RDT Standard

REQUIREMENTS FOR DESIGN OF
NUCLEAR SYSTEM COMPONENTS AT
ELEVATED TEMPERATURES
(SUPPLEMENT TO ASME
CODE CASE 1331)

JANUARY 1974

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R D T S T A N D A R D

UNITED STATES ATOMIC ENERGY COMMISSION
DIVISION OF REACTOR RESEARCH AND DEVELOPMENT

RDT F 9-4T
DATE January 1974
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REQUIREMENTS FOR DESIGN OF NUCLEAR SYSTEM COMPONENTS AT ELEVATED TEMPERATURES (SUPPLEMENT TO ASME CODE CASE 1331)

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UNITED STATES ATOMIC ENERGY COMMISSION
DIVISION OF REACTOR RESEARCH AND DEVELOPMENT

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REQUIREMENTS FOR DESIGN OF NUCLEAR SYSTEM COMPONENTS AT ELEVATED TEMPERATURES (SUPPLEMENT TO ASME CODE CASE 1331)

0. FOREWORD

0.1 Scope. This standard provides rules for the design and construction of Class 1 nuclear components, parts, and appurtenances for use at elevated temperatures. This standard is a complete set of requirements only when used in conjunction with Code Case 1331, Section III of the ASME Boiler and Pressure Vessel Code (including Addenda), and RDT E 15-2.

0.1.1 Applicability. The rules of RDT F 9-4 and Section III of the Code, as modified by Code Case 1331 and RDT E 15-2, are mandatory.

0.1.2 Definitions. The definitions of terms used in RDT F 9-4 are consistent with those employed by Section III of the ASME Boiler and Pressure Vessel Code (herein referred to as the ASME Code). Terms not now defined by the ASME Code, or defined herein differently from the ASME Code, are defined in Section 3.0 or where they are first used in this standard.

0.2 Organization of Standard. RDT F 9-4 contains requirements that are additional to those of Code Case 1331. The organization of Section 1 through 6 of RDT F 9-4 corresponds to the section, paragraph, figure and equation designation of the code case to permit insertion of supplements to existing portions and addition of new items.

RDT F 9-5, Guidelines and Procedures for Design of Nuclear System Components at Elevated Temperatures, is a non-mandatory standard which supplements RDT F 9-4 and provides the manufacturer with general guidelines and procedures to satisfy the requirements of RDT F 9-4 with respect to the design of components for nuclear systems. It addresses guidelines for the stress analysis aspects of design and supplies procedures for consideration and use by the manufacturer.

RDT F 9-6,* Background Information for Design of Nuclear System Components at Elevated Temperatures, is also non-mandatory but is supplemental to RDT F 9-4 and provides:

1. Design philosophy upon which the requirements of RDT F 9-4 are based.
2. Design philosophy upon which the guidelines and procedures of RDT F 9-5 are based.
3. Criteria justification and design philosophy.

*This standard not published, planned for future release.

4. Reference sources for design techniques.
5. Explanation of rules and other information useful to the designer.

0.3 Effective Date and Revisions.

a. Unless otherwise specified in the procurement specification or the system design description (SDD), the issue of this document and of any referenced RDT standards in effect on the date of the request for proposal (RFP), including any amendments in effect on that date, shall apply except as provided for in b, c, and d.

b. In the case of referenced sections of the ASME Code, editions of the ASME Code (including mandatory addenda) in effect on the date of contract shall apply unless later editions of addenda are specified in the procurement specification or design specification. ASME Code Cases are referred to by specific revision and only those specified are permitted.

c. In the design and procurement of piping systems (as differentiated from other components), and for such cases where the manufacturer for the system has been selected prior to the preparation and approval of the design specification, the date of approval of the design specification shall constitute the contract date for the design analysis of that system. As covered in 3.10, the SDD may serve as the design specification for the piping system provided it meets the requirements for design specification as set forth under the ASME Code. Where the design specification has been prepared before a contract is awarded, the date of the actual contract shall constitute the contract date for that system. The contract date for the system does not govern the ASME Code edition and addenda, or the revision of this standard applicable to subcontracted components which may be incorporated into the system.

d. Revisions of this standard, or the referenced documents in 0.5, effective later than those specified above may be used only by mutual consent of the owner and the manufacturer. The owner's approval will be indicated by a certified version of, or an approved revision to, the procurement or design specification as applicable. The manufacturer shall not use revisions of this standard which are not referenced in the procurement or design specifications or which have not been formally approved by the owner through a certified revision of such documents.

0.4 Conflicts. The requirements of this standard shall in no way be construed to relieve any ASME Code designated party of his responsibility for meeting the requirements of the ASME Code. Where this standard appears to conflict with the requirements of a referenced document, this shall be immediately brought to the attention of the owner for resolution.

0.5 Applicable Documents. The following documents are a part of this standard to the extent specified herein. The issue of a document in effect shall be as defined in 0.3, including any amendments also in effect on that date, shall apply unless otherwise specified.

