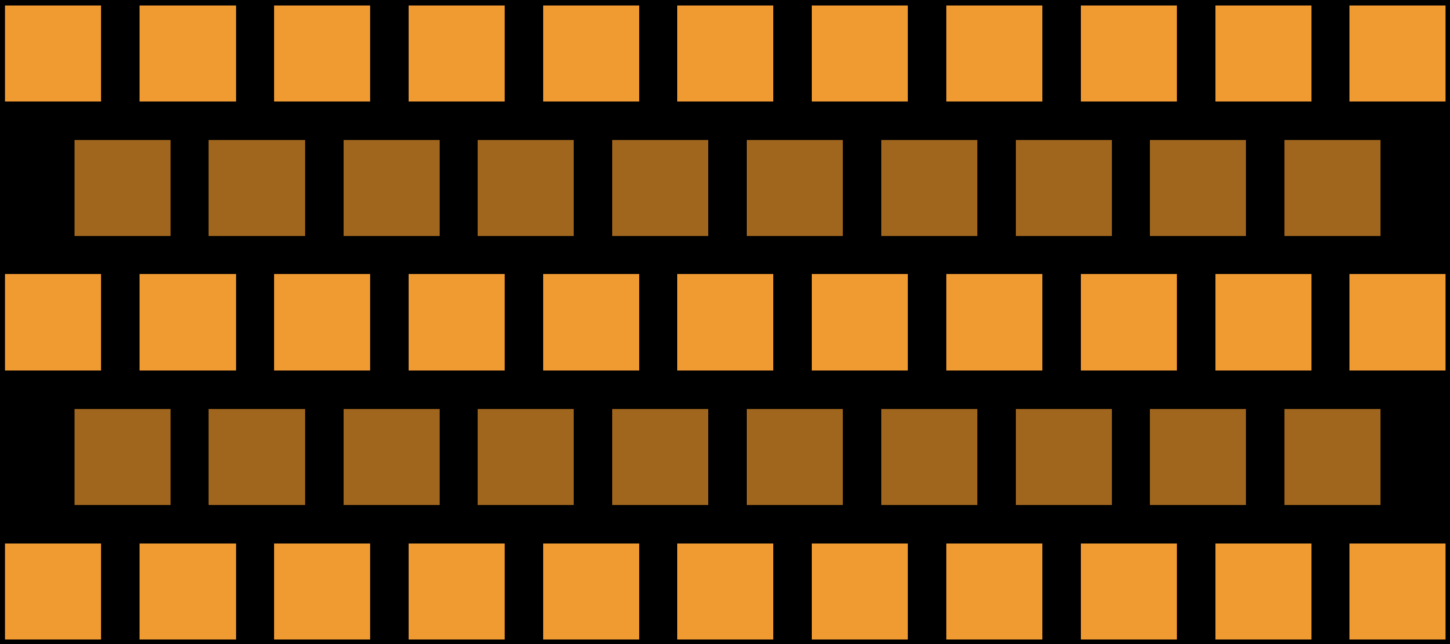
STP-NU-040

UPDATE AND IMPROVE SUBSECTION NH – SIMPLIFIED ELASTIC AND INELASTIC DESIGN ANALYSIS METHODS



ASME STANDARDS
TECHNOLOGY, LLC

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UPDATE AND IMPROVE SUBSECTION NH – SIMPLIFIED ELASTIC AND INELASTIC DESIGN ANALYSIS METHODS

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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 9 titled " Update and Improve Subsection NH – Simplified Elastic and Inelastic Design Analysis Methods."

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.

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ABSTRACT

This report is the result of work performed under Task 9 titled " Update and Improve Subsection NH – Simplified Elastic and Inelastic Design Analysis Methods." 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.

1 SUBTASK 9.1 – OUTLINE OF AN "IDEAL" HIGH TEMPERATURE CODE

The objective of this subtask is to develop a template for the "Ideal" high temperature design Code, in which individual topics can be identified and worked on separately in order to provide the detail necessary to comprise a comprehensive Code.

Like all ideals, this one may not be attainable as a practical matter. The purpose is to set a goal for what is believed the "Ideal" design Code should address, recognizing that some elements are not mutually exclusive and that the same objectives can be achieved in different way. Most, if not all existing Codes may therefore be found to be lacking in some respects, but this does not mean necessarily that they are not comprehensive.

While this subtask does attempt to list the elements which individually or in combination are considered essential in such a Code, the authors do not presume to recommend how these elements should be implemented or even, that they should all be implemented at all.

The scope of this subtask is limited to compiling the list of elements thought to be necessary or at minimum, useful in such an 'Ideal' Code; suggestions are provided as to their relationship to one another. Except for brief descriptions, where these are needed for clarification, neither this subtask, nor the report as a whole, attempts to address details of the contents of all these elements. Some, namely primary load limits (elastic, limit load, reference stress), and ratcheting (elastic, e-p, reference stress) are dealt with specifically in other subtasks of this report. All others are merely listed; the expectation is that they will either be the focus of attention of other active DOE-ASME GenIV Materials Tasks, e.g., creep-fatigue, or to be considered in future DOE-ASME GenIV Materials Tasks.

Since the focus of this report is specifically approximate methods, the authors have deemed it necessary to include some discussion on what is meant by "approximate." However, the topic will be addressed in one or more later subtasks.

1.1 Definition of "High Temperature"

"High temperature" is taken to refer here to the operating range of temperature within which time dependent, thermally activated deformation and damage processes, even under nominally steady loads below yield, become a significant factor in the behavior of load bearing components.

This definition is commonly taken to mean the appearance of creep as a significant mechanism, but others, such as thermal ageing and oxidation/corrosion are also important.

In practice, time dependency is a smooth function of temperature. Consequently, there is no clear context free boundary separating time-independent from time-dependent behavior. For specific forms of service conditions and material response, it is possible to define a temperature limit below which "high temperature" may be considered negligible in that the time dependent phenomena associated with high temperature behavior do not have a significant effect on design decisions. For the purpose of defining the applicability of a high temperature design Code, the threshold temperature marking the point above which time dependency first reaches significance is one valid criterion defining "high temperature" design.

The threshold temperature is not unique. It is strictly a function of the mode of failure being considered, as well as the design lifetime. For instance, the threshold temperature for constant loading conditions, where stresses are expected to relax to a relatively low steady state, will be higher than one based on cyclic conditions which cause stresses to be repeatedly reset to the yield stress by cyclic plastic deformation. The specified design lifetime will also influence the