U.S. NUCLEAR REGULATORY COMMISSION

Revision 1
June 1975

REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

REGULATORY GUIDE 1.87

GUIDANCE FOR CONSTRUCTION[1] OF CLASS 1 COMPONENTS IN ELEVATED-TEMPERATURE REACTORS (SUPPLEMENT TO ASME SECTION III CODE CASES 1592, 1593, 1594, 1595, AND 1596)

A. INTRODUCTION

Section 50.55a, "Codes and Standards," of 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires, in part, that structures, systems, and components be designed, fabricated, erected, tested, and inspected to quality standards commensurate with the importance of the safety functions to be performed. General Design Criterion 1, "Quality Standards and Records," of Appendix A,[2] "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 permits use of recognized codes and standards, provided they are identified and evaluated to determine applicability, adequacy, and sufficiency and are supplemented or modified as necessary to ensure a quality product in keeping with the required safety function. This guide describes interim licensing guidelines to aid applicants in implementing these requirements with respect to ASME Class 1 components operating at elevated temperatures. This guide applies to high-temperature gas-cooled reactors (HTGRs), liquid-metal fast-breeder reactors (LMFBRs), and gas-cooled fast-breeder reactors (GCFBRs).

[1] As defined in Section III of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME B&PV Code), construction is an all-inclusive term comprising materials, design, fabrication, examination, testing, inspection, and certification required in the manufacture and installation of components.

[2] Appendix A to 10 CFR Part 50 is directly applicable to water-cooled nuclear power plants; however, as indicated in that appendix, the General Design Criteria are considered applicable to other types of nuclear power units and are intended to provide guidance in establishing principal criteria for such other units.

B. DISCUSSION

The rules for construction of nuclear components given in Section III of the ASME Boiler and Pressure Vessel Code, including Class 1 nuclear components that are covered in Subsection NB of Section III, apply to components at temperatures where creep effects are insignificant. Material behavior considerations are limited to either elastic or elastic-plastic response, which, in effect, provides protection against only time-independent failure modes such as ductile rupture, gross distortion, and fatigue.

The service temperatures and load conditions for HTGRs, LMFBRs, and GCFBRs are such that time-dependent phenomena such as creep and relaxation are important. Subsection NB of Section III does not provide adequate guidance for construction of components subject to elevated-temperature service. Therefore, as an interim step, the ASME has developed five Code Cases (1592, 1593, 1594, 1595, and 1596) to provide guidance in this area. Code Cases 1593, 1594, 1595, and 1596 were approved on November 5, 1973, as interpretations of the ASME Boiler and Pressure Vessel Code. Code Case 1592 was approved on April 29, 1974.

These Code Cases cover design, fabrication and installation, examination, testing, and protection against overpressure. They reflect both time-independent and time-dependent material properties and structural behavior (elastic and inelastic) by considering the following modes of failure:

1. Ductile rupture from short-term loadings;

2. Creep rupture from long-term loadings;

3. Creep-fatigue failure;

4. Gross distortion due to incremental collapse and ratcheting;

5. Loss of function due to excessive deformation;

6. Buckling due to short-term loadings;

7. Creep buckling due to long-term loadings.

Consideration of these complex failure modes serves as a basis for developing design methods and procedures to provide adequate protection throughout a reactor lifetime of 30 to 40 years.

The Code Cases under discussion utilize recently acquired information on material behavior, extended use of accepted practice, and special consideration of safety-related aspects of the nuclear system to establish rules of construction for components in elevated-temperature service. These rules establish procedures that are consistent with current knowledge and the state of the art.

Code Case 1592 presents rules for component design and includes data on material properties. The complex influence of temperature, environment, and geometry on material properties and structural behavior for extended time periods requires evaluation of component design by analytical techniques. Although present knowledge is sufficient to design with a high probability of safe service, it will be necessary for component designs to consider and accommodate inservice inspection and surveillance programs. The intent, within the context of this guide, is to establish that potential access and coupon-test-material needs for both inspection and surveillance programs should be considered at the component design stage.

The provision to consider inservice inspection and surveillance test programs at the design stage will allow systematic monitoring of component and material behavior. This approach will help to detect and assess accumulation of damage, excessive deformation, incipient failure, or possible synergistic effects of elevated temperature, load conditions, and environment on materials and components during a design life of 30 to 40 years. Additionally, the limited material response data base (tensile, creep, stress rupture, fatigue, etc.) and lack of prototypical service experience will also be augmented by results from ongoing research programs.