0.5.1 RDT Standards.

RDT E 15-2T	Requirements for Nuclear Components (Supplement to ASME Boiler and Pressure Vessel Code, Section III)
RDT F 1-2T	Preparation of System Design Descriptions
RDT F 9-5T	Guidelines and Procedures for Design of Nuclear System Components at Elevated Temperatures
RDT M 2-2T	Stainless and Low Alloy Steel Forgings (ASME SA-182 with Additional Requirements)
RDT M 2-4T	Alloy Steel Forgings (ASME SA-336 with Additional Requirements)
RDT M 2-5T	Austenitic Stainless Steel Welding Fittings (ASME SA-403 with Additional Requirements)
RDT M 3-2T	Stainless and Alloy Steel Seamless Tubes (ASME SA-213 with Additional Requirements)
RDT M 3-3T	Austenitic Stainless Steel Seamless Pipe (ASME SA-376 with Additional Requirements)
RDT M 3-4T	Nickel Alloy Seamless Tubes (ASME SB-163 with Additional Requirements)
RDT M 3-5T	Austenitic Stainless Steel Welded Tubing (ASME SA-249 with Additional Requirements)
RDT M 3-6T	Austenitic Stainless Steel Pipe (ASME SA-312 with Additional Requirements)
RDT M 3-7T	Austenitic Stainless Steel Welded Pipe, Large Diameter (ASME SA-358 with Additional Requirements)
RDT M 3-9T	Nickel-Iron-Chromium Alloy Seamless Pipe and Tubing (ASME SB-407 with Additional Requirements)
RDT M 3-11T	Carbon and Low Alloy Steel Welded Pipe (ASME SA-155 with Additional Requirements)
RDT M 3-12T	Ferritic Alloy Steel Seamless Pipe (ASME SA-335 with Additional Requirements)
RDT M 5-1T	Stainless Steel Plate, Sheet and Strip (ASME SA-240 with Additional Requirements)
RDT M 5-5T	Low Alloy Steel Plates (ASME SA-387 with Additional Requirements)

RDT M 5-7T	Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip (ASME SB-409 with Additional Requirements)
RDT M 6-3T	Alloy Steel Bolting Material for High Temperature Service (ASME SA-193 with Additional Requirements)
RDT M 7-3T	Stainless Steel Bars and Shapes (ASME SB-479 with Additional Requirements)
RDT M 7-10T	Nickel-Iron-Chromium Alloy Rod and Bar (ASME SB-408 with Additional Requirements)

0.5.2 American Society of Mechanical Engineers (ASME) Specifications.

ASME Boiler and Pressure Vessel Code,

Section III Nuclear Power Plant Components

Code Case 1331-8 Nuclear Components in Elevated Temperature Service

Code Case 1521 Use of H Grades of SA-240, SA-479, SA-336, and SA-358, Section III

SA-369 Specification for Ferritic Alloy Steel Forged and Bored Pipe for High Temperature Service

SA-409 Specification for Welded Large Outside Diameter Light-Wall Austenitic Chromium-Nickel Alloy Steel Pipe for Corrosive or High-Temperature Service

SA-426 Specification for Centrifugally Cast Ferritic Alloy Steel Pipe for High Temperature Service

SA-452 Specification for Centrifugally Cast Austenitic Cold-Wrought Pipe for High Temperature Service

0.5.3 Other Documents.

HEDL-TME 71-32 Liquid Metal Fast Breeder Reactor Materials Handbook

0.5.4 Applicable Version of ASME Code. RDT F 9-4, in referring to sections of the ASME Code refers specifically to the 1971 Edition, including all addenda in effect on the date of the contract. The term "Code Case 1331" refers specifically to Code Case 1331-8 of the ASME Code and is a mandatory requirement.

0.6 Functional Integrity. The requirements of this standard shall not relieve the manufacturer of his responsibility to furnish equipment which meets the functional requirements contained in the design specification for the entire design lifetime under the specified loads of service.

0.7 Notes.

0.7.1 Actions of the Owner. A time-temperature-loading history (histogram) of the component will be provided in the design specification. This histogram will contain a set of operational cycles which define the operating conditions of the component including the loading, number of occurrences of each loading event, and the duration and expected time interval between each occurrence such that the manufacturer has a firm basis for design against the failure modes listed in 2.2. In the event the design specification does not include the time sequence and duration of each operation cycle, agreement shall be established between the owner and manufacturer on the time sequence and duration; this agreement will be documented in a revised design specification.

1.0 INTRODUCTION

Add:

1.1 Structural Evaluation Program. To facilitate the orderly review and certification of the stress report to be provided to the owner by the manufacturer, a structural evaluation plan (SEP) shall be provided to the owner as part of the manufacturer's proposal. The SEP shall provide a description of the methods of analysis which the manufacturer contemplates using in various phases of the structural analysis. The plan shall indicate the degree to which the manufacturer anticipates using elastic, simplified inelastic and rigorous inelastic methods of analysis in design iterations and for demonstrating compliance with the requirements of RDT F 9-4. The manufacturer shall identify any computer programs to be used and shall describe, or provide the basic theory of the programs, and identify the assumptions involved in their use. The manufacturer shall also describe the extent to which the computer programs have been verified, or will be verified, and the extent to which they have been qualified for applications comparable to those involved in the proposed project.

As the design analysis progresses, the manufacturer shall provide the owner with an updated SEP and interim design analysis reports which document stress calculations in support of conclusions that the design shown by drawings used, or to be used, comply with the requirements of RDT F 9-4 and the ASME Code; or, when it is concluded that the requirements have not been met by the design analyzed, the manufacturer shall provide data concerning any redesign proposed, the additional analysis methods proposed for use in further analysis, or both. RDT F 9-5 provides a complete description of the contents and use of the SEP.

2.0 SCOPE

2.1 Materials. Add at the end: For RDT F 9-4 applications to non-ASME Code components, the use of materials other than those listed in Table 1 is permitted when prior approval of the owner is obtained. The request for

Table 1. Permissible Materials.

Replace with the following:

