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RD T E 2-3T

Supersedes

RD T E 2-3T, October 1972

RD T Standard

REACTOR VESSEL FOR LIQUID METAL SERVICE

DECEMBER 1973

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REACTOR VESSEL FOR LIQUID METAL SERVICE

1. SCOPE

This standard delineates the requirements for reactor vessels for reactor systems with loop-type sodium cooling that are constructed in accordance with the Class 1 requirements of the ASME Boiler and Pressure Vessel Code, Section III (hereinafter referred to as the Code), and supplementary requirements that are additive or more restrictive.

1.1 Definitions.

Reactor Vessel. A vessel with a removable closure head that encloses a nuclear reactor core. The reactor vessel includes a support structure, inlet and outlet nozzles, internal thermal baffles and radiation shields, and provisions for attaching internal and external structures.

Vessel Shell. That part of the reactor vessel below the closure head joint exclusive of attached structures, which consists primarily of a cylindrical shell with an integral bottom head and contains the inlet and outlet nozzles for the reactor primary coolant system.

Head. The closure head of the reactor vessel which supports the associated reactor equipment and contains penetrations for control rods, instrumentation, and access for refueling.

Core Support Structure. A support structure within the vessel shell which supports the nuclear reactor core and forms the upper boundary of the inlet plenum.

Inlet Plenum. The interior portion of the reactor vessel between the bottom head and the core support structure.

Outlet Plenum. The interior portion of the reactor vessel between the top of the reactor core and the closure head.

1.2 Supplier Responsibility. The supplier is responsible for assuring that all design, fabrication, inspection, testing, and field engineering requirements of the equipment specification have been satisfied. Purchaser approval of any supplier-submitted document does not relieve the supplier of this responsibility.

2. APPLICABLE DOCUMENTS

The following documents are a part of this standard to the extent specified herein. The issue of a document in effect on the date of invitation to bid, including any amendments, addenda, etc., also in effect on that date, shall apply unless otherwise specified. Where this standard appears to

conflict with the requirements of a reference document such conflict shall be brought to the attention of the purchaser for resolution.

2.1 Exceptions. Where the materials or specifications to be employed in the manufacture of any part are not identified in this standard or the documents referenced herein, the supplier shall submit his specifications, with supporting technical justification demonstrating adequacy for the service conditions, for purchaser approval.

2.2 RDT Standards.

RDT E 15-2T	Requirements for Nuclear Components (Supplement to ASME Boiler and Pressure Vessel Code, Section III)
RDT F 2-2	Quality Assurance Program Requirements
RDT F 3-6T	Nondestructive Examination
RDT F 3-15T	Requirements for Inspection of Dimensional Characteristics
RDT F 4-20T	Operation and Maintenance Manuals
RDT F 5-1T	Cleaning and Cleanliness Requirements for Nuclear Components
RDT F 6-10T	Repair of Materials by Welding
RDT F 7-2T	Preparations for Sealing, Packaging, Packing, and Marking of Components for Shipment and Storage
RDT F 7-3T	Requirements for Identification Marking of Reactor Plant Components and Piping
RDT F 8-1T	Preloading Threaded Fasteners and Closures
RDT F 8-6T	Hoisting and Rigging of Critical Components and Related Equipment
RDT F 9-1T	Requirements for Nuclear Components at Elevated Temperatures (Supplement to ASME Elevated Temperature Code Case 1331)
RDT M 6-2T	Mechanical Locking Devices
RDT M 9-1T	Nickel-Chromium-Iron and Austenitic Chromium-Nickel Alloy Seals

2.3 American National Standards (ANSI).

ANSI B1.1	Unified Screw Threads
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ANSI B46.1 Surface Texture

ANSI Y14 Drafting Manual

2.4 American Society of Mechanical Engineers (ASME).

ASME Boiler and Pressure Vessel Code

Section III, Nuclear Power Plant Components

Code Case 1331, Nuclear Vessels in High Temperature Service,
Section III

2.5 Other Documents.

Code of Federal Regulations, Title 10, Atomic Energy

2.6 Applicable Drawings. (To be specified in the Ordering Data)

3. TECHNICAL REQUIREMENTS

3.1 General Requirements.

3.1.1 Reactor Vessel Description. The reactor vessel consists of the reactor vessel shell, removable closure head with penetrations, reactor vessel support structure, inlet and outlet nozzles, reactor vessel internals such as thermal baffles and nozzle liners, and provisions for attachment of internal and external structures or equipment. All parts, components, attachments, and provisions for attached structures to be provided by others will be itemized and described in the Ordering Data.

The principal functions of the reactor vessel are to:

1. Contain and distribute the flowing sodium coolant that removes heat generated in the fuel core, reflector, shield, and other internal structures.
2. Contain an inert gas cover over the sodium pool.
3. Maintain submergence of the core in sodium under all operating and accident conditions.
4. Provide exact positioning and support for all core components, auxiliary operation equipment, and internal vessel structures.
5. Provide primary containment of coolant, cover gas, fuel materials, and associated thermal and nuclear activities under all operating and accident conditions.

3.1.2 Basis of Construction. The reactor vessel shall be constructed in accordance with the Class 1 requirements of the Code, the

supplementary requirements of RDT E 15-2, and this standard.* The reactor vessel shall be Code stamped by the supplier.

3.1.3 Configuration. Physical characteristics of the reactor vessel shall be in accordance with the purchaser's configuration requirements, limiting dimensions, weight limitations, penetration locations, etc., as specified in the Ordering Data. All boundaries of Code jurisdiction, the boundaries of each pressure zone in the reactor vessel, and the specific dimensional locations of such boundaries shall be as specified in the Ordering Data. The boundaries of internal structures will comply with Code rules for defining the boundaries of specific components such as the core support structure and thermal sleeves.