Construction aspects associated with fabrication and installation, examination, testing, and overpressure protection are covered in Code Cases 1593, 1594, 1595, and 1596, respectively. These rules generally account for potential safety-related problems during elevated-temperature service by invoking more stringent application of accepted construction practices. However, certain aspects of testing and overpressure protection relative to test liquids and "noncritical" component protection need further clarification as indicated in the regulatory position of this guide.

These code cases were developed to supplement Subsection NB, "Requirements for Class 1 Components," of Section III of the ASME B&PV Code. In some instances, they also refer to use of other ASME rules such as Appendix E, "Minimum Bolt Cross-Section Area," Appendix F, "Rules for Evaluation of Faulted Conditions," Subsection NF, "Component Supports," and Subsection NG, "Core Support Structures." These referenced rules do not include consideration of elevated-temperature or time-dependent effects during service life. Therefore, the use of Appendices E or F, Subsections NF or NG, or other portions of Section III of the ASME B&PV Code should be justified with respect to applicability for elevated-temperature service when used with these Code Cases. Some representative areas of concern are repeated stress relaxation, dynamic load considerations, deformation limits, and irradiation effects.

A note of caution is also raised concerning Code Case reference to Articles in Subsection NB of Section III of the ASME B&PV Code. The primary problem is that literal compliance with a specific Code Case could possibly introduce unintended construction practices by referring to a certain Article in Subsection NB that has subsequently been superseded by another Code Case. As an example, Code Case 1593 (in the Reply to Inquiry) refers to fabrication and installation in accordance with the rules of Section III, Article NB-4000. Subparagraph NB-4223.1 of that Article subsequently references Table NB-3642.1-1 which in turn refers to subparagraph NB-3641.1 of Article NB-3000. However, for Class 1 components in elevated-temperature service, Code Case 1592 has replaced Article NB-3000 and, in the process, the requirements of Table NB-3642.1-1 and subparagraph NB-3641.1 were changed. This illustrates that compliance with one Code Case may inadvertently conflict with another Code Case. Therefore, care should be exercised to determine that referenced Articles in Subsection NB are consistent with all applicable Code Cases and the supplements of the regulatory position of this guide.

The rules in Appendix II of Section III of the ASME B&PV Code permit component acceptance by means of experimental stress analysis in lieu of analytical techniques. Code Case 1592 establishes intent to extend this concept to permit acceptance of elevated-temperature components by experimental analysis. Detailed guidelines have not been provided; therefore, it will be necessary to document test procedures and acceptance criteria for experimental analysis of components to be used in elevated-temperature service.

C. REGULATORY POSITION

The requirements of Code Cases 1592, "Section III, Class 1 Components in Elevated Temperature Service," 1593, "Fabrication and Installation of Elevated Temperature Components, Section III, Class 1," 1594, "Examination of Elevated Temperature Components, Section III, Class 1," 1595, "Testing of Elevated Temperature Components, Section III, Class 1," and 1596, "Protection Against Overpressure of Elevated Temperature Components, Section III, Class 1," will be used with Section III of the ASME Boiler and Pressure Vessel Code, including Addenda, in evaluating applications for construction permits, as supplemented by the following:*

1. General Items.

a. All five Code Cases should be invoked, where applicable, for components in high-temperature gas-cooled reactors, liquid-metal fast-breeder reactors, and gas-cooled fast-breeder reactors.

b. These Code Cases may be used in conjunction with Subsection NB of Section III of the ASME Boiler and Pressure Vessel Code. When other portions of Section III such as Appendices E and F and Subsections NF and NG are used with these Code Cases, justification of the bases relative to elevated-temperature applicability should be submitted in the Preliminary Safety Analysis Report (PSAR).

If the requested justification and documentation are not available at the time the PSAR is submitted, they should be included in a subsequent submittal, and the PSAR should contain a preliminary discussion of bases and approaches to be utilized and should reference the appropriate regulatory position paragraph of this guide such as C.1.b for this item. This procedure should be implemented for all paragraphs of this guide that request submittal of information in the PSAR.

c. Component designs should accommodate the required inservice inspection and surveillance programs for material or component integrity. Representative environmental factors should consider the compatibility of the coolant such as sodium, helium, air, and contaminants; irradiation effects that might induce ductility loss; and aging resulting from prolonged exposure to elevated temperature.

