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SODIUM-HEATED STEAM GENERATOR

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SODIUM-HEATED STEAM GENERATOR

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SODIUM-HEATED STEAM GENERATOR

1. SCOPE

This standard defines the requirements for the design, development testing, material selection, fabrication, shop testing, inspection, shipping, handling, and installation of sodium-heated steam generators. Steam generators designed, built, tested, and inspected in accordance with this standard will meet the requirements of Section III of the ASME Boiler and Pressure Vessel Code (the Code). This standard covers only the heat exchange components (superheater and evaporator).

1.1 Definitions.

1.1.1 Crevice. A gap between two adjacent surfaces within the steam generator sufficiently narrow such that gravitational or capillary forces prevent free movement of material in the crevice and the volume to which it is connected.

1.1.2 Design Basis Leak (DBL). The leak of water or steam into sodium analyzed for establishing steam generator design parameters and relief system design basis.

1.1.3 Interstitial Element Transport. The removal by sodium of the interstitial elements such as carbon, nitrogen, and boron from material in one part of the system and the transfer to materials in other parts of the system.

1.1.4 Sodium-Water Reaction. The chemical reaction of sodium with either water or steam. The reaction releases heat and gaseous hydrogen forming sodium oxide, hydroxide, and hydride.

1.1.5 Thermal Center. The geometric location in a steam generator where one half of the sodium temperature drop has been achieved.

1.2 Abbreviations and Acronyms.

AA - arithmetic average as defined by ANSI B46.1

DNB - departure from nucleate boiling

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 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 RDT Standards.

RDT C 7-6T	Thermocouple Assembly, Nuclear Grade, Chromel-P vs. Alumel, Stainless Steel Sheathed, Magnesium Oxide Insulated
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 3-37T	Special Requirements for Metal Products
RDT F 4-20T	Operation and Maintenance Manuals
RDT F 5-1T	Cleaning and Cleanliness Requirements for Nuclear Components
RDT F 6-5T	Welding Qualifications (Supplement to ASME Boiler and Pressure Vessel Code, Section IX)
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 F 9-2T	Seismic Requirements for Design of Nuclear Power Plants and Test Facilities

RDT M 1-1T	Stainless Steel Covered Welding Electrodes (ASME SFA-5.4 with Additional Requirements)
RDT M 1-2T	Stainless Steel Welding Rods and Bare Electrodes (ASME SFA-5.9 with Additional Requirements)
RDT M 1-3T	Mild Steel Covered Welding Electrodes (ASME SFA-5.1 with Additional Requirements)
RDT M 1-4T	Low Alloy Steel Covered Welding Electrodes (ASMS SFA-5.5 with Additional Requirements)
RDT M 1-6T	Mild Steel Electrodes and Welding Rods (ASME SFA-5.18 with Additional Requirements)
RDT M 1-11T	Nickel and Nickel-Alloy Bare Welding Rods and Electrodes (ASME SFA-5.14 with Additional Requirements)
RDT M 2-1T	Carbon Steel Forgings (ASME SA-105 with Additional Requirements)
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 2-7T	Carbon and Alloy Steel Forgings, Vacuum Treated (ASME SA-508 with Additional Requirements)
RDT M 2-8T	Alloy Steel Forgings (ASME SA-541 with Additional Requirements)
RDT M 2-15T	Nickel-Chromium Alloy Bars, Forgings, and Forging Stock (ASME SA-637 with Additional Requirements)
RDT M 3-1T	Carbon Steel Seamless Pipe (ASME SA-106 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 3-9T	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 4-1T	Carbon Steel Castings (ASME SA-216 with Additional Requirements)
RDT M 4-2T	Austenitic Stainless Steel Castings (ASME SA-351 with Additional Requirements)
RDT M 5-1T	Stainless Steel Plate, Sheet and Strip (ASME SA-240 with Additional Requirements)
RDT M 5-2T	Carbon Steel Plates (ASME SA-516 with Additional Requirements)
RDT M 5-3T	Low Alloy Steel Plates (ASME SA-533 with Additional Requirements)
RDT M 5-4T	Nickel-Chromium-Iron Alloy Plate, Sheet and Strip (ASME SB-168 with Additional Requirements)
RDT M 5-5T	Low Alloy Steel Plates (ASME SA-387 with Additional Requirements)
RDT M 6-1T	Alloy Steel Bolting Material for Low Temperature Service (ASME SA-320 with Additional Requirements)
RDT M 6-2T	Mechanical Locking Devices
RDT M 6-3T	Alloy Steel Bolting Material for High Temperature Service (ASME SA-193 with Additional Requirements)
RDT M 6-4T	Alloy Steel Nuts for Bolting for High Temperature Service (ASME SA-194 with Additional Requirements)
RDT M 7-3T	Stainless Steel Bars and Shapes (ASME SA-479 with Additional Requirements)
RDT M 9-1T	Nickel-Chromium-Iron and Austenitic Chromium-Nickel Alloy Seals

2.2 American Society of Mechanical Engineers (ASME).

ASME Boiler and Pressure Vessel Code with Addenda and applicable Code Cases:

Section III Nuclear Power Plant Components

ASME Steam Tables

2.3 American National Standards (ANSI).

ANSI B1.1 Unified Screw Threads

ANSI B16.25 Buttwelding Ends

ANSI B46.1 Surface Texture

ANSI Y14 Drafting Manual

2.4 Other Documents.

Standards of Tubular Exchanger Manufacturers Association (TEMA)

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

3. TECHNICAL REQUIREMENTS

3.1 General Design Requirements.

3.1.1 Description. The steam generator shall be a sodium-to-water-steam heat exchanger and shall generate saturated or superheated steam by utilizing sodium as a heating medium. Details of its type and its function shall be as specified in the Ordering Data. The steam generator shall be designed and constructed in accordance with the Code, applicable Code cases, this standard, RDT E 15-2, and the Ordering Data.

3.1.2 Integrity. The design objective for the boundaries between sodium and water shall be the prevention of leaks that may result in a sodium-water reaction. All welded construction shall be used where bolted joints are not essential for access. Bolted joints exposed to sodium shall be seal-welded (See 3.1.5). Nondestructive examinations and leak tightness tests of materials and weld joints shall be performed in accordance with 4.3 and 4.6.2.