Material Type	Grades	RDT Standard	ASME Specification	Product Form	Minimum Specified Properties At Room Temperature	
					Y.S. KSI	T.S. KSI
304 SS	304, 304H, 316, 316H	M 2-2	SA-182	FFBS	30	75
and	B8, B8M	M 6-3	SA-193	Bolting	30	75
316 SS ^a	304, 304H, 316, 316H	M 3-2	SA-213	Seamless tube	30	75
	304, 304H, 316, 316H ^b	M 5-1	SA-240	Plate	30	75
	304, 304H, 316, 316H	M 3-5	SA-249	Welded tubing	30	75
	304, 304H, 316, 316H	M 3-6	SA-312	Welded and seamless pipe	30	75
	304, 304H, 316, 316H ^b	M 3-7	SA-358	Welded pipe	30	75
	304, 305H, 316, 316H	M 3-3	SA-376	Seamless pipe	30	75
	WP304, WP316	M 2-5	SA-403	Fittings	30	75
	304, 316 ^d	-	SA-409	Welded pipe	30	75
	304H, 316H ^d	-	SA-452	Cast pipe	30	75
	304, 304H, 316, 316H ^b	M 7-3	SA-479	FFBS	30	75
Ni-Fe-Cr	Solution Annealed	M 3-4	SB-163	Seamless tubes	25	65
Alloy 800,	Solution Annealed	M 3-9	SB-407	Seamless pipe and tube	25	65
Grade 2	Solution Annealed	M 7-10	SB-408	Rod and bar	25	65
	Solution Annealed	M 5-7	SB-409	Plate and sheet and strip	25	65
2 1/4 Cr-1 Mo ^c	Annealed D	M 5-5	SA-387	Plate	30	60
	Annealed 2 1/4 Cr	M 3-11	SA-155	Welded pipe	30	60
	T22	M 3-2	SA-213	Seamless tube	30	60
	F22a	M 2-4	SA-336	Fittings, forgings, bars and shapes	30	60
	F22	M 3-12	SA-335	Seamless pipe	30	60
	FP22 ^d	-	SA-369	Seamless pipe	30	60
	CP22 ^d	-	SA-426	Seamless pipe	30	60

^aThese materials have a minimum room temperature yield strength of 30,000 psi, a minimum room temperature ultimate tensile strength of 75,000 psi, and a minimum carbon content of 0.04 percent.

^bSee Code Case 1521 for H-grades. Not all materials in Case 1521 are approved for use with this standard.

^cThe design stress intensities and properties of this case for 2 1/4 Cr-1 Mo have been derived from tests of material having a carbon content greater than 0.07 percent. Material having less carbon may exhibit inferior strength. Therefore, the stress intensity values and properties are applicable only when the carbon content equals or exceeds 0.07 percent.

^dPending the preparation of appropriate RDT material standards, the use of materials conforming to these specifications shall require prior approval of the Owner.

approval to use alternate materials shall contain the specific properties to be utilized, the associated structural limits, the effect of environmental factors, and the justification for these values.

The listings in Table 1 are not intended to prohibit the use of special purpose materials for bearing and contact-face use. The materials, processes, and design limits for such applications are not covered by RDT F 9-4.

2.3 Temperature Add:

(a) Temperature Limits. Limits which protect against time-dependent failure modes as well as the time-independent modes shall be in accordance with RDT F 9-4. Metal temperatures only slightly above the limits of the ASME Code or metal temperatures which exceed the limits of the ASME Code for only short time durations may not require the use of the time-dependent structural limits of RDT F 9-4. Maximum temperature limits for the application of time-independent rules are provided in RDT F 9-5.

Replace the heading for 2.4 with:

2.4 Analysis Methods and Material Properties

Add at the end of first paragraph: Guidelines for analysis are given in RDT F 9-5.

Add:

(a) Material Properties. Material properties from the following sources may be used without the prior approval of the owner:

- (1) Code Case 1331 and RDT F 9-4.
- (2) Section III, ASME Code.
- (3) HEDL-TME 71-32 (for data not contained in the above).

If the necessary data are not available from the above sources or if the values given therein are not appropriate for specific use, the specific values judged by the manufacturer to accurately represent the subject material shall be approved by the owner prior to use. Recommendations, technical bases, and design implications of the proposed material properties shall be provided for the owner's consideration.

Add:

(b) Material Properties for Inelastic Analysis. In the detailed inelastic analysis associated with the creep-fatigue interaction damage assessment and the evaluation of accumulated strain, average or representative

properties should be used. Guidance on the use of conservative combinations of stress-strain and creep properties where creep-fatigue damage or deformations are critical is given in RDT F 9-5.

Add:

2.5 Functional Limits. The functional aspects of the design of a component, part, or appurtenance will in some cases require more restrictive limits on stress (see 2.4(b)) or total accumulated deformation (see 5.1(a)) than those imposed by RDT F 9-4 for the purpose of structural integrity. Functional aspects should be carefully considered, especially those that may impact safety capabilities of the plant (see 1.1(b)(2)).

Add:

2.6 Fabrication and Environmental Effects. The limits of Code Case 1331 are based on tensile, creep, stress-rupture, and fatigue tests performed in air. The effects of other environments and fabrication processes on materials behavior, when significant, shall be accounted for in all structural and functional evaluations.

(a) The environmental factors which may modify material behavior include:

- (1) The environmental fluid (e.g., sodium, inert gas, air, and vacuum).
- (2) The exposure to elevated temperature for long time durations.
- (3) Irradiation.

(b) Possible effects of these factors include:

- (1) Aging.
- (2) Irradiation-induced loss of ductility.
- (3) Loss of alloying elements (including N, C, B, Mn) on both local and an overall basis.
- (4) Loss of surface material due to erosion, corrosion, or oxidation.
- (5) Alteration of the microstructure, especially at the surface of the component.

As an aid to the manufacturer, RDT F 9-5 contains some information on the effects of environment upon structural integrity. The SEP shall describe the degree and scope of the fabrication and environmental effect considerations.

3.0 DEFINITIONS

Replace 3.4 with:

3.4 Ratchetting. Progressive incremental inelastic deformation which can occur in a component that is subjected to cyclic variations of mechanical secondary stress, thermal secondary stress, or both in the presence of a sustained primary stress. (Total inelastic strain per cycle may vary from cycle to cycle). Where creep effects are significant, creep ratchetting can occur, even in the absence of plastic yielding. At least two mechanisms are involved in creep ratchetting. First, creep can alter the residual stresses and thus affect the time-independent behavior. Secondly, the time-independent deformation can be enhanced because of the nonlinear interaction of primary and secondary stresses. This latter effect is referred to as enhanced creep.