2. Code Case 1592

a. A description of analysis methods and delineation of areas that have been subjected to elastic analysis or inelastic analysis should be included in the PSAR. All computer programs used should be identified and sufficiently described in the PSAR with respect to those portions utilized to identify basic theory, assumptions, constitutive relations, extent of verification, limitations, and justification of applicability, including validation of computer models and modeling techniques.

b. Identification of whether the strength properties used in analysis are minimum, average, or maximum should be included in the PSAR for each part of the analysis, except where the properties are specified by, or are an integral part of, the analytical method. Where an option exists, the use of minimum, average, or maximum strength properties relative to critical failure modes, damage laws, and deformation limits should be justified on the basis of increased safety. If the material property data given in the Code Case are inadequate (including alteration or extrapolation) for design evaluation of all modes of failure, the appropriate properties used in design should be documented and justified in the PSAR. This material data base, together with a description of the methods used to account for environmental effects throughout design life, should be documented in the PSAR.

c. The acceptability criteria applied as strain, deformation, and fatigue limits pursuant to 3250 should be consonant with the rules of Appendix T of this Code Case. When any acceptability criteria or material properties are invoked as alternatives to the rules of Appendix T, the affected areas (material, parts, components, systems, etc.) should be identified, and justification for such rules should be documented in the PSAR.

d. A full description of the buckling analysis pursuant to T-1500 should be documented in the PSAR. This should also include the following:

(1) Indication of the margin for a design factor on load applied *throughout service life,* in addition to the suggested end-of-life design factor in Table T-1520-1.

(2) Justification that a process is purely strain-controlled and not combined with load-controlled or significant elastic followup when the strain-controlled design factor in Table T-1520-1 is used.

(3) Description of the methods used to determine the minimum stress-strain curve suggested in T-1520(c).

e. The intent of Appendix II (ASME B&PV Code) rules should be used for guidance when design is justified by experimental analysis. A description of procedures used for experimental analysis, the evaluation techniques, and acceptance criteria should be included in the PSAR.

*Lines indicate substantive changes from previous issue.

3. **Code Case 1593**

All Articles of Subsection NB referenced in this Code Case should be applied in a manner consistent with all applicable elevated-temperature Code Cases and the corresponding supplements in the regulatory position of this guide.

4. **Code Case 1594**

All Articles of Subsection NB referenced in this Code Case should be applied in a manner consistent with all applicable elevated-temperature Code Cases and the corresponding supplements in the regulatory position of this guide.

5. **Code Case 1595**

a. The "nonhazardous liquid" in 6212(a) should be nonhazardous relative to possible reactions between residual test liquid and the normal coolant fluid and nonhazardous with respect to deleterious effects to the component (material) such as corrosion by either the test liquid or a fluid created by reaction of test liquid and coolant. Appropriate posttest procedures that ensure proper draining and drying may be instituted in some instances where a potential test liquid would be excluded from use because of the aforementioned effects. When a test liquid is considered "nonhazardous" as a result of such prescribed posttest procedures, the posttest procedures should be documented in the PSAR and included as part of the Data Report Form required by NA-8400 of the ASME B&PV Code. All areas subject to these procedures should be identified in the PSAR.

b. All Articles of Subsection NB referenced in this Code Case should be applied in a manner consistent with all applicable elevated-temperature Code Cases and the corresponding supplements in the regulatory position of this guide.

6. **Code Case 1596**

a. The Overpressure Protection Report should indicate those components considered to be "noncritical" pursuant to 7110(a)(4) and 7110(b). The evaluation techniques and acceptance criteria used to justify designation as a "noncritical" component should also be included.

b. All Articles of Subsection NB referenced in this Code Case should be applied in a manner consistent with all applicable elevated-temperature Code Cases and the corresponding supplements in the regulatory position of this guide.

c. The potential overpressure due to failure of a system component in 7121(d) should include consideration of pressure from an adjacent system by leaks or chemical reaction or both.

d. For those reactors using liquid sodium as the coolant, a description of the methods used to determine overpressure resulting from possible shock loads mentioned in 7122 should appear in the Overpressure Protection Report. This should include a definition of what constitutes rapid valve closure relative to pressure-wave velocity and valve closing time. A description of how the pressure shock and momentum change effects have been accounted for with respect to pressure relief, piping design, and support systems should also be included.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for utilizing this regulatory guide.

Except in those instances in which the applicant proposes an alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used in the evaluation of submittals for construction permit applications docketed after January 1, 1976.

If an applicant wishes to use this regulatory guide in developing submittals for applications docketed on or before January 1, 1976, the pertinent portions of the application will be evaluated on the basis of this guide.