3.1.3.1 Inspectability. The design shall enhance access for inservice inspection, maintenance, and repair of tubes, tubesheets, shells, internals, and welds. Particular attention shall be paid to tube walls, tube-to-tubesheet junctions, tubesheet-to-shell junctions, and shell walls. Inspection of all sodium-side boundary welds including nozzle-to-pipe welds shall be possible with ultrasonic equipment or other recommended methods approved by the purchaser (See 3.11.6, items 8 and 9).

3.1.3.2 Tube Leak Testing. The design shall permit leak testing of individual tubes to determine the location of indicated leaks. A sodium-water reaction in the unit will require testing and inspection of the tubes to locate the leak and establish the extent of damage to the leaking tube and to other affected tubes (See 3.11.6, item 10).

3.1.3.3 Maintainability. Provisions shall be made for in-place tube repair or plugging and sodium removal to facilitate maintenance. The steam generator shall be designed so that single tubes can be plugged or tube joints sealed without removal of the tube bundle.

3.1.3.4 Unit Cleanup and Requalification. Provisions for cleaning sodium-water reaction products from the steam generator internals shall be included in the design. The supplier shall propose methods of cleanup and requalification for purchaser approval.

3.1.4 Safety and Control Instrumentation. All safety and control instrumentation shall be designed so that it can be inspected, maintained, repaired, and replaced during a normal shutdown interval. Inservice inspection capability shall permit plant operations to verify instrument readings. For example, it shall be possible to determine if the water leak detection equipment is functioning correctly.

3.1.5 Seals. Seals used at the interfaces of separable or removable parts shall be designed in accordance with the Code. The seals shall prevent the leakage of sodium, sodium vapor, cover gas, water or steam, or combinations of these. All sodium containment boundary seals shall be of the strength-welded or seal-welded type. The seal-weld construction shall be in accordance with the requirements of the Code and RDT E 15-2. Requirements for seal membranes shall conform to those of RDT M 9-1. Specialized sealing situations such as instrumentation penetrations and rupture disc shall be seal welded or utilize sealing designs which have been demonstrated to provide leakproof service under the specified temperature and operating conditions.

3.1.6 Cover Gas. When the design provides for the use of a cover gas, the type, working pressure, the nature of the impurities normally expected in the gas and their permissible relative concentrations shall be as specified in the Ordering Data.

3.1.7 Drainability.

3.1.7.1 The design shall provide for draining the shell (sodium) side and for removing the water from the tube (water and steam) side. Since the complete gravity drainage of sodium may not be practicable, alternate method(s) shall be provided to remove the residual sodium. Alternate methods for removing the residual water from a nondrainable tube bundle (such as by gas pressure or by evaporation through boiling) shall be submitted for purchaser approval.

3.1.7.2 The sodium drain line sizes shall be defined for approval by the purchaser. Drain ports shall be provided for draining the regions

behind thermal and wastage shields and other possible traps. Residual sodium on horizontal surfaces shall not exceed the quantity specified in the Ordering Data.

3.1.7.3 The design shall minimize areas of reduced flow or pockets that contribute to entrapment of sodium or corrosion products. Residual liquid metal on horizontal surfaces (such as baffles and tube sheets) shall be minimized by design configuration.

3.1.8 Size and Weight. Limits on size and weight shall be as specified in the Ordering Data.

3.1.9 Preheating.

3.1.9.1 The requirements and provisions for attachment of the insulation and preheating system used for heatup under dry conditions (filled with argon), from ambient temperature to 350°F; and for maintaining, under filled conditions, a minimum temperature of 350°F during reactor shutdown shall be submitted for approval.

3.1.9.2 Heatup rates shall be as specified in the Ordering Data. Before, during, and after sodium filling, the maximum allowable stress limits specified by the Code shall not be exceeded at the specified heatup rates.

3.1.9.3 Insulation and trace heaters shall be provided as specified in the Ordering Data. Interface design information relevant to the power supply and control heaters shall be provided to the purchaser.

3.1.10 Gas Entrainment. The design shall eliminate the possibility of gas accumulation in corners or dead spaces.

3.1.11 Environmental Conditions. The environmental conditions will be given in the Ordering Data.

3.2 Thermal and Hydraulic Design Requirements.

3.2.1 General Requirements.

3.2.1.1 The design shall satisfy the following thermal and hydraulic performance requirements:

1. Safe, stable, and predictable operation throughout the load range and transients specified in the Ordering Data.

2. Justification of the adequacy of the flow distribution profile on both the tube and shell sides for all flow rates, pressure and temperature conditions, to prevent hot or cold spots, minimize thermal gradients, and thermal transient loadings.

3. Provision for elimination or control of thermal stratification, internal recirculation of sodium and reverse flow of water or steam over the entire performance range specified in the

Ordering Data.

4. Assurance that the hydraulic characteristics are consistent with drainability requirements as provided in the Ordering Data.

5. Provision for adequacy with respect to thermal transient and cycling caused by chugging, flooding, or other phenomena under operating conditions specified in the Ordering Data.

6. Provision for thermally stable behavior, shell side sodium bypass, and static and dynamic stability in the tube bundle.
7. The ASME Steam Tables shall be used for analysis.

3.2.1.2 A stability and flow balance analysis over the full operating range shall be conducted and included in the specified design report.

3.2.1.3 When development testing is necessary, the type and extent required to satisfy the design requirements shall be proposed for purchaser approval.

3.2.2 Thermal Design Requirements.

3.2.2.1 Thermal Performance. The design shall meet the specified thermal duty for the process temperatures and flowrates given in the Ordering Data and shall meet the steady-state, part-load, and transient performance requirements specified in the Ordering Data.

3.2.2.2 Natural Circulation. The design shall ensure natural circulation under the service conditions specified in the Ordering Data. The supplier shall specify the location of the effective thermal center and the variation in the location with load, for the load range as specified in the Ordering Data.

3.2.3 Physical Properties and Purity of Sodium. The design shall utilize the sodium physical properties as specified in the LMFBR Materials Handbook and the sodium purity as specified in the Ordering Data.