Replace 3.5(b) with:

(b) Design Pressure and Design Mechanical Loads. Design pressure and design mechanical loads are defined as in the ASME Code (NB-3112). Short term loading conditions (impact, earthquake, and vibration loads) falling within the provisions of RDT F 9-4 and which would normally be classified as design pressure and as design mechanical loads under the ASME Code (NB-3112) shall be classified in the design specification as normal or upset conditions and evaluated in accordance with the rules provided herein.*

3.9 Stress Symbols

(c)(1) Add: However, if a condition of elastic followup exists as defined in 6.6, net bending stresses which cannot be reduced by small deformation shall be considered as primary bending stresses, P_b , in the portion of the system so affected.

Add:

3.10 Supplemental Terms

(a) Owner. As used in RDT F 9-4, "owner" shall mean the owner or his designated agent.

(b) Procurement Specification. The document or documents which form a part of a contract between the owner and the manufacturer, and which contain, as a minimum, all of the information required by the manufacturer to properly apply ASME Code rules; as set forth in the requirements for a certified design specification, plus any additional or supplemental requirements which have to be satisfied to ensure adequacy of the component for the intended application.

(c) System Design Description (SDD). The SDD is a comprehensive document which defines the design, operation, and maintenance requirements

for systems which comprise a nuclear power plant or test facility (RDT F 1-2). As such, the SDD shall serve as the ASME Code required design specification for systems and components not otherwise covered.

(d) Verification. Demonstration that an analysis method operates properly and provides solutions of acceptable accuracy by comparison with known solutions or experimental results for the model(s) programmed. Level of confidence in the verification is dependent on the diversity and complexity of problems solved, the options checked, and the range of parameters investigated.

(e) Qualification. Demonstration that the structural approximation, the description of material behavior, the loading system, and the boundary conditions are consistent with analysis method limitations and can be combined to yield an acceptable solution to the particular physical problem being evaluated.

4.0 DESIGN RULES FOR LOAD-CONTROLLED STRESSES

4.3 Normal and Upset Conditions

(a) Add: When entering Fig. 4 and t is less than the lowest value provided, use the stress limit for the lowest t value provided.

(c) Add: The K and 1.5 factors of Eq 4 are based on the response of solid rectangular cross sections to primary bending loads. For cross sections in which the use of the K and 1.5 factors of Eq 4 would be unconservative these values shall be adjusted (e.g., the section factor for an I-beam may be ≈ 1.1). See RDT F 9-5 and article A-9000 of the ASME Code for further guidance.

4.4 Emergency Conditions

(d) In the last line and in Fig. 6, replace " $(P_L + P_b)/K$ " with " $P_L + P_b/K$."

4.5 Faulted Conditions.

(a) Add: When alternate rules are employed, they shall have been reviewed and approved by the owner.

Replace (e) with:

(e) In addition, the use-fraction rule of 4.4(b) shall be satisfied for all loadings with the following modification: Use a stress value of $(P_L + P_b/K)1.2$ (instead of $(P_L + P_b/K)$) to obtain the t_{ib} values from the curves of Fig. 4 for the faulted conditions.

5.0 STRAIN, DEFORMATION, AND FATIGUE LIMITS

(d) Replace "Faulted - No deformation analysis required" with "Faulted - Strain and deformation limits not applicable except as necessary to satisfy faulted condition functional requirements."

5.1 Deformation Limits for Functional Requirements

(a) Add: The deformation limits imposed by the design selected by the manufacturer shall be identified in the stress report. The stress report shall demonstrate that all deformation limits, whether imposed by specification or design choice, are satisfied.

5.2 Deformation and Strain Limits for Structural Integrity. Add introduction: Simplified procedures for meeting the rules of 5.2(a) are given in RDT F 9-5.

(a) Strain limits for Inelastic Analysis

(3) Change to read: Strains at all locations, 5 percent

(b) Strain Limits for Elastic Analysis

(1) At the end of the first paragraph following "in Fig. 9". add: As an alternate to the above definition of S_q , $S_q = S_y$ may be used even when S_y is greater than $1.25 S_t$ (where $t = 10^4$ hours) provided that, to prevent creep ratchetting, one of the extreme conditions which defines the secondary stress intensity range, Q_R , is such that negligible creep relaxation occurs at this point in the loading cycle. This requirement of negligible relaxation is satisfied provided the temperature is below the value corresponding to the point where $S_m = S_t$ for $t = 10^5$ hours (see Fig. 3 for the appropriate material). To use temperatures above this value, it shall be demonstrated to the owner's satisfaction that the hold time results in negligible creep relaxation.

5.3 Creep Fatigue Evaluation

(a) General Rules

(1) In the definition of " T_d " replace "stress intensity" with "peak stress intensity" and replace "effective stress" with "peak effective stress." Add: Where peak stress effects (beyond primary plus secondary stress effects) have been included in the fatigue curve (Fig. 11), the primary plus secondary stress values may be used to determine the creep damage.

(3) Replace the second sentence of the first paragraph with: As an alternate or when principal strains change direction during the cycle, the following procedure may be used to determine an equivalent strain range.

Add:

(4) Where local discontinuities are analytically modeled, the analysis shall demonstrate the ability of the model to determine the local stress and strain. Otherwise, the fatigue damage sum shall be evaluated by using Eq 16 to obtain the strain range and by entering the fatigue design curve, Fig. 11.

(b) Limits Using Inelastic Analysis

Replace the third item with:

The fatigue damage sum shall be evaluated by using the maximum principal or the maximum effective strain range when entering the fatigue design curve, Fig. 15.

(c) Limits Using Elastic Analysis

Add to Table 17:

<u>Material</u>	<u>K'</u>
2 1/4 Cr, 1 Mo	0.9

5.4 Buckling and Instability

Table 5.4 Buckling Limits Note 5 add:

Guidance in simplified methods to meet this requirement is provided in RDT F 9-5.

6.0 SPECIAL LIMITS AND NOTES

6.3 Welds

(a) After each reference to NB-4424 and NB-4426 add: as supplemented by RDT E 15-2.

Replace (b) with:

(b) The analysis for stresses, strains, and creep-fatigue interactions at welds shall consider the geometrical effects of welding. Among the factors to be considered are overall (as well as local) geometry distortions due to weld shrinkage, weld reinforcement, mismatch, and transitions between regions containing different types of weld-induced distortions. The manner in which these distortions are accounted for in the structural evaluation shall be included in the stress report (see NA-3350 and RDT E 15-2).

6.4 Bolting

(a) Add: Note that S_m here refers to the values given in Fig. 3.

(d) Add: Bolt preload may be classified as secondary in nature. Thus, it is included in the "service stress" category but is not considered in 4.4(b) (P_m) or 4.4(d) ($P_L + P_b/K$) categories.

(e) Replace " $(P_L + P_b)/K$ " with " $(P_L + P_b/K)$."

Fig. 10 change the heading on the abscissa to read: THE HIGHER of $\Sigma(n/N_d)$ or $\Sigma\beta(t/t_d)$.

Fig. 15A change "Cyclic Strain: 1×10^3 in./in./sec" to "Cyclic Strain Rate: 1×10^{-3} in./in./sec."

900
Cup handle

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(Supplement to ASME Code Cases 1592, 1593,
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RDT Standard

REQUIREMENTS FOR CONSTRUCTION
OF NUCLEAR SYSTEM COMPONENTS
AT ELEVATED TEMPERATURES
(SUPPLEMENT TO ASME CODE
CASES 1592, 1593, 1594, 1595,
AND 1596)

SEPTEMBER 1974

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RDT STANDARD

UNITED STATES ATOMIC ENERGY COMMISSION
DIVISION OF REACTOR RESEARCH AND DEVELOPMENT

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DATE	September 1974	
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REQUIREMENTS FOR CONSTRUCTION OF NUCLEAR SYSTEM COMPONENTS AT ELEVATED
TEMPERATURES (SUPPLEMENT TO ASME CODE CASES 1592, 1593, 1594, 1595, AND 1596)

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REQUIREMENTS FOR CONSTRUCTION OF NUCLEAR SYSTEM COMPONENTS AT ELEVATED TEMPERATURES (SUPPLEMENT TO ASME CODE CASES 1592, 1593, 1594, 1594 AND 1596)

0. FORWARD

0.1 Scope. This standard provides rules for the construction of Class 1 nuclear components, parts, and appurtenances for use at elevated temperatures. This standard is a complete set of requirements only when used in conjunction with the ASME Code Cases 1592, 1593, 1594, 1595 and 1596, Section III of the ASME Boiler and Pressure Vessel Code (including Addenda), and RDT E 15-2.

0.1.1 Applicability. The requirements of Section III of the Code as modified by Code Cases 1592, 1593, 1594, 1595 and 1596; the requirements of RDT E 15-2; and the requirements of RDT F 9-4 are applicable.

0.1.2 Definitions. The definitions of terms used in RDT F 9-4 are consistent with those employed by Section III of the ASME Boiler and Pressure Vessel Code (herein referred to as the ASME Code). Terms not now defined by the ASME Code, or defined herein differently from the ASME Code, are defined in Section 3.0 or where they are first used in this standard.

0.2 Organization of Standard. RDT F 9-4 contains requirements that are additional to those of Code Cases 1592, 1593, 1594, 1595 and 1596. The organization of RDT F 9-4 corresponds to the section, paragraph, figure and equation designations of the Code Cases.

Requirements which supplement an existing Code Case paragraph are designated in this standard by the Code Case paragraph number prefixed with an "A." For example, the addition to paragraph -3114 is designated "A-3114."

The requirements of this standard that are not designated as additions to existing Code Case paragraphs are designated as new Code Case paragraphs at the location of similar requirements. These paragraphs are numbered using the next sequential Code Case paragraph number and prefixing it with an "N." For example, the new paragraph of this standard that is to be added to -6100 is designated as "N-6128."

RDT F 9-5, Guidelines and Procedures for Design of Nuclear System Components at Elevated Temperatures, is a non-mandatory standard which supplements RDT F 9-4 and provides the manufacturer with respect to the design of components for nuclear systems. It addresses guidelines for the stress analysis aspects of design and supplies procedures for consideration and use by the manufacturer.

RDT F 9-6*, Background Information for Design of Nuclear System Components at Elevated Temperatures, is also non-mandatory, but is supplemental to RDT F 9-4 and F 9-5.

0.3 Revisions. Revisions of this standard, or the referenced documents in 0.5, effective later than those specified in the procurement or design specification may be used only by mutual consent of the owner and the manufacturer. The owner's approval will be indicated by a certified version of, or an approved revision to, the procurement or design specification as applicable. The manufacturer shall not use revisions of this standard which are not referenced in the procurement or design specifications or which have not been formally approved by the owner through a certified revision of such documents.

0.4 Conflicts. The requirements of this standard shall in no way be construed to relieve any ASME Code designated party of his responsibility for meeting the requirements of the ASME Code. Where this standard appears to conflict with the requirements of a referenced document, this shall be immediately brought to the attention of the owner for resolution.

0.5 Applicable Documents. The following documents are a part of this standard to the extent specified herein.

0.5.1 United States Atomic Energy Commission RDT Standards.

RDT E 15-2T	Requirements for Nuclear Components (Supplement to ASME Boiler and Pressure Vessel Code, Section III).
RDT F 9-5T	Guidelines and Procedures for Design of Nuclear System Components at Elevated Temperatures.

0.5.2 American Society of Mechanical Engineers (ASME) Specifications.

ASME Boiler and Pressure Vessel Code,

Section III	Rules for the Construction of Nuclear Power Plant Components.
Code Case 1592	Class 1 Components in Elevated Temperature Service Section III.
Code Case 1593	Fabrication and Installation of Elevated Temperature Components Section III, Class 1.

*This standard not published, planned for future release.

Code Case 1594 Examination of Elevated Temperature Components
Section III, Class 1.

Code Case 1595 Testing of Elevated Temperature Components
Section III, Class 1.

Code Case 1596 Protection Against Overpressure of Elevated Temperature Components Section III, Class 1.

Code Case 1521 Use of H Grades of SA-240, SA-479, SA-336, and SA-358
Section III.

0.5.3 Other Documents.

HEDL-TME 71-32 Liquid Metal Fast Breeder Reactor Materials Handbook*

0.5.4 Applicable Version of ASME Code. RDT F 9-4, in referring to sections of the ASME Code, refers specifically to the 1974 Edition, including all applicable addenda. The term "Code Case 1592" (or 1593, 1594, 1595, 1596) refers specifically to "Code Case 1592-0 (or 1593-0, 1594-0, 1595-0, 1596-1) of the ASME Code.

1.0 SUPPLEMENTS TO CODE CASE 1592

For RDT F 9-4 applications, any reference in Code Case 1592 to the rules of Subsection NB shall mean the rules as supplemented by RDT E 15-2. Where the Code Case provides rules in lieu of those contained in Subsection NB, the following supplemental requirements shall apply.

Where Code Case 1592 permits use of the rules of NB-3000, the requirements of NB-3000 as modified by RDT E 15-2 shall be satisfied.

-1000 INTRODUCTION

Add:

N-1200 STRUCTURAL EVALUATION PROGRAM

To facilitate the orderly review and certification of the stress report to be provided to the owner by the manufacturer, a structural evaluation program shall be provided to the owner as part of the manufacturer's proposal. A structural evaluation plan (SEP) is one part of the structural evaluation program. The SEP shall provide a description of the methods of analysis which the manufacturer contemplates using in

*May be obtained from the Hanford Engineering Development Laboratory, Westinghouse Hanford Company, P. O. Box 1970, Richland, Washington 99352. The replacement for HEDL-TME 71-32, the Nuclear System Materials Handbook shall be used where contractually required.

various phases of the structural analysis. The plan shall indicate the degree to which the manufacturer anticipates using elastic, simplified inelastic and more detailed inelastic methods of analysis in design iterations and for demonstrating compliance with the requirements of RDT F 9-4. The manufacturer shall identify any computer programs to be used and shall describe, or provide the basic theory of the programs, and identify the assumptions involved in their use. The manufacturer shall also describe the extent to which the computer programs have been verified, or will be verified, and the extent to which they have been qualified for applications comparable to those involved in the proposed project.

As the design analysis progresses, the manufacturer shall provide the owner with an updated SEP and interim design analysis reports which document stress calculations in support of conclusions that the design shown by drawings used, or to be used, complies with the requirements of RDT F 9-4 and the ASME Code; or, when it is concluded that the requirements have not been met by the design analyzed, the manufacturer shall provide data concerning any redesign proposed, the additional analysis methods proposed for use in further analysis, or both. RDT F 9-5 provides a complete description of the contents and use of the SEP.

Add:

N-1300 SUPPLEMENTAL TERMS

(a) Owner. As used in RDT F 9-4, "owner" shall mean the owner or his designated agent.

(b) Procurement Specification. As used in RDT F 9-4, "procurement specification" shall mean the document or documents which contain all of the information required by the ASME Code for a design specification, plus any additional requirements which have to be satisfied to ensure adequacy of the component for the intended application.

-2000 MATERIALS

Add the following new sub-paragraph:

N-2121(d) Materials shall also meet the requirements of RDT Material standards as listed below.

<u>RDT Standard</u>	<u>ASME Specification</u>
M 2-2	SA-182
M 2-4 and M 2-19	SA-336
M 2-5	SA-403
M 3-2 and M 3-33	SA-213
M 3-3	SA-376

<u>RDT Standard</u>	<u>ASME Specification</u>
M 3-4	SB-163
M 3-5	SA-249
M 3-6	SA-312
M 3-7**	SA-358
M 3-9	SB-407
M 3-11	SA-155
M 3-12	SA-335
M 5-1**	SA-240
M 5-5 and M 5-22***	SA-387
M 5-7	SB-409
M 6-3	SA-193
M 7-3**	SA-479
M 7-10	SB-408
*	SA-369
*	SA-409
*	SA-426
*	SA-430
*	SA-452

-3000 DESIGN

Add the following new subparagraph:

N-3111 (c) Functional Limits. The functional aspects of the design of a component, part, or appurtenance will in some cases require more restrictive limits on stress or total accumulated deformation (See Appendix T-1300) than those imposed by RDT F 9-4 for the purpose of structural integrity. Functional aspects should be carefully considered, especially those that may impact safety capabilities of the plant.

A-3114 Load Histogram. Add to the end of 3114:

In the event the design specification does not include the time sequence and duration of each operation cycle, agreement shall be established between the owner and manufacturer on the time sequence and duration; this agreement shall be documented in a revised design specification.

A-3213.9 Secondary Stress. Add the following after the third sentence of -3213.9:

*Where RDT material standards are not available, the use of materials conforming only to the ASME specification shall require the prior approval of the owner.

**See Code Case 1521 for H Grades. Not all materials in Case 1521 are approved for use with this standard.

***This standard, not published, planned for future release.

However, if a condition of elastic followup exists as defined in -3138, net bending stress which cannot be reduced by small deformation shall be considered as primary bending stresses, P_b , in the portion of the system so affected.

A-3214.3 Mechanical Properties. Add the following at the end of the existing subparagraph:

Material properties from the following sources may be used without the prior approval of the owner:

- (1) Code Case 1592, and Section III, ASME Code.
- (2) HEDL-TME 71-32 (for data not contained in the above).

If the necessary data are not available from the above sources or if the values given therein are not appropriate for specific use, the specific values judged by the manufacturer to accurately represent the subject material shall be approved by the owner prior to use. Recommendations, technical bases, and design implications of the proposed material properties shall be provided for the owner's consideration.

Add:

N-3214.4 Material Properties for Inelastic Analysis. In the detailed inelastic analysis associated with the creep-fatigue interaction damage assessment and the evaluation of accumulated strain, average or representative properties as identified in -3214.3 shall be used.

Add:

N-3214.5 Fabrication and Environmental Effects. The limits of Code Case 1592 are based on tensile, creep, stress-rupture, and fatigue tests performed in air. The effects of other environments and fabrication processes on materials behavior, when significant, shall be accounted for in all structural and functional evaluations.

(a) The environmental factors which may modify material behavior include:

- (1) The environmental fluid (e.g., sodium, inert gas, air and vacuum).
- (2) The exposure to elevated temperature for long-time durations.
- (3) Irradiation.

(b) Possible effects of these factors include:

- (1) Aging.

- (2) Irradiation-induced loss of ductility.
- (3) Loss of alloying elements (including N, C, B, Mn) on both local and an overall basis.
- (4) Loss of surface material due to erosion, corrosion, or oxidation.
- (5) Alteration of the microstructure, especially at the surface of the component.

As an aid to the manufacturer, RDT F 9-5 contains some information on the effects of environment upon structural integrity. The SEP shall describe the degree and scope of the fabrication and environmental effect considerations.

-3223 Normal and Upset Conditions.

A-3223(c) In addition to the requirements of -3223 the following limits shall apply:

$$P_L + P_b \leq K S$$

and

$$P_L + \frac{P_b}{K_t} \leq S_t$$

-3224 Emergency Conditions.

A-3224(c) In addition to the requirements of -3224 the following limits shall apply:

$$P_L + P_b \leq 1.2K S_m$$

and

$$P_L + \frac{P_b}{K_t} \leq S_t$$

A-3224(d) Change " $(P_L + P_b)/K_t$ " to " $(P_L + P_b/K_t)$ "

-3225 Faulted Conditions.

A3225(d) In addition to the requirements of -3225 the following limit shall apply:

$$P_L + \frac{P_b}{K_t} \leq 1.2 S_t$$

A-3225(e) Change to read:

In addition, the use-fraction rule of -3224(b) shall be satisfied for all loadings with the following modification: use a stress value of $(P_L + P_b/K_t)/1.2$ [instead of $P_L + P_b/K_t$] in obtaining the t_{ib} values from the curves of Fig. -3224-2.

-3230 Stress Limits for Load-Controlled Stresses on Bolts. Add:

N-3230(a) "When criteria alternate to those of Appendix E are used, the criteria shall be approved by the owner prior to use."

-3352 Permissible Types of Welded Joints. Add the following new subparagraphs:

N-3352(h) Joint designs having internal crevices, such as backing strips which are not removed or socket welds, shall not be used for components intended for liquid metal service unless the prior written approval of the owner is obtained for each application.

N-3352(i) Welded joints shall be designed to permit required physical and visual accessibility for welding and nondestructive examination personnel and equipment. The weld joint designs shall make allowance for welder environment, position, and comfort due to the potential necessity to weld in close quarters while the part is under a high degree of preheat and due to location and orientation of the weld joint.

N-3352(j) Joints of Category C and D for which the Code requires ultrasonic examination in addition to radiographic examination shall be permitted only if the manufacturer demonstrates that meaningful ultrasonic examination can be performed.

N-3365 Special Joints. The requirements of ANB-3365 of RDT E 15-2 shall apply.

-3671.7 Patented Joints. Add the following new subparagraph:

N-3671.7(d) The use of these types of joints shall require prior approval of the owner.

APPENDIX T

T-1300 DEFORMATION AND STRAIN LIMITS FOR STRUCTURAL INTEGRITY

T-1321 General Requirements.

AT-1321 Revise the fourth line to read, ". . .1322, T-1323, T-1324, T-1325, or T-1326 is satisfied. The . . ."

Also, revise the last sentence of the first paragraph to read, ". . .be evaluated in T-1322, T-1323, T-1324, T-1325, and T-1326."

AT-1321(c) Revise the first sentence to read, ". . . of T-1323, T-1324, T-1325, or T-1326, whichever . . ."

Modify the second sentence to read, ". . .that T-1325 and T-1326 provide for . . ."

AT-1321(d) Modify the second line to read, ". . .satisfy the conditions of T-1322, T-1323, or T-1325 then . . ."

Modify the second sentence to read, "T-1324 and T-1326 provide methods for . . ."

Modify the last sentence to read, ". . .of T-1322, T-1323, and T-1325."

AT-1321(e) The time and temperature conditions used in selecting the isochronous curves in T-1324 or T-1326 shall always sum to the entire life regardless of whether all or only part of the cycles are evaluated under the procedures of T-1324 or T-1326.

Modify to read, ". . . the criteria of T-1322 or T-1326."

AT-1324(a) Modify the first sentence to read, ". . . the criteria of T-1322, T-1323, and T-1325 may be . . ."

Add the following new paragraph:

NT-1325 Test No. 4. The strain limits of T-1310 are considered to have been satisfied if the rules of NB-3222.2, NB-3222.3 and NB-3222.5 are satisfied for normal, upset, and emergency operating conditions and the requirements of (a), (b), and (c) below are met.

$$(a) \quad \sum_i \frac{t_i}{t_{id}} \leq 0.1$$

Where: t_i = total duration of the metal temperature T_i during design life time,

t_{id} = maximum allowable time duration of Temperature T_i ,

t_{id} is determined by entering Fig. I-14.6 at a temperature of T_i and at a stress value equal to 1.5 times the average yield strength (S_y) at temperature T_i . When $1.5 S_y$ is above the stress values given in Fig. I-14.6 for temperature, T_i , this limit cannot be satisfied. When the $1.5 S_y$ value is below the lowest stress value provided in Fig. I-14.6 for temperature T_i , the constant temperature line may be extrapolated to larger t_{id} values using the highest slope given on Fig. I-14.6 (for that material). Note that $\sum_i (t_i) = \text{design lifetime}$.

(b) $\sum_i (\epsilon_i) < 0.2\%$ where ϵ_i is the creep strain due to the existence of a stress equal to 1.00 times the average yield strength, at the metal temperature, T_i , for the design lifetime. Where the design lifetime is evaluated using more than one time period;

Design life = t_1 hours + t_2 + t_3 + etc.

The creep strain contribution from each time period shall ignore any creep strain hardening from other time periods.

(c) The limits of T-1435 are met.

T-1326 Test No. 5. For axisymmetric structures subject to axisymmetric loading away from local structural discontinuities (as defined in paragraph -3213.3) the procedure of 6.1.3.2.b of RDT F 9-5 may be used to bound the accumulated inelastic strains.

T-1400 CREEP-FATIGUE EVALUATION

AT-1411 Creep Fatigue Evaluation. In the definition of " T_d ," Modify the first sentence to read: "allowable time at a given peak stress intensity (for elastic analysis) or at a given peak effective stress (for inelastic analysis) from load, k

Add:

Peak stress effects (creep-rupture damage due to peak stresses) have been included in the Fig. T-1430 design fatigue curves. Thus, the primary plus secondary stress values (rather than the primary plus secondary plus peak values) may be used to determine the creep damage when Fig. T-1430 is used in the fatigue evaluation.

T-1420 Limits Using Inelastic Analysis. Add:

NT-1420(d) Where local discontinuities are analytically modeled, the analysis shall demonstrate the ability of the model to determine the local stress and strain. Otherwise, the fatigue damage sum shall be evaluated by using Eq 7 to obtain the strain range and by entering the fatigue design curve, Fig. T-1430.

T-1433 Creep Damage Evaluation.

AT-1433(a) Replace the phrase "minimum specified yield strength" with "average yield strength."

Add the following new paragraph:

NT-1435 Alternate Creep-Fatigue Evaluation. Providing the limits of NT-1325 are satisfied, the rules of T-1431, T-1432, and T-1433 may be replaced (totally, or not at all) by NB-3222.4, except:

(a) reference to Fig. I-9.0 shall be replaced by Fig. T-1430-1, where S_a is one-half the product of ϵ_t and Young's Modulus, E at that temperature.

(b) The cumulative usage factor, U , shall not exceed 0.9.

(c) The rules of NB-3228.3 may be used for types 304 and 316 stainless steels and Ni-Fe-Cr Alloy 800, Grade 2 with the temperature limit of 800°F replaced by 1300°F.

(d) The references to NB-3222 and NB-3227 (in subparagraph (e)) shall be replaced by references to -3222 and -3227, respectively.

T-1300 SPECIAL REQUIREMENTS

AT-1714 Analysis of Geometry.

Add:

Among the factors to be considered are overall (as well as local) geometry distortions due to weld shrinkage, weld reinforcement, mismatch, and transitions between regions containing different types of weld-induced distortions. The manner in which these distortions are accounted for in the structural evaluation shall be included in the stress report (see NA-3350).

2.0 SUPPLEMENTS TO CODE CASE 1593

For RDT F 9-4 applications, any reference in Code Case 1593 to the rules of Subsection NB shall mean the rules as supplemented by RDT E 15-2.

3.0 SUPPLEMENTS TO CODE CASE 1594

For RDT F 9-4 applications, any reference in Code Case 1594 to the rules of Subsection NB shall mean the rules as supplemented by RDT E 15-2. Where the Code Case provides rules in lieu of those contained in Subsection NB, the following supplemental requirements shall apply.

4.0 Required Examination of Structural Attachment Welds. Add the following to 4.1(a)(2) of Code Case 1594:

A-4.1(a)(2) Progressive magnetic particle and liquids penetrant examination shall include the root layer of the weld.

4.3 Visual Examination. Add the following new paragraph:

N-4.3 Visual Examination. A visual examination shall be performed

4.0 SUPPLEMENTS TO CODE CASE 1595

For RDT F 9-4 applications, any reference in Code Case 1595 to the rules of Subsection NB shall mean the rules as supplemented by RDT E 15-2. Where the Code Case provides rules in lieu of those contained in Subsection NB, the following supplemental requirements shall apply.

-6000 TESTING

-6100 GENERAL REQUIREMENTS

Add the following to 6116:

A-6116(b) The volumetric and surface nondestructive examination shall also satisfy the requirements of Code Case 1594. This requirement shall apply regardless of component diametral dimensions.

Add the following new paragraph to -6120:

N-6128 Pressure Relief. The test setup shall be provided with a pressure-relief device set at a maximum level of one and one-third times the test pressure.

-6200 HYDROSTATIC TEST

Add the following new paragraph:

N-6214 Pressure Application. The component shall be filled with test fluid, and time shall be allowed for the temperatures of both the component and the fluid to reach the test temperature. Pressure shall be gradually applied until it is approximately one-half of the required test pressure. Thereafter, the pressure shall be increased in increments of approximately one-tenth of the test pressure until the full test pressure has been reached. The component shall be visually examined for leakage or deformation at each pressure increment.

-6222 Maximum Permissible Hydrostatic Test Pressure.

Add the following:

A-6222(a) Multichamber components which are tested with pressure simultaneously applied to adjacent chambers to meet the stress limits of NB-3226 shall also be tested with individual chambers pressurized at a pressure meeting the stress limits of NB-3226.

-6322 Maximum Permissible Pneumatic Test Pressure. Add the following:

A-6322(a) Multichamber components which are tested with pressure simultaneously applied to adjacent chambers to meet the stress limits of NB-3226 shall also be tested with individual chambers pressurized at a pressure meeting the stress limits of NB-3226.

Add the following new paragraph:

N-6500 POST-TEST EXAMINATION

After the hydrostatic or pneumatic test has been performed, the examination required by NNB-5420 of RDT E 15-2 shall be performed.

N-6600 REPAIRS AND RETESTS

Any leak, permanent deformation, or failure which occurs during hydrostatic or pneumatic test and any rejectable indication found during post-test examination shall be reported to the owner. Repair or retests shall not be performed without the prior approval of the owner.