3.2 Design Requirements.

3.2.1 Standards of Design. The reactor vessel shall be designed in accordance with the Class 1 requirements of the Code and RDT E 15-2. Unless otherwise specified in the Ordering Data, the design of parts and components for design temperatures exceeding 800°F shall be in accordance with Code Case 1331 and the supplemental requirements of RDT F 9-1.

Those parts of the reactor vessel outside the limits of Code jurisdiction shall be designed by methods equivalent to those required by the Code. The supplier shall submit such design rules, methods, or standards to the purchaser for approval prior to use by the supplier.

3.2.2 Design Conditions.

3.2.2.1 Design Pressure. The internal and external design pressures for each pressure zone of the reactor vessel (3.1.3) and the static and dynamic pressure heads of sodium in each zone will be specified in the Ordering Data.

3.2.2.2 Design Temperature. The design temperature for each pressure zone and any significant differential temperatures that will exist in each zone will be specified in the Ordering Data.

3.2.2.3 Design Mechanical Loads.

3.2.2.3.1 Weights. The estimated weights of the vessel shell, closure head and attached equipment, reactor core, core support structure and other internals, and contained sodium will be listed in the Ordering Data. The supplier shall update and list the revised values in the interim reports (3.7.2).

* The term "construction" is used in this standard as defined in the Code, viz, an all inclusive term pertaining to the materials, design, fabrication, examination, testing, inspection and certification required in the manufacture and installation of components, parts, and appurtenances.

3.2.2.3.2 Earthquake Loads. Where applicable in the analysis of design conditions, e.g., for piping, the earthquake data for the operating basis earthquake* (3.2.3) shall be used.

3.2.2.3.3 Piping Interface Loads. The mechanical loads imposed at the interfaces of piping attached to vessel shell will be specified in the Ordering Data.

3.2.2.3.4 Core Support Loads. The mechanical loads imposed on the reactor vessel by the reactor core and core support structure at the core support interface will be specified in the Ordering Data.

3.2.2.3.5 Closure Head Loads. The mechanical loads imposed by both internal and external structures attached to the closure head will be specified in the Ordering Data. Loads will be included for thermal and radiation shielding supported from the head, refueling equipment, control rod drive mechanisms, instrumentation structures, etc. Loadings will be defined relative to points of fixed attachment or the penetration interface, as applicable. The specific operating mode in which the loadings occur will be identified, e.g., normal reactor operation; hot standby; refueling.

3.2.3. Operating Conditions. The reactor vessel shall be designed for the normal, upset, emergency, and faulted conditions specified in the Ordering Data. The data required for the calculation of secondary and peak stress, for analysis of cyclic operation, and for assessing the conformance to special stress limits of the Code will be specified in the Ordering Data for each operating condition. Data such as operating cycle description, duty cycle frequency, and associated temperature transients will be supplemented by reactor coolant data, internal heat generation rate, etc., as required for calculating local metal temperatures and other localized conditions.

3.2.4 Testing Conditions. The testing conditions for additional tests other than the hydrostatic or pneumatic pressure tests permitted by the Code will be specified in the Ordering Data.

3.2.5 Environmental Conditions. The environmental conditions will be specified in the Ordering Data. These conditions will include, but not be limited to, the following:

1. The ambient gas or fluid and its pressure and temperature.
2. The extent and type of sodium contamination.
3. Nuclear radiation intensity in the sodium.
4. Neutron fluence.

* Earthquake terminology is defined in 10 CFR 100, Appendix A.

3.2.6 Service Life. The reactor vessel shall be designed for the service life specified in the Ordering Data based on the number and duration of the described operating events and conditions.

3.2.7 Maintainability. All vessel parts that are not permanently attached to the vessel shell or closure head shall be designed to be completely removable by remotely operated means. Thermal liners and flow baffles shall be removable by remote means without cutting into or compromising the pressure boundary. Where threaded fasteners are used, the design shall permit access for cutting or otherwise removing seized fasteners.

3.2.8 Surveillance and Inservice Inspection. The reactor vessel shall be designed to provide for surveillance and inservice inspection capability in accordance with the requirements specified in the Ordering Data. The areas or portions of the reactor vessel to be periodically evaluated, the applicable visual inspection and nondestructive examination, the vessel conditions at the time of inspection, and any required provisions for the installation of material surveillance coupons will be specified in the Ordering Data. Where design considerations appear to make the desired evaluation impractical, the supplier shall describe the problem and recommend alternatives in the periodic progress report (3.7.3).

3.3 Design and Construction.

3.3.1 Design for Sodium Service. The reactor vessel shall be designed for containment of liquid sodium. The properties of liquid sodium used for design purposes shall be as specified in the Ordering Data. The design of the reactor vessel and the internal parts shall promote free, natural circulation of the liquid sodium. The possibility of gas entrapment in the sodium-immersed internals shall be minimized. Stagnant pockets where dissolved contaminants may accumulate shall be avoided. Erosion of internals shall be avoided by designing passages, channels, and ports to limit sodium velocities under operating conditions to the values specified in the Ordering Data.

3.3.1.1 Corrosion. Corrosion allowances for the reactor vessel components and parts shall be established as specified by the Ordering Data. Corrosion allowances shall provide for all damaging material loss and surface deterioration that may result from corrosion, erosion, mass transfer effects, and other mechanisms during the service life.

3.3.2 Vessel Cooling. The reactor vessel design shall provide for limiting the operating temperature of the vessel shell, outlet nozzles, and other penetrations affected by outlet sodium temperatures in order to reduce the magnitude of temperature transients. Basic design features, such as thermal baffles and use of inlet sodium for bypass cooling, and the associated design criteria will be specified in the Ordering Data.

3.3.3 Vessel Heating. The reactor vessel shall be equipped with an external heat source for preheating the vessel prior to liquid sodium fill and for maintaining the sodium in a liquid condition during extended periods of reactor shutdown. The vessel preheat temperature, the sodium

temperature to be maintained, and the description of any partially-filled conditions under which the sodium temperature is to be maintained will be specified in the Ordering Data. Unless otherwise specified, the supplier shall recommend the external heat source and method of application for the approval of the purchaser.

3.3.4 Head Thermal Protection. The reactor vessel design shall provide for cooling and heating of the head to maintain a nominally constant head temperature during all modes of operation in accordance with the head temperature criteria specified in the Ordering Data. Unless otherwise specified, the supplier shall recommend the requirements for the head heating and cooling system for the approval of the purchaser.

3.3.5 Vessel and Head Insulation. The top and bottom surfaces of the closure head and the exterior surface of the vessel shell shall be insulated to limit heat flow to the ambient environment and to provide protection to personnel as specified in the Ordering Data. Insulation below the top of the guard vessel shall not be attached directly to the reactor vessel. The lower limit for direct attachment of insulation on the reactor vessel shell will be specified in the Ordering Data.

3.3.6 Radiation Damage. Where possible, the design of internal features of the reactor vessel shall minimize local environmental conditions that deteriorate the inherent mechanical properties of pressure-retaining boundary material to assure that the material properties at end-of-life exceed the minimum requirements specified in the Ordering Data.

3.3.7 Vessel Support. Requirements for heating, cooling, and insulating the vessel support structure and other requirements related to the vessel support configuration (3.1.3) will be specified in the Ordering Data.

3.3.8 Design for Earthquake Conditions. The reactor vessel, closure head, inlet and outlet piping, supports, and internal structures shall be designed to remain functional and without significant loss of structural integrity after experiencing a safe shutdown earthquake (SSE). The internal structures supporting the nuclear core shall remain intact. The displacement of the core relative to the control rod positions shall not exceed the limits specified in the Ordering Data. The incremental misalignment of the head with respect to the vessel and the amount of head deflection resulting from a SSE shall not exceed the limits specified in the Ordering Data. Criteria for designing the upper portion of the reactor vessel for SSE conditions shall be as specified in the Ordering Data.

3.3.8.1 Seismic Analysis. Seismic analysis of the reactor vessel shall be performed in accordance with the requirements specified in the Ordering Data.

3.3.9 Vibration. The reactor vessel shall be designed to preclude impairment of operability due to hydraulically-induced vibration. Applicable hydraulic data, including the hydraulic and mechanical forcing frequencies generated by the sodium pumps, will be specified in the Ordering Data. The

design analysis shall be documented in the Stress Report (3.7.1).

3.3.10 Assembly Adjustments. The reactor vessel design shall provide for adjustment of linear and angular alignment, concentricity, clearances, etc., during assembly by simple modifications to such components as keys, shims, and spacers. Quantitative requirements for adjustability shall be as specified in the Ordering Data.

3.3.11 Threaded Connections. Threaded connections shall conform to the following requirements:

1. All screw threads shall be in accordance with ANSI B1.1.
2. Unless otherwise specified, threads shall conform to the Unified Thread Form.
3. Unless otherwise specified, thread fits shall be the Unified 2A or 2B.
4. Threaded connections shall not be used at locations that will normally be immersed in sodium except when approved by the purchaser for a specific application.
5. Stud bolts shall be used except where the use of headed fasteners is specifically approved by the purchaser.
6. Installation and preloading of fasteners shall be in accordance with RDT F 8-1.
7. All threaded fasteners shall have locking devices conforming to the requirements of RDT M 6-2.

3.3.12 Weld Design. Welds shall be designed to permit radiographic examination wherever practicable. Purchaser approval is required for all structural welds that cannot be radiographed. (Such approval will be limited to only those welds in which radiography is not a Code requirement.)

3.3.13 Vessel Penetrations. Except for reactor coolant inlet nozzles, there shall be no penetrations in the reactor vessel shell that are located below the coolant outlet nozzles.

3.3.14 Vessel Closure and Head Penetrations. Requirements for seals and sealing surfaces and other requirements related to the configuration of the vessel closure and closure head penetrations (3.1.3) will be specified in the Ordering Data. The maximum allowable cover gas leakage rates will be specified in the Ordering Data. Unless otherwise specified, integral and non-integral seals shall satisfy the requirements of RDT M 9-1.

3.3.15 Instrumentation. The reactor vessel design shall provide for the installation of sensors, detectors, leads, and conductors required for reactor vessel instrumentation. Requirements for these items and their

required location shall be as specified in the Ordering Data.

3.3.16 Radiation Shielding. Shielding shall be provided to limit radiation at the top surface of the closure head to the levels specified in the Ordering Data. Shield penetrations for items extending down through the head shall be designed within the constraint that the combined effect of clearance and shield/head misalignment shall not result in mechanical interference between the shield and items penetrating the structure under any normal, upset, or emergency condition which would deleteriously affect reactor operation.

3.3.17 Surface Roughness. Unless otherwise specified, the maximum surface roughness as determined in accordance with ANSI B46.1 and RDT F 3-15 shall not exceed:

1. 63 microinch (AA) for all aligning, sealing, and sliding surfaces between mating parts.
2. 250 microinch (AA) for all other machined surfaces.
3. 500 microinch (AA) for unmachined surfaces.

3.4 Materials.

3.4.1 General. All materials for parts within the boundaries of Code jurisdiction shall be in accordance with the Code and the supplemental requirements of RDT E 15-2. Material specifications to be used shall be limited to those RDT standards listed in Tables NNB-2120-1 and NNB-2120-2 of RDT E 15-2. The specific material, including type and grade to be used for specific parts and components and any additional material requirements - such as optional requirements of the RDT material standard or limitations on chemical composition that are to apply - shall be as specified in the Ordering Data or as recommended by the supplier and approved by the purchaser.

3.4.2 Pressure-Retaining Boundary and Sodium-Containing Parts. Unless otherwise specified, all parts of the reactor vessel that form part of the pressure-retaining boundaries or that are exposed to liquid sodium or sodium-containing environments shall be fabricated from either 304 or 316 austenitic stainless steel. Specific selection of alternate materials shall be based on the mechanical properties, metallurgical stability, sodium compatibility, and response to radiation under the applicable design and environmental conditions. When recommending the use of alternate materials, the supplier shall document the justification which shall include, as a minimum, a summary of available test or experience data and discussion of the adequacy of the recommended material(s) relative to 304 or 316 stainless steel or other purchaser-specified alternate.

3.4.2.1 Where approved by the purchaser, cladding may be used to resist localized wear and galling or in closure head construction.

3.4.2.2 Specific approval of the purchaser is required for the use of hard surfacing or other materials for resistance to wear and galling.

3.4.3 Other Applications. Materials used for applications not within the scope of 3.4.1 shall be as specified in the Ordering Data or as recommended by the supplier and approved by the purchaser prior to the supplier ordering the material.

3.4.4 Archive and Surveillance Samples. Samples of materials used in the fabrication of the reactor vessel shall be obtained, identified, and preserved for use as archive specimens and surveillance coupons. These samples shall have the same metallurgical and fabrication histories as the parent materials in the completed vessel parts. The samples shall be large enough to provide all test specimens needed to duplicate the original material acceptance tests. Records shall be maintained to provide traceability of all material samples back to original material certifications and inspection data. Requirements pertaining to sampling locations and the number of samples will be specified in the Ordering Data.

3.5 Fabrication.

3.5.1 General. The fabrication of parts, components, and assemblies shall be in accordance with the Code and the supplemental requirements of RDT E 15-2. The fabrication of any item shall not be initiated without prior purchaser approval.

3.5.2 Welding and Thermal Cutting. All welding, hard surfacing, and thermal cutting shall be in accordance with the Code and the supplemental requirements of RDT E 15-2. Brazing shall not be used.

3.5.2.1 Weld Repair. Purchaser approval is required to make weld repairs to correct defects that recur:

1. After the first cycle of weld repair of defects in the fusion zone and adjacent base metal where welds are not heat treated following repair.
2. After the second cycle of repair in welds that are heat treated after each repair cycle.

Purchaser approval is required for the repair of crater cracks restricted to the crater of any weld pass if the third repair cycle results are not acceptable.

The supplier shall keep a continuous cumulative record of all weld repairs to welds and base metal. The supplier shall submit copies of this record to the purchaser for information within 10 working days of a purchaser request. In addition, with shipment of the component from the suppliers plant, the supplier shall submit to the purchaser five copies of all welding repair records and five copies of drawings of the assembled components on which the location of the repairs - specified to within 0.1 inches of their centers - is shown.

3.5.2.2 Material Repair. Unless otherwise specified, welding

processes for repair of defects in material may be used where permitted by the Code and the applicable material standard. Any such repair welding shall be performed in accordance to the requirements of RDT F 6-10. No repair welding of bolting material shall be permitted.

3.5.3 Heat Treatment. The supplier shall recommend for purchaser approval all heat treatments other than those performed by the material supplier. Unless otherwise specified, or approved by the purchaser, all heat treatments shall be in accordance with the applicable material standard.

3.5.3.1 Sensitization. Austenitic stainless steel which has become sensitized during heat treatment, welding, or forming shall be solution annealed per the applicable material standard or be protected against corrosion during all subsequent manufacturing, testing, shipment, and storage operations. Protection of parts which are not solution annealed subsequent to becoming sensitized shall be based on procedures submitted by the supplier and approved by the purchaser.

3.5.4 Bending and Forming. Bending and forming shall be performed in accordance with the requirements of the Code. Where the Code does not require heat treatment after bending or forming, the supplier shall evaluate the need for stress-relief heat treatment to insure dimensional stability of the parts at operating temperatures. The supplier's recommendation shall be approved by the purchaser prior to initiation of the proposed fabrication operation. Unless otherwise specified or approved by the purchaser, solution annealing shall be used where stress-relief of austenitic stainless steel is required.

3.5.5 Plating. Plating shall not be permitted unless the purchaser's approval has been obtained. Plating shall not be used for corrosion protection of surfaces in contact with the sodium coolant.

3.5.6 Precautionary Measures. Shop practices and restrictions on the use of materials shall meet the requirements of RDT F 5-1. Hoisting and rigging of the reactor vessel and the major parts and components of the reactor vessel that are designated as "critical" in the Ordering Data shall satisfy the requirements of RDT F 8-6. Unless otherwise specified in the Ordering Data, load testing and inspection of hoisting and materials handling equipment in accordance with paragraphs 9.1.3, 9.1.4, and 9.1.5 of RDT F 8-6 is required. The supplier shall include appropriate instructions and restrictions in his fabrication procedures and other documents defining acceptable shop practices.

3.5.7 Cleaning. The fabrication of a part, combination of parts, subassembly, or assembly shall be conducted so as to facilitate cleaning and inspection for cleanliness and to minimize contamination. Surfaces shall be cleaned in accordance with - and to meet the cleanliness requirements of - RDT F 5-1. Items shall be maintained in a clean condition up to delivery.

3.5.8 Identification Marking. The marking of materials, parts, components, and assemblies for both in-process and permanent identification shall be in accordance with RDT F 7-3. In addition to the materials

identification data required to meet the traceability requirements of the Code and RDT F 2-2, identification marking shall include part numbers, serial numbers, etc., as specified in the Ordering Data. Permanent nameplates shall be in accordance with the Code and the following requirements:

1. The nameplate shall be made of a corrosion-resistant material compatible with the surface to which it is attached.
2. Caustic-resistant enamel shall be used to fill the nameplate markings.
3. The nameplate shall be attached to the component in accordance with the requirements of the Code and RDT E 15-2 and in a location approved by the purchaser.
4. The nameplates shall contain all data required by the Code and any additional information specified in the Ordering Data.
5. Nameplates shall not be painted over or otherwise covered or concealed by insulation or adjacent parts.

3.5.9 Assembly. Component parts shall be assembled in accordance with a detailed assembly procedure prepared by the supplier and approved by the purchaser. As a minimum, each procedure shall include:

1. Assembly sequence with reference to part numbers and drawings.
2. Cleaning procedures and precautionary rules.
3. Any special machining or fitting-at-assembly instructions.
4. Intermediate and final inspection criteria and hold points.
5. Handling methods and precautionary rules.
6. Tightening limits, allowable lubricants, etc., for threaded parts and fasteners.
7. Locking device or tack welding instructions.
8. Drawings or photographs as required to illustrate assembly techniques.
9. A summary of special data measurements and observations to be recorded.

3.6 Drawings. Supplier drawings shall be prepared in accordance with ANSI Y14. As a minimum, the supplier shall prepare the following types of drawings for each component required by the equipment specification. The time and approval requirements for supplier submittals to the purchaser shall be as specified in the Ordering Data.

3.6.1 Preliminary Drawings. When required by the Ordering Data,

preliminary engineering drawings shall be submitted for the purchaser's information with the supplier's initial bid. These drawings shall depict component configuration, design features, engineering concepts, interface data, etc., proposed as a basis for meeting the requirements of the specification.

3.6.2 Interface Control Drawings. When required by the Ordering Data, the supplier shall submit interface control drawings for purchaser approval prior to the design evaluation drawings (3.6.3). Such drawings shall provide complete physical and functional interface data required for the construction of support structures and connected components and services.

3.6.3 Design Evaluation Drawings. Design evaluation drawings shall be submitted to the purchaser for approval prior to the initiation of manufacture. These drawings, which may include design layout drawings, interface control drawings, etc., shall provide a complete basis for independent design review prior to detailing. The drawings shall include, but not be limited to:

1. Complete configuration and arrangement of all components and parts showing assembled relationships.
2. All principal and critical dimensions including critical tolerances.
3. Material to be used for each part including referenced material specifications or standards.
4. Location and design of all welds to be employed.
5. Referenced mandatory and special fabrication processes, heat treatment, etc.
6. Referenced nondestructive examination requirements.
7. Calculated displacements and mechanical loadings of connecting parts from thermal and pressure effects during operation relative to the vessel support interface.
8. Type and location of instrumentation sensors.
9. Design provisions for maintainability.
10. Interface control drawing if not previously submitted (3.6.2).
11. Calculated weights and center of gravity of assembled vessel and of the principal components.
12. Provisions for thermal shielding, vibration control, and any other special features.

3.6.4 Detail Drawings. Detail drawings shall define all features of each part shown including, as applicable: configuration, dimensions, required

nondestructive examination, tolerances, materials, mandatory processes, surface finish, markings, etc. All documents required to supplement the drawing through definition of material, fabrication, inspection and test requirements shall be referenced thereon.

3.6.5 Assembly Drawings. Assembly drawings shall define the assembled relationship of all components and parts. Drawings of subassemblies shall reflect the division of the vessel into practical units for assembly. Each assembly drawing shall depict or specify by reference all physical or functional requirements not included on subordinate detail or special purpose drawings. All parts lists, data lists, and index lists not included on the drawing shall be referenced.

3.6.6 "As-Built" Drawings. The supplier shall provide both assembly and detail drawings revised to show the final configuration of the components and parts at the time of acceptance by the purchaser for shipment. Actual measured values of dimensions taken with the component oriented to its intended installed position shall be given on these drawings.

3.6.7 Drawing and Specification Lists. The supplier shall maintain a current listing of all drawings and specifications in accordance with RDT F 2-2. Each drawing number shall include the current revision number.

The supplier shall maintain a current list of specifications. This list of specifications shall include as applicable, requirements for design, materials, fabrication, construction, installation, testing, inspection, maintenance, cleaning, shipping, storage, operation, and quality assurance.

3.6.8 Parts List. The supplier shall provide a complete list of parts organized by assemblies and keyed to drawing numbers. Each drawing number shall include the current revision number. The supplier shall provide a copy of the parts list which shall serve as a reference against which further changes may be monitored.

3.6.9 Weights and Centers of Gravity. The design evaluation drawings and assembly drawings shall indicate the following:

1. The dry weight, center of gravity, and radius of gyration of the reactor vessel.
2. The weight and center of gravity of the closure head assembly.

3.7 Reports and Documentation. The supplier shall prepare the following documents for submittal to the purchaser. The time and approval requirements of submittals to the purchaser and the number copies of each document required shall be as specified in the Ordering Data.

3.7.1 Design Report. This report shall cover the design of the reactor vessel and shall include, as a minimum:

1. Design description which defines and integrates the various technical, operational, and safety considerations.

2. A Stress Report in accordance with Code requirements which is prepared in accordance with the guidelines presented in Appendix C of the Code.
3. Thermal analyses for steady-state and transient conditions.
4. All known parameters, assumptions, approximations, calculations and references in sufficient detail to permit independent checking.
5. Copies of the design analysis plan and interim design analysis reports (3.7.2).

The supplier shall be responsible for making such additions or corrections to the report as are required to keep the information current and correct. These revisions shall be suitably numbered and dated.

3.7.2 Design Analysis Plan and Interim Design Analysis Reports. The supplier shall submit a design analysis plan and subsequent interim design analysis reports in accordance with the requirements of RDT F 9-1 and any additional requirements specified in the Ordering Data.

3.7.3 Periodic Progress Reports. Reports on the status of design, fabrication, inspection, testing, shipping, cost, and schedule shall be made at intervals specified in the Ordering Data. These reports shall relate the progress made since the last report with only enough repetition of previously reported events to frame the contents of the present report. These periodic reports should also include difficulties encountered (such as failures and malfunctions) and the efforts made or planned for overcoming them. Problems foreseen as possible disruptions of the schedule shall be brought to the attention of the purchaser as early as possible. Break-throughs of significance should be discussed.

3.7.4 Operation and Maintenance Manual. The supplier shall provide an Operation and Maintenance Manual in accordance with those requirements of RDT F 4-20 that are specified in the Ordering Data. This manual shall reflect the "as-built" configuration of the delivered item. Information shall include, but not be limited to, the following:

1. A detailed description of the reactor vessel and instructions for installation, operation, preventive maintenance, repair of equipment, and surveillance inservice inspection.
2. Instructions for use of lifting and handling fixtures and special tools and equipment.
3. Reduced-size drawings for operation, maintenance, and instructional purposes, including drawings of special tools and equipment.

3.7.5 Special Tool List. The supplier shall prepare and keep current a list of all special tools, including gages, plugs, and fixtures. The list shall identify each tool by name, drawing number, function, and

operation(s) for which it is required, and whether it is an in-process tool or a deliverable item.

3.7.6 Repair Parts and Special Tools List. The supplier shall recommend a list of spare parts to be stocked at the plant site. This list is to contain those parts and tools likely to be damaged or expended during delivery, plant operations, or both. When approved, the supplier shall process and deliver these spares in accordance with the requirements for deliverable items.

3.8 Installation Services. The supplier shall provide technical advice and assistance and shall monitor quality assurance implementation during the installation and any subsequent repair or replacement of equipment to the extent specified in the Ordering Data. Field welding or other field assembly operations to be performed by the supplier will be specified in the Ordering Data.

3.9 Field Modification. The supplier shall provide engineering services and technical direction for any field modifications to those items which he has supplied. The supplier shall perform all field modifications in accordance with the requirements of this standard and the Ordering Data.

4. QUALITY ASSURANCE REQUIREMENTS

4.1 Quality Assurance Program. The supplier shall plan, establish, implement, and maintain a documented quality assurance program that fulfills all requirements of Sections 1, 2, 3, 4, 5, and 8 of RDT F 2-2, the Code, and any additional requirements of this standard.

4.2 Quality Assurance Documents. The supplier shall submit for purchaser approval quality assurance documents required by RDT F 2-2 as specified in the Ordering Data. Other documentation required by RDT F 2-2 shall be maintained by the supplier in his records.

4.3 Marking and Identification.

4.3.1 Materials. All materials used in the manufacture of items shall be examined to ensure compliance with requirements of 3.5.8.

4.3.2 Permanent Marking. All finished components, spare parts, and special handling fixtures to be delivered as part of the contractual requirements shall be examined to ensure that they are permanently marked for purposes of identification in accordance with 3.5.8. Marking of sample material shall be examined for identification, location, and orientation.

4.4 Nondestructive Examination Requirements.

4.4.1 General. Nondestructive examination of materials and fabricated components shall be in accordance with the Code as supplemented by RDT E 15-2, the requirements of the applicable RDT material standards, and the additional requirements of this standard. Acceptance criteria shall

be in accordance with the Code as supplemented by RDT E 15-2 or the requirements of the applicable RDT material standards.

4.4.2 Equipment Calibration. Instrumentation, reference blocks and other physical standards, and measuring equipment used in conjunction with nondestructive examinations shall be calibrated and controlled in accordance with RDT F 2-2.

4.4.3 Designation of Certification Level. Each written examination procedure shall specify the certification level (Levels I, II, or III) required of personnel who:

1. Perform the nondestructive examination.
2. Interpret and evaluate the results of the examination.

4.4.4 Post Examination Cleaning. Following any nondestructive examination in which examination materials remain on the surface, the part shall be thoroughly cleaned to satisfy the cleanliness requirements of RDT F 5-1 before proceeding to the next weld pass, fabrication, or inspection step.

4.5 Examination of Materials.

4.5.1 General. Prior to use in fabrication, all materials shall be:

1. Visually examined for conformance to cleanliness requirements and to detect obvious defects.
2. Nondestructively examined in accordance with the requirements of 4.4.1 and any additional requirements specified in the Ordering Data (3.4.1).

4.5.2 Examination of Repaired Material. Areas in materials where defects have been removed and repair welding is not required shall be examined as required by the Code as supplemented by RDT E 15-2. Areas in materials that have been repaired by welding shall be examined in accordance with RDT F 6-10. In addition to the requirements of RDT F 6-10, all weld-repaired areas shall be re-examined for conformance to the original acceptance criteria using the method(s) which originally revealed the defect.

4.6 Examination of Fabricated Items.

4.6.1 General. All items shall be visually examined and measured to verify conformance to purchaser-approved drawings. Inspection of dimensional characteristics shall conform to the requirements of RDT F 3-15. Any requirements for recording measurements other than required by RDT F 3-15 will be specified in the Ordering Data. All dimensional limits depicted on the approved drawings shall be interpreted as absolute, as defined in RDT F 3-15. Formed pressure boundary parts shall be examined throughout for conformance to the specified shape and thickness. Nozzles and other interfacing attachments shall be examined for proper fit to items to which they will be attached.

4.6.2 Weld Examination. Visual, dimensional, and nondestructive examination of welds and weld repairs shall be in accordance with the Code as supplemented by RDT E 15-2 and the additional requirements of this standard.

4.6.2.1 Unless otherwise specified, all welds shall be volumetrically examined by two independent nondestructive examination methods.

4.6.2.2 Non-Code structural welds (3.3.12) which cannot be adequately examined by radiography shall be 100 percent examined by ultrasonic methods in accordance with RDT F 3-6. Welds which cannot be adequately examined by either radiography or ultrasonics, or a combination of both, shall be progressively examined by a liquid penetrant or magnetic particle method at the intervals specified in RDT E 15-2. For welds where this interval is not specified in RDT E 15-2, the progressive liquid penetrant or magnetic particle examination shall be performed after the root pass and each successive 1/2 inch or 1/3 T (whichever is smaller) of deposited weld, where T is the thickness of the finished weld.

4.6.3 Seals and Seal Membranes. Unless otherwise specified in the Ordering Data, seals and seal membranes (3.3.14) shall be examined in accordance with the requirements of RDT M 9-1.

4.6.4 Examination of Lifting Attachments. Following load tests, slinging eyes, lugs, trunnions, and other lifting attachments to vessel components and supporting structures such as cradles shall be visually inspected and examined by the magnetic particle or liquid penetrant method in accordance with the method requirements of RDT F 3-6. Evidence of permanent distortion or the occurrence of stress-related mechanical defects from load testing is not acceptable.

The supplier shall submit an inspection procedure and obtain purchaser approval prior to performing the load tests. The inspection procedure shall include provisions for determining both the pre-test and post-test condition of the lifting attachments and specify the acceptance criteria for the particular types of attachments to be examined.

4.7 Testing.

4.7.1 Pressure Tests. Either a pneumatic or hydrostatic pressure test shall be performed in accordance with the Code as supplemented by RDT E 15-2 and this standard. The supplier shall recommend which type of test should be performed in the inspection and test plan. Unless otherwise specified in the Ordering Data, the vessel shell and the head may be tested separately. The supplier shall submit a detailed test procedure for the purchaser's approval.

Prior to testing, the interior surfaces of the component shall be cleaned to meet the cleanliness requirements of RDT F 5-1. The temperatures of the component materials and test medium shall be continuously monitored during the test.

The maximum number of tests above design pressure shall be limited to the number of tests specified in the Ordering Data.

Any indication of leakage in the vessel or head pressure-retaining boundaries shall be reported to the purchaser before any corrective action is taken. The supplier shall recommend the necessary corrective action, with technical justification, for purchaser approval.

4.7.2 Leak Test. Leak tests of flanged joints and other sealed joints shall be performed to verify the requirements of 3.3.14 when and as specified in the Ordering Data.

4.7.3 Special Tests. The supplier shall propose a program to perform vibration, shock, and other special tests needed to substantiate the reactor vessel design. For each test proposal approved by the purchaser, the supplier shall prepare a test procedure for the purchaser's approval. The test report - including test data, analyses of the data, and interpretation of the data relative to design objectives - shall be submitted to the purchaser.

5. PREPARATION FOR DELIVERY

5.1 Delivery Requirements. The supplier shall deliver items to the delivery point specified in the Ordering Data. The supplier shall submit for the purchaser's approval a Packaging and Shipment Plan that presents the practices, procedures, and instructions to be followed in meeting the requirements of this section of the standard.

5.2 Preparation. Upon completion of all shop testing and inspection, the supplier shall prepare all items for delivery to the designated site. This shall include, but is not limited to, any disassembly required, re-cleaning and drying, application of any protective surface treatment, final visual examination, etc.

5.3 Packaging and Packing. All deliverable items shall be packaged and packed in a manner that will assure delivery in a clean, undamaged condition. All sealing, packaging, packing, and identification marking shall be in accordance with RDT F 7-2. Packaging shall be adequate to protect items while at the supplier's facilities, during transportation to the delivery point, and storage prior to installation. The supplier shall package the components to accommodate the type of storage conditions and storage time at the delivery point as specified in the Ordering Data. These requirements shall apply to any items fabricated or assembled in the field as well as to those items shipped ready for installation.

5.4 Shipping. Unless otherwise specified, the supplier shall be responsible for the safe shipment and delivery of all deliverable items to the delivery point designated by the purchaser in the Ordering Data. In support of the Packaging and Shipment plan, the supplier shall submit documentation justifying the supplier-proposed shipping with respect to cost and safety of the components. The supplier shall make all necessary shipping arrangements.

5.4.1 Routing. The supplier shall recommend the means of transportation and the routing to be used.

5.4.2 Shipping Instructions. The supplier shall prepare suitable instructions to the shipper that include requirements for handling, shipping, loading and unloading, in-transit storage, etc., for all deliverable items. The required shipping position, crating, supports, and tie-down points shall be determined by the supplier. The supplier shall supervise the loading of the items at his facilities.

5.5 Handling. Hoisting and rigging of the reactor vessel or vessel components during preparation for delivery and loading shall meet the requirements of 3.5.6 for those items identified as "critical". In addition, these requirements shall apply to lifting cradles and fixtures provided by the supplier that are to be used for loading or for maintaining the position of components during shipment and installation.

Lifting points and tie-down points shall be provided for shipping and installation fixtures. If a loaded fixture requires upending, points of attachment for tackle, trunnions, or other features required for safe, controlled positioning shall be provided.

The supplier shall submit drawings and supporting stress analyses for fixtures, cradles, and temporary lifting attachments and obtain purchaser approval prior to start of fabrication of the item.

Shipping fixtures and lifting attachments fabricated from ferritic materials shall be sufficiently ductile to permit safe handling and shipment at an ambient temperature of -10°F . The supplier shall take special precautions to prevent brittle fracture of these devices if shipping is scheduled during the months of October through March and ambient temperatures below -10°F may be anticipated.

6. NOTES AND ORDERING DATA CHECKLIST

6.1 Notes.

6.1.1 The specification for the reactor vessel, which will consist of this standard, modifications (if any), and the Ordering Data, must be certified by a registered professional engineer representing the purchaser to be correct, complete, and in compliance with the Design Specification requirements of NA-3250 of the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components.

6.1.2 As RDT standards may not be readily available, copies of all RDT standards referenced in the reactor vessel specification should be provided to every prospective supplier. In addition, all sub-referenced RDT standards - which are not listed in the Applicable Documents section - should also be provided unless their use is precluded by the specific requirements of the specification. For example, RDT E 15-2 references eight other RDT standards. Three of these (F 3-37, F 6-5, and F 6-14) are not directly

referenced or listed in this standard, RDT E 2-3.

6.1.3 The supplier should be requested to provide the following minimum information in his proposal:

1. Preliminary drawings (3.6.1).
2. Materials of construction (3.4).
3. Reactor vessel support requirements (interface with the Architect-Engineer).

6.2 Ordering Data Checklist. The detailed requirements and conditions necessary to design, fabricate, examine, test, and deliver a reactor vessel in accordance with this standard are to be included in the Ordering Data. These requirements are listed below in the Ordering Data Checklist. The list includes topics to which the standard makes specific reference, as well as other supplemental information which must be defined by the purchaser.

The applicable paragraph number of the standard is used herein to identify information and its location. Any omission of a paragraph number in this checklist indicates that the particular paragraph of the standard is believed to adequately specify the requirements.

1. Scope. This section should include a statement indicating that this document is the Ordering Data which supplements this standard. In addition, include a brief presentation of basic information which will aid the supplier in performing his work. Coverage should include:

- a. Application, a brief description of the nature of the application.
- b. The location of the installation site as may be required for Code purposes.
- c. Summary of the components and services to be furnished.

2. Applicable Documents. List all documents which are specifically called out in sections 3, 4, or 5 of the Ordering Data and this standard. List applicable drawings (2.6). Identify the applicable issues, amendments, addenda, etc., as required to clarify what documents are in effect or are to apply. As mandatory application of Code rules is based on contract date for the component, the effective Code issue and addenda and the issue and amendments of RDT Code Supplements that are to apply may require redefinition at the time contractual action is implemented.

3. Technical Requirements.

- 3.1.1 Itemize and describe all parts, components, attachments, and provisions for attached structures. Identify, if any, such items as exterior piping to be included in the reactor vessel assembly as delivered.

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- 3.1.3 Specify configuration requirements, boundaries of Code jurisdiction, boundaries of pressure zones (drawings required).
 - 3.2.1 Specify any alternate high temperature design rules.
 - 3.2.2.1 Specify design pressures and sodium heads.
 - 3.2.2.2 Specify design temperature and significant temperature differentials (if any) for each pressure zone.
 - 3.2.2.3.1 List estimated weights of parts, components, attached structures and contained fluid.
 - 3.2.2.3.3 Specify piping interface loads.
 - 3.2.2.3.4 Specify loads imposed by reactor core and core support structure.
 - 3.2.2.3.5 Specify loads imposed by attached structures and operating equipment on the closure head.
 - 3.2.3 Specify operating conditions and all supporting data required for design including earthquake data.
 - 3.2.4 Specify conditions to be used for any tests other than the pressure tests required by the Code.
 - 3.2.5 Specify environmental conditions.
 - 3.2.6 Specify service life.
 - 3.2.8 Specify surveillance and inservice inspection requirements.
 - 3.3.1 Specify sodium properties.
Specify maximum allowable sodium velocities.
 - 3.3.1.1 Specify criteria, data, and methods applicable to establishing corrosion allowances.
 - 3.3.2 Identify any design features to be incorporated for vessel cooling and applicable design criteria. Provide drawings as required if these features are not identified in 3.1.3.
 - 3.3.3 Specify reactor vessel preheating and heating requirements with attendant fill conditions.

Specify heating system requirements if supplier's recommendation is not sought.

- 3.3.4 Specify head operating temperature criteria.
- 3.3.5 Specify maximum temperatures to be permitted at exterior boundaries of the vessel.

Specify lower limit for insulation application on vessel shell.
- 3.3.6 Specify minimum end-of-life mechanical properties required for pressure-retaining boundary materials.
- 3.3.7 Specify vessel support requirements.
- 3.3.8 Specify maximum displacement, deflection, distortion, or misalignment permitted for specific parts and components as a result of a SSE.

Specify any supplementary criteria for seismic design.
- 3.3.8.1 Specify seismic analysis requirements.
- 3.3.9 Specify pump data relative to hydraulically-induced vibration in the reactor vessel.
- 3.3.10 Specify quantitative adjustability requirements for assembly of reactor vessel.
- 3.3.11 Specify any alternate fastener requirements.

Identify any locations where immersed threaded connections will be permitted (if any).
- 3.3.14 Specify sealing and other requirements.

Specify maximum allowable leak rates for sealed interfaces.

Specify alternate seal standards (if any).
- 3.3.15 Specify instrumentation required and the locations for installation.
- 3.3.16 Specify maximum allowable radiation permitted at top surface of closure head.
- 3.3.17 Specify any alternate surface roughness requirements.
- 3.4.1 Specify (if desired) the use of specific alternate materials and additional requirements that apply.
- 3.4.3 Specify (if desired) materials for non-Code applications.

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- 3.4.4 Specify requirements for archive samples and surveillance coupons.
 - 3.5.2.2 Specify any additional restrictions on material repair by welding.
 - 3.5.3 Specify any alternate heat treatment requirements.
 - 3.5.4 Specify any alternate stress-relief heat treatment.
 - 3.5.6 Specify which components are "critical" relative to F 8-6 usage.
 - 3.5.8 Specify any additional identification marking to be required.
 - 3.6.1 Specify whether the preliminary drawings are to be provided with supplier's proposal.
 - 3.6.2 Specify whether interface control drawings are required prior to the design evaluation drawings.
 - 3.7 Tabulate document submittal requirements.
 - 3.7.2 Specify any additional requirements for interim reports.
 - 3.7.3 Specify progress report requirements.
 - 3.7.4 Specify which requirements of RDT F 4-20 are to apply.
 - 3.8 Specify installation and field services required.
 - 3.9 Specify any requirements for possible field modifications.
 - 4.2 Tabulate submittal requirements.
 - 4.6.1 Specify any key dimensions to be recorded.
 - 4.6.3 Specify any alternate examination and acceptance criteria for seals.
 - 4.7.1 Prohibit (if desired) separate testing of vessel and head.
Specify maximum number of tests above design pressure to be permitted.
 - 4.7.2 Specify leak test requirements.
 - 5.1 Specify delivery point.
 - 5.3 Specify storage time and conditions for equipment packaging requirements.