3.2.4 Properties of Feedwater. The feedwater and boiler water purity limits and other properties shall be as specified in the Ordering Data.

3.2.5 Heat Transfer Surface.

3.2.5.1 The excess heat transfer area needed to account for tube plugging, design uncertainties, fouling, and any other factor which may reduce the effective thermal duty during the steam generator service life shall be recommended for approval by the purchaser. Limitation on the number of tubes and their distribution that may be plugged at the time of delivery and installation of the steam generator shall be as specified in the Ordering Data.

3.2.6 Pressure Drop. The water/steam-side and sodium-side pressure drops shall not exceed the values specified in the Ordering Data.

3.2.7 Fouling. Fouling resistance on the sodium side shall be considered in the design analysis as specified in the Ordering Data. The magnitude of fouling resistance of the water/steam-side shall be recommended by the supplier as a result of specified feedwater chemistry, experimental testing, prior experience of users of this water, or all three of these, and submitted for the purchaser approval. The supplier shall recommend, for purchaser approval, the specifications for boiler water chemistry, based upon considerations of cleaning frequency, boiler feedwater chemistry and blowdown requirements. The water-side cleaning procedure shall be recommended by the supplier.

3.2.8 Flow Bypass. Flow bypass shall be kept to a minimum. Effects of flow bypass on the heat transfer area, and the possible resulting effects on the temperature distribution, shall be accounted for in the design.

3.2.9 Orifices. The effect of orificing on the water and sodium sides for the purpose of flow distribution shall be included in the appropriate analyses.

3.2.10 Thermal Transients. An analysis shall be performed to evaluate the response of the steam generator to the inlet flow and temperature transients of both water and sodium, specified in the Ordering Data. The analytical model used for thermal transient analysis shall be submitted for purchaser approval. The analytical model(s) shall also be described in the design report in sufficient detail to permit its use by the purchaser.

3.3 Structural Design Requirements.

3.3.1 General. The structural design shall be in accordance with the Code, RDT E 15-2, and RDT F 9-1 for the conditions specified in the Ordering Data.

3.3.2 Seismic. The steam generator shall be designed to withstand the effects of seismic loads specified in the Ordering Data in accordance with RDT F 9-2.

3.3.3 Vibration.

3.3.3.1 The steam generator, including all internals, shall be designed to preclude damage or malfunction caused by internally generated vibrations, such as flow-induced vibrations, or by mechanical vibrations, such as pump vibrations, check valve slam vibration, or vibrations and impact loads caused by shipping. Baffles and tube support plates, tie rods, impingement plates, and other internals, shall be provided so that natural frequencies of all unsupported tube spans are at least 50 percent higher than hydrodynamically generated frequencies in the flow range specified in the Ordering Data.

3.3.3.2 Engineering vibration analyses of the tube bundle structural design, covering peak velocities over the range of sodium and water

flows described in the Ordering Data, shall be included in the design report. The complete analytical method shll be described in detail, giving all references and assumptions in an orderly way to facilitate verification. The analyses shall show that the maximum amplitude of tube vibration does not exceed 25 percent of the nominal distance between the outer surfaces of adjacent tubes and satisfy the applicable Code Case requirements for stress limit. Additional requirements for vibration testing to provide verification of analytical techniques will be specified in the Ordering Data or recommended to the purchaser by the supplier if required.

3.3.4 Differential Thermal Expansion. Under all steady-state and transient conditions, as specified in the Ordering Data, differential thermal expansion between individual tubes (including plugged tubes), tubes and shell, and between all connected parts of the steam generator shall be accommodated without exceeding the allowable Code stresses. Analyses shall be included in the design report.

3.3.5 Thermal Stresses. The steam generator shall be analyzed for thermal stresses resulting from the operation and from the number of sodium and water/steam temperature transients set forth in the Ordering Data including those occurring during shutdown operations. These stresses shall not exceed allowable stresses as defined in the Code or applicable Code Cases and RDT F 9-1, and the analyses shall be included in the design report.

3.3.6 Nozzle Loads. The shell and nozzles shall be designed to withstand the piping loads and time dependent response characteristics of the piping system as specified in the Ordering Data.

3.3.7 Ligament Thickness. The nominal thickness of ligaments between adjacent tube holes of the tubesheet shall be in accordance with TEMA standards, Class R. The ligaments shall be not less than 0.250 in. unless mockups of the tubesheet prove that acceptable welds, as defined by RDT E 15-2, can be made and unless the stress analysis shows that smaller ligaments are acceptable. Approval for the use of ligaments less than 0.250 in. thick shall be obtained from the purchaser.

3.3.8 Baffles and Support Plates.

3.3.8.1 Impingement baffling, other protective features, or both, shall be provided, as required, to avoid vibratory or erosive failure caused by direct impingement of incoming fluid on tube bundles or other steam generator internals. The effects of impingement baffles on flow distribution and thermal performance shall be determined and the analysis included in the design report.

3.3.8.2 Sizing of bundles, the thickness of cross-flow baffles and tube support plates, and tube hole clearance shall, as a minimum, meet the requirements of TEMA standards, Class R, for heat exchangers, supplemented by the high-temperature design criteria specified in the Ordering Data. Analyses of these factors; i.e., bundles, baffles, support plates, size, and clearances, shall be included in the design report. For noncircular holes,

the design shall be submitted for approval by the purchaser.

3.3.9 Shell Protection. A liner of barrier material shall be located between the tube bundle and the shell, cladding on the inner surface of the shell, or both, as specified in the Ordering Data, to protect the shell from wastage (erosion, corrosion) and the effects of a sodium-water reaction caused by a steam/water leak occurring at the outer periphery of the tube bundle.

3.3.10 Sodium-Water Reaction. The design shall accommodate the pressure and shock loadings associated with the DBL specified in the Ordering Data. The supplier shall submit, for purchaser approval, the requirements for pressure relief which shall be imposed on the pressure relief system external to the steam generator. The steam generator internals (baffles, tube supports, etc.) shall be designed such that a sodium-water reaction will not cause them to fail in such a way as to cause additional tube failures.

3.3.11 Sodium-Water Reaction Relief Path. The tube bundle, supports, baffles, and shell geometrical layout shall be designed such that the resistance to the relief of reaction products in traveling through the bundle is minimized. In those instances where, by analysis, the tube bundle resistance is deemed to be excessive, alternate paths for the relief of reaction products shall be considered.

3.3.12 Corrosion Allowance. A corrosion allowance for all pressure boundaries shall be established and submitted for approval by the purchaser, based upon criteria provided in the Ordering Data. The allowance shall include compensation for the loss or degradation of material resulting from erosion, corrosion, chemical cleaning, and other environmental effects.

3.3.13 Crevices. Dead spaces, crevices, or regions of fluid or particle entrapment, on both the sodium side and the water side shall be avoided or held to an absolute minimum. Where the design cannot avoid crevices, special precautions shall be taken to prevent contamination during manufacture.

3.3.14 Failure Modes and Effects Analysis. The supplier shall perform a failure modes and effects analysis quantitatively evaluating the safety and reliability of the steam generator design. Each component, including tubes, shells, tube-to-tubesheet attachments, tubesheets, baffles, and nozzles, shall be considered. The manner in which failure can occur shall be postulated. The analysis shall indicate the design features which are failure-preventive in nature, and the fail-safe devices designed to prevent and reduce the probability of human error or contain the effects of a failure should it occur. The results of this analysis shall be submitted to the purchaser for approval.

3.4 Connections, Accesses, and Appurtenances.

3.4.1 Accessibility for Inspection. The number, size, location, and type of all accesses and openings shall be recommended by the supplier for approval by the purchaser. Eyebolts, hinged covers, lifting lugs or similar

devices shall be provided for handling handhole and manway covers.

3.4.2 Auxiliary Lines. The number, location, and size of vent connections, drain connections, appurtenances for relief and safety valves, internal chemical feed lines (if any), cooldown connections (if any), instrumentation taps and other additional connections and appurtenances shall be defined by the supplier for approval by the purchaser.

3.4.3 Insulation Supports. When specified in the Ordering Data, supports shall be provided on the exterior surface of the steam generator for the application of insulation. Means for supporting insulation shall be provided prior to final heat treatment. Requirements for insulation shall be established, based on criteria and operating conditions specified in the Ordering Data.

3.4.4 Identification Plates. Identification plate(s) and support bracket(s) shall be furnished and the plate(s) shall be mounted so that they are visible after installation of the thermal insulation. The plates shall be in conformance with the Code and 3.8.13.3.

3.4.5 Lifting Lugs.

3.4.5.1 Lifting lugs or other appropriate lifting devices shall be provided to permit safe handling during shipment, installation, operation, and maintenance for the life of the component. These lifting lugs and lifting devices shall be designed, fabricated, and examined in accordance with RDT F 8-6. The lifting device design shall be engineered to account for structural degradation which may occur from extended operation at high temperatures. Dynamic loads imposed during crane lifts and imposed loads from breakway forces during disassembly of flanged joints or from solidified sodium residual shall be considered in the design. The lifting devices shall permit lifting of the steam generator while it is full of sodium. Where multiple lifting lugs are provided, the failure of any one lug shall not result in dropping of the part being lifted.

3.4.5.2 The purchaser shall be informed of the locations of the lifting lugs as soon as the information is available. Limitiations on the allowable movement of the steam generator during installation and removal will be provided by the purchaser. Lifting lugs shall be included in periodic inspections, by both visual and liquid penetrant or magnetic particle processes.

3.4.6 Foundation and Support Structures.

3.4.6.1 The steam generator shall include the necessary supports to match the purchaser's foundations or support structure, as specified in the Ordering Data.

3.4.6.2 The support structure material shall be of the same material as the shell, where welded to the shell. A pad of the same material as the shell shall be welded to the shell if dissimilar support structure material is to be used.

3.4.6.3 Parameters to be considered in the selection and design of the steam generator supports and bracing are:

1. Operating temperature and thermal expansion.
2. Accessibility for inspection and repair.
3. Height above floor level.
4. Interference with external piping.
5. Nozzle location.
6. Surrounding structures and equipment.
7. Weight distribution.
8. Earthquake loadings.
9. Available floor space.

3.4.7 Piping Connections. All piping connections, other than flanged connections, shall be prepared for butt welding in accordance with Class 1 requirements of the Code, RDT E 15-2, and ANSI B16.25. The pipe sizes shall be proposed for approval by the purchaser.

3.4.8 Threaded Elements and Bolts. Threaded connections shall conform to the following requirements:

1. All screwthreads shall be in accordance with ANSI B1.1 unless otherwise specified in the Ordering Data.

2. All threaded fastenings in pressure boundaries shall have a minimum diameter of 1/2 in., nominal.

3. Lubricants applied to all threaded parts shall be in accordance with the requirements of RDT F 8-1. The use of lubricant which will be in constact with sodium shall be approved by the purchaser.

4. Torquing and thermal straining shall be in accordance with RDT F 8-1.

5. All threaded fasteners shall have locking devices in accordance with RDT M 6-2.

6. Procedures to prevent galling, including the use of anti-seize compounds, shall be approved by the purchaser prior to use.

7. Lugs and other devices, such as jacking bolts, to assist in lifitng and moving shall be designed as part of the steam generator head, tube bundle, and shell, where required.

8. Threaded connections shall not be used on the sodium side pressure boundary (sodium-water or sodium-air boundaries) of the steam generator without purchaser's approval.

3.4.9 Preheating System Supports. When a preheating system is required, supports on the external surfaces of the steam generator shall be provided. These shall be installed prior to final heat treatment. Specific details will be included in the Ordering Data.

3.5 Instrumentation.

3.5.1 Instrument Listings.

3.5.1.1 The instruments shall be furnished as identified and listed in the Ordering Data and shall be in accordance with 3.5.2 through 3.5.8. Calibration shall be in accordance with 4.8.

3.5.1.2 Provisions shall be made for incorporating instrumentation furnished by the purchaser for installation by the supplier or later by the purchaser. Such instrumentation and its location shall be recommended by the supplier for approval by the purchaser.

3.5.2 Sodium Level Indication. When specified in the Ordering Data, provisions shall be made for the monitoring of the sodium level within the steam generator. On all steam generators incorporating a sodium-free surface, the monitoring shall be done by a continuous indication of the sodium level.

3.5.3 Pressure Gages. Provisions shall be made for pressure-indicating devices on both water/steam and sodium sides for measurement of pressure, pressure drop, and any other pressure information, as specified in the Ordering Data.

3.5.4 Temperature Instrumentation. When specified in the Ordering Data, the steam generator shall be fitted with or have provisions for temperature-measuring devices for the measurement of sodium inlet and outlet, water inlet and outlet, and shell temperatures. Thermocouples shall be in accordance with RDT C 7-6.

3.5.5 Flow Instrumentation. If specified in the Ordering Data, flow-measuring instrumentation shall be provided.

3.5.6 Water-to-Sodium Leak Detection. When specified in the Ordering Data, the provisions for leak detection shall be incorporated in the steam generator design.

3.5.7 External Leak Detection. Provisions for external leak detection shall be incorporated in the design when specified in the Ordering Data.

3.5.8 Instrumentation Inspection, Maintenance, and Repair. Instrumentation shall be designed to permit inservice inspection, calibration, maintenance, repair, and replacement where required during the normal plant shutdown intervals.

3.6 Operating Conditions. Design shall satisfy the requirements for operation under normal operating, upset, emergency, faulted, and test

conditions. These conditions will be specified in the Ordering Data.

3.7 Materials of Construction.

3.7.1 General. Materials of construction shall be selected from the Code approved RDT materials standards listed in 2.1 and as specified in the Ordering Data. Any materials proposed for use in construction which are not in accordance with the above requirements shall be submitted to the purchaser for approval. All materials of construction shall be described in the design report. Repair of materials shall be accomplished in accordance with the requirements of the applicable material standard and RDT F 6-10.

3.7.2 Factors in Material Selection. The following factors shall be considered to obtain the optimum selection of materials.

1. Strength and creep properties at the operating temperature.

2. Resistance to stress-corrosion cracking.

3. Resistance to wastage resulting from a sodium-water reaction.

4. Deleterious effects caused by mass transfer in sodium.

5. Deleterious effects of interstitial mass transfer.

6. Resistance to the operating environment, including weld materials, cleaning agents, and examination and testing agents, in addition to sodium, water, and steam.

7. Fabricability, inspectability, weldability, and weld repairability.

3.7.3 Material Samples. Samples of construction materials shall be provided to the purchaser as specified in the Ordering Data.

3.8 Fabrication. The steam generator shall be constructed in accordance with the Code and RDT E 15-2.

3.8.1 Fabrication Release. Purchaser approval shall be obtained prior to fabrication. Prior to receiving fabrication approval, the following documents shall be submitted for approval.

1. Basis for release
2. Quality assurance index.
3. Assembly procedure.
4. Fabrication plan (including heat treatment).
5. Manufacturing drawings.
6. Welder and weld procedure qualification plan.
7. Cleaning plan.

Fabrication release described in this paragraph in no way abrogates the

requirement to qualify welder and welding procedures in accordance with RDT F 6-5 prior to start of component fabrication.

3.8.2 Welding.

3.8.2.1 Dissimilar Metal Welds. Parts made of dissimilar metals shall not be welded directly together where physical or metallurgical incompatibility will result. An intermediate link (or weld filler material), compatible with both metals, shall be selected to act as a transition piece. All dissimilar metal welds, welding procedures, and weld locations shall be submitted for purchaser approval.

3.8.2.2 Tube Plug Welding. The supplier shall demonstrate to the purchaser that individual tubes can be sealed off to prevent leakage which results from tube or tubesheet weld failure. The supplier shall provide a tube plugging weld procedure which is capable of sealing leaks without overstressing other tubes or the tubesheet under subsequent operating conditions and which can be carried out in the time period specified in the Ordering Data. A tube plugging demonstration shall be performed on a mockup illustrating typical access restrictions and tube surface conditions. The absence of any leak path shall be proven by thermal cycling or other proof testing, and nondestructive and destructive examinations, to the extent specified in the Ordering Data. The number of demonstrations required to establish the procedure as acceptable shall be as specified in the Ordering Data, and the method shall be established before starting fabrication of the tube-to-tubesheet assembly. The number of plugs to be provided to the purchaser shall be recommended by the supplier for purchaser approval.

3.8.2.3 Weld Repair. Weld repairs shall be in accordance with the requirements of the Code. The supplier shall submit documentation to the purchaser describing qualification procedures and requesting approval for the following:

1. Any repairs of the sodium-water pressure boundary welds at the fusion zone, or adjacent base material.

2. Any repairs to pressure boundary welds (other than sodium-water pressure boundaries) which are required after the second cycle of weld repair.

3. Any repairs of all other welds after the third cycle of weld repair.

Repair of crater cracks restricted to the crater of the weld pass does not require purchaser approval.

3.8.2.4 Tube-to-Tubesheet and Tube-to-Tube Welds. All tube-to-tubesheet and tube-to-tube welds on the steam generator shall be full penetration butt welds and conform to RDT E 15-2, and shall be radiographed prior to postwelding heat treatment. The supplier shall submit material purchase specifications, all welding and fabrication procedures, all inspection procedures

and inspection standards related to these areas for purchaser approval (this also includes the tube sheet). All samples used in the weld qualification, samples of any rod, wire, or inserts used in the welding process and all qualification data shall be made available to the purchaser as specified in the Ordering Data and shall be retained by the supplier for archive purposes.

3.8.3 Heat Treatment. All heat treatment shall be in accordance with procedures prepared by the supplier and approved by the purchaser. The thermal history of all heat treatments shall be provided. The approval requirements and number of copies of heat treatment records including furnace charts to be submitted shall be as specified in the Ordering Data.

3.8.4 Fabrication Mockups. The supplier, with approval by the purchaser, may perform mockups of difficult, new, or unusual fabrication procedures which have not been previously attempted or demonstrated in order to obtain weld procedure qualification.

3.8.5 Surface Finish. The supplier shall certify that the following surface finish requirements are met, the surface finish being determined in accordance with ANSI B46.1:

1. All surfaces in contact with sodium: 250 μin. AA maximum.
2. Heat transfer tubing: 63 μin. AA maximum on the outer and inner surfaces.
3. All mating parts: 125 μin. AA or better unless otherwise specified in the Ordering Data, or because more stringent requirements are needed for seals or other mating surfaces.
4. Tubesheet holes: 125 μin. AA maximum.
5. Surfaces not included above: 250 μin. AA maximum.
6. Surface finishes shall not be disturbed after heat treatment.

3.8.6 Bending and Forming. Bending and forming operations for shaping tubes, shells, heads, etc., shall be in accordance with the Code and with procedures prepared by the supplier and approved by the purchaser. Preproduction samples of tube bends shall be submitted to the purchaser for approval. The wall thickness after the bending and forming operation shall not be less than the minimum design thickness. The supplier shall evaluate the need for heat treatment in connection with bending or forming operation and submit to purchaser for approval. After any bending or cold straightening causing plastic deformation, austenitic stainless steel tubing shall be solution annealed. Such solution annealing shall be conducted on the entire tube.

3.8.7 Tubesheet Fabrication.

3.8.7.1 Tubesheet Tube Holes. Drill drift for the tube holes

shall not exceed that which would violate the minimum ligament requirements in 3.3.7. For internal bore welds, the tube-hole tolerances shall be based on joint configuration, and shall require purchaser approval.

3.8.7.2 Tubesheet Ligaments. The minimum tubesheet ligament thickness shall be within 0.050 in. of the nominal ligament thickness, or shall be the minimum thickness required for structural design, whichever is greater.

3.8.8 Platings and Coatings. Plating shall not be permitted on surfaces in contact with sodium or water. Use of coatings shall be proposed by supplier for approval by purchaser.

3.8.9 Cleaning. The supplier shall submit for purchaser approval procedures for cleaning and cleanliness control required by RDT F 5-1 and as specified in the Ordering Data. The supplier shall submit for purchaser approval the specific criteria to be used to determine if cleanliness requirements of RDT F 5-1 are met. Surfaces shall be maintained in a clean condition up to and including all assembly procedures.

3.8.10 Sensitization. Austenitic stainless steel which has become sensitized during heat treatment, welding, or forming shall be solution annealed in accordance with the applicable material standard, or shall be protected against corrosion and moisture during all subsequent manufacturing, testing, and storage operations. The method of protecting sensitized material which is not solution annealed subsequent to heat treatment, welding, or forming shall be recommended by the supplier subject to the approval of the purchaser.

3.8.11 Assembly. Assembly shall be performed in accordance with an inspection and assembly procedure prepared by the supplier and approved by the purchaser. The use of lubricants during assembly is prohibited. The procedure shall contain as a minimum:

1. Assembly sequence.
2. Design schedule coordinated with the assembly sequence.
3. Cleaning procedures, sequence, and precautionary rules.
4. Intermediate and final inspection criteria and holdpoints.
5. Any special machining or fitting at assembly instructions.
6. Handling methods equipment and precautions.
7. Procedures for the locking of locking devices or tack welding.
8. Drawings or photographs as required to illustrate assembly problems or techniques.

9. Special data measurements or observations to be recorded in quality control records.

10. Welding procedures.

11. Heat treating procedures.

3.8.12 Interchangeability. Design tolerances, fabrication, and dimensional inspection shall be such as to ensure interchangeability of parts. The supplier shall furnish drawings of special gages or fixtures, as-built dimensions, and other specified information to enable the purchaser to determine that interchangeability does exist. To achieve or maintain perpendicularities or concentricities, the supplier shall identify and mark on the component drawings, or the assembly outline, the reference surfaces used during fabrication.

3.8.13 Identification and Marking.

3.8.13.1 Marking. Materials, components, equipment, and auxiliaries shall be marked in accordance with the requirements of RDT F 7-3 and the Code.

3.8.13.2 Identification of Subcomponents. When specified in the Ordering Data, subcomponents positions in the completed steam generator (tubesheet holes, tubes, shell members, etc.) shall be marked to maintain source and final position documentation, using the methods specified in 3.8.13.1. Final location of parts shall be recorded on assembly drawings.

3.8.13.3 Nameplates. The supplier shall permanently attach to the exterior of the steam generator a nameplate which conforms to the following requirements:

1. The plate shall be of a corrosion-resistant material compatible with the surface to which it is fastened.

2. The nameplates shall contain the information required by the Code and specified in the Ordering Data.

3. Nameplates shall not be painted over or otherwise covered (including thermal insulation) and shall be located in a readily accessible place. Standoffs may be used to prevent covering the nameplate with insulation or to make it more accessible.

3.8.13.4 Permanent Marking. All finished components, spare parts, and special handling fixtures to be delivered as part of the contractual requirements shall be permanently marked for purposes of identification in accordance with RDT F 7-3. Sample material shall be marked for identification, location, and orientation.

3.9 Installation and Field Services Requirements.

3.9.1 Services to be Rendered. The supplier shall provide technical advice and assistance and quality assurance requirements during the installation, preoperational and performance testing, and any repair, replacement, alteration, and field modification of component required as a result of the installation and testing to the extent specified herein and in the Ordering Data.

3.9.2 Unloading. The supplier shall provide written procedures in accordance with RDT F 8-6 for unloading items for which he has delivery responsiblity. The supplier shall also provide all special lifting devices, supports, and fixtures necessary to unload the components from the carrier and to transport them to a designated storage area. When required, the center of gravity shall be clearly marked on the component or its container, or both, to facilitate handling.

3.9.3 Storage. Items to be stored at the designated site for a significant period of time before use will be specified in the Ordering Data. The supplier shall provide written procedures in accordance with RDT F 4-20 detailing precautions, procedures, and other protective measures, for all items to be stored. All items which will be stored for a significant period shall be packaged in accordance with RDT F 7-2.

3.9.4 Handling. The supplier shall be responsible for providing handling equipment to the extent required by this standard and the Ordering Data. The supplier shall also provide instructions in accordance with RDT F 8-6 for handling all major components which he has supplied, and for monitoring these operations.

3.9.5 Unpacking. The supplier shall provide written procedures for removing all packaging from major items which he has supplier in accordance with RDT F 4-20.

3.9.6 Installation Requirements. The supplier shall furnish written requirements in accordance with RDT F 4-20 for the installation of any equipment furnished by him that requires special tools or rigging. The supplier shall monitor the installation operations specified in the Ordering Data.

3.9.7 Installation Procedures. Preparation for installation at the site will include the preparation, by the purchaser, of detailed procedures for handling and installation operations in accordance with RDT F 4-20. These will be based on the requirements established by the supplier (3.9.6) and shall be reviewed by the supplier for concurrence prior to installation.

3.9.8 Preoperational Testing. The supplier shall specify all preinstallation and preoperational tests required for the equipment which he has supplied. This specification shall be part of the technical manual(s) furnished with the equipment. During such testing, the supplier shall provide the assistance of technical personnel to verify that all equipment performs in the specified manner.

3.10 Safety.

3.10.1 Water-Steam Side Pressure Relief. Provisions for water side pressure relief devices and water side pressure relief design parameters shall be as specified in the Ordering Data.

3.10.2 Sodium-Side Pressure Relief. Recommendations shall be submitted for pressure relief nozzle sizes and locations for purchaser approval unless otherwise specified in the Ordering Data. Nozzle sizes and locations shall be selected to minimize the possibility of plugging with sodium-water reaction products and for noninterference with other shell penetrations, and for accessibility. (See 6.1.2 for sodium side pressure relief provisions.)

3.10.3 Isolation.

3.10.3.1 The steam generator shall be capable of withstanding rapid isolation and emptying of the water/steam side and simultaneous pressurization of the water side by an inert gas as specified in the Ordering Data.

3.10.3.2 The steam generator shall be capable of withstanding rapid removal of the sodium as specified in the Ordering Data.

3.11 Reports and Documentation.

3.11.1 Design Report.

3.11.1.1 A design report shall be submitted to the purchaser as the basis for approval of the steam generator design. As a minimum, the design report shall include:

1. A detailed description of the steam generator including operating characteristics, operating limitations, and safety consideration.

2. Heat-transfer and fluid-flow analyses.

3. Curves of calculated water/steam-side and sodium-side pressure drops (including nozzle losses) from 0 to 100 percent flow, for clean and fouled tubes.

4. A thermal analysis of the response of the steam generator to the inlet flow and temperature transients specified in the Ordering Data.

5. A stress report satisfying the requirements of the Code and RDT F 9-1. This report shall include a discussion of the high-temperature criteria employed in the design.

6. Vibration analyses.

7. Differential thermal expansion analysis.

8. If an unusual fabrication procedure is chosen, the reasons for using this fabrication procedure.

9. The procedures for the location of tube leaks and the plugging of leaking tubes.

10. Weight and center-of-gravity calculations of the steam generator and its component parts in the dry, normal operation, flooded, and skidded conditions.

11. Predicted deflections and deformations with evaluations of their effects.

12. A materials list.

13. Descriptions of external loads including seismic loading.

14. Environmental conditions.

15. Corrosion allowance used.

16. Sodium-water reaction analysis, including the DBL.

17. Failure and effects analysis.

18. Steam/water stability and flow imbalance analysis.

19. Preheating and insulation calculations.

20. Material mechanical properties degradation allowance due to operating environment.

21. Analysis which shows that the instrumentation provided by the supplier as installed in the steam generator will measure the required parameters to establish design verification.

3.11.1.2 All information furnished in the design report shall be in enough detail to permit independent checking. The references from which data or formulas are taken shall be identified. The validity of the data and the conclusions which support the recommended design shall be discussed. All computer programs used shall be identified and described in the report to enable independent verification.

3.11.1.3 Additions or corrections to the report as are required shall be made to keep the information current. These revisions shall be numbered and dated, and shall be submitted to the purchaser for approval.

3.11.2 Interim Reports.* Interim design reports as specified in the Ordering Data shall be submitted to the purchaser for approval prior to completion of the final design report. The interim report shall include:

1. Identification of areas requiring inelastic analysis consistent with RDT F 9-1, and, for the required analysis, the technical basis for assuming adequacy pending completion of this analysis.

2. Heat-transfer and fluid-flow analyses.

3. A thermal analysis of the response of the steam generator to the inlet flow and temperature transients specified in the Ordering Data.

4. Steam-side stability and flow imbalance study.

5. Any new or unusual analytical techniques or fabrication procedures.

6. Additional items as specified in the Ordering Data.

3.11.3 Periodic and Progress Reports. Reports of progress in design, procurement, fabrication, inspection testing, and shipping shall be made at the 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 shall also include difficulties encountered, such as failures and malfunctions, and the efforts made or planned for overcoming them. The problems foreseen as possible disruptions of the schedule shall be brought to the attention of the purchaser as early as possible. Breakthroughs of significance shall be discussed in detail.

3.11.4 Final Report. The final report shall present the complete history of the design, development, fabrication, testing, and shipping of the steam generator and its auxiliary equipment. The final report should include, in addition to detailed accounts of the areas mentioned, the following:

1. The analyses specified in this standard, the design report, the shipping report, and any other required reports. These may appear as appendixes.

2. Copies of drawings specified in this standard, of the as-built

*The purpose of the interim reports is to obtain agreement on the basis design at early stages. These preliminary reviews will reduce or eliminate the need for extensive redesign when, in the opinion of the purchaser, the design contains features that require additional justification.

configuration reduced to convenient, legible sizes for binding with the final report.

3. Illustrations, sketches, schematic diagrams, weld maps, and photographs of major stages of fabricating, assembling, inspecting, cleaning, testing, repairing, packing, and shipping, as specified in the Ordering Data.

4. Steam generator pressure test report.

5. Mass spectrometer leak test results.

3.11.5 Time and Approval Requirements. The time and approval requirements of reports, procedures and other documentation to be issued to the purchaser, as well as the number of copies required, shall be as specified in the Ordering Data.

3.11.6 Quality Assurance Documents. The supplier shall prepare the following documents based on the requirements of RDT F 2-2; requirements for submittal of these documents shall be as specified in the Ordering Data.

1. Quality assurance index.

2. Inspection and test plan.

3. Special process control and nondestructive examination procedures.

4. Inspection and test procedures including sampling plans.

5. Nonconforming item documentation.

6. Handling, preservation, packaging, and storing procedures.

7. Proposed new practices, codes, and RDT standards.

8. Inservice inspection procedures.

9. Post operation procedures for evaluating corrosion and erosion, distortion measurement, creep evaluation, and visual examination.

10. Post operation procedures to locate tube leakage and evaluation of the extent of damage without causing unacceptable contamination of the sodium or water sides from testing.

3.11.7 Quality Records.

3.11.7.1 The quality records shall conform with the requirements of RDT F 2-2.

3.11.7.2 During fabrication, the following documents shall be

maintained at the supplier's facility for review at any time by the purchaser, or if noted in the Ordering Data, shall be submitted to purchaser:

1. Special Processes and Nonstructive Examination Qualifications. Certifications of special processes and nondestructive examination procedures and euqipment qualifications, as specified in RDT F 2-2.

2. Nonconformance Records. A copy of each nonconformance and corrective action record including rework, repair, and retest procedures.

3. Certification. Certifications of conformance specified in RDT F 2-2.

4. Test Reports. Results of all tests conducted on the steam generator or its component parts.

5. Final Inspection. Results of the final inspection made before preparation for shipment.

The supplier shall retain the above documents after shipment for the time specified in the Ordering Data.

3.11.8 Operation and Maintenance Manual. The supplier shall provide an operation and maintenance manual. This manual shall conform to RDT F 4-20 and shall reflect the as-built configuration. Information shall include, as a minimum:

1. A detailed description of the steam generator and all equipment furnished.

2. Detailed instructions for the installation, operation, preventive maintenance, and repair, such as locating leaking tubes, tube plugging, cutting, cleaning, and rewelding of seal welds, and removing the steam generator head and tube bundle. These procedures shall include a description of the tools required to make repairs with the unit installed in the power generating plant.

3. Procedures for replacing seals and other replaceable components.

4. Instructions for use of all lifting and handling fixtures and special tools and equipment.

5. Legible reduced size drawings for operation, maintenance, and instructional purposes, including drawings of special tools and equipment. Photographs, when specified in the Ordering Data, shall also be included.

6. Instructions for disassembly, cleaning, and preparation for

shipment and for crating parts.

7. A list of furnished spare parts and tools.

8. Inservice inspection requirements and procedures.

9. Instrumentation specification, calibration and maintenance instructions.

3.12 Drawings. Drawings shall be prepared in accordance with ANSI Y14. The time and approval requirements of drawings to be issued to the purchaser, and the number of copies required, shall be as specified in the Ordering Data.

3.12.1 Preliminary Outline Drawings. Preliminary drawings, sketches, or data necessary or useful in illustrating or describing the steam generator intended design shall be submitted to the purchaser. The drawings and descriptions shall include as a minimum:

1. Design and salient features, including principal dimensions.

2. Information required for the preparation of mechanical supports.

3. Thermal and pressure movement of all connections with respect to the equipment support.

4. Any special instructions necessary for hoisting, alignment, installation, or storage.

5. A list of reference drawings.

3.12.2 Assembly Drawings. These drawings shall include the following information, where applicable:

1. A bill of material which includes location, identity (drawing and part numbers), and material type of each part.

2. Lubricants to be used during assembly and locations where their use is permitted.

3. The location of final closure welds and seal welds, with appropriate procedures.

4. Dimensions establishing size, shape, fits, and clearances of each part.

5. Pressure and temperature data, including design pressure and temperature and test pressure.

6. All as-built changes.

7. Pertinent references to cleaning, marking, torquing, locking

handling, and packaging instructions.

8. The procedure recommended for tube plugging.

3.12.3 Final Outline Drawings. These drawings shall contain the information specified in 3.12.1 above, and all as-built changes including size and location of all connections and fittings. The supplier shall furnish to the purchaser, for preliminary approval, a drawing showing recommended as-built dimensions whcih are to be recorded on the final archive drawing. The selected measurements will be made after the final heat treatment of the component.

3.12.4 Detail Drawings. Detail drawings shall include, as appropriate, the following information:

1. Tolerance block, including geometric tolerances.

2. Detailed dimensions, tolerances, and the required surface finish of each surface.

3. Material specification and any special requirements, including nondestructive examination, heat treatment, and hardness.

4. Fabrication instructions, including welding, hardfacing, cleaning, inspection symbols, and references to assembly procedure requirements.

5. Such additional information as required to describe equipment having special features or characteristics.

6. All as-built design changes.

3.12.5 Records, Drawings, and Specification Lists.

3.12.5.1 The supplier shall maintain a current listing and file of all drawings associated with the components of this standard during the course of design and fabrication and for a period thereafter as specified in the Ordering Data. Each drawing number shall include the current revision number.

3.12.5.2 The supplier shall maintain a current list and file of specifications. The list shall include, as applicable, requirements for design, materials, fabrication, construction, welding, installation, NDE, testing, inspection, maintenance, tube plugging procedures, cleaning, packaging, shipping and storage and quality assurance specifications.

3.12.5.3 The supplier shall maintain a current list and file of supporting design analysis (including thermal/hydraulic, structural, and component transient response analysis).

3.12.6 Parts List. The supplier shall provide a complete list of

parts organized by assemblies. Each drawing number shall include the current revision number. The supplier shall provide a copy of the parts list which shall serve as a baseline against which further changes may be monitored. Spare tube plugs shall be included in the parts list.

3.12.7 Weights and Centers of Gravity. The outline drawings and assembly drawings shall indicate the following:

1. The dry weight and center of gravity of the steam generator.

2. The weight and center of gravity of the steam generator when filled with sodium only.

3. The weight and center of gravity of the steam generator when filled with water only.

4. The weight and center of gravity of the steam generator when filled with sodium and water.

5. The dry weight and center of gravity of the steam generator tube bundle assembly (if designed for removal).

6. The weight and center of gravity of each subassembly into which the steam generator would be divided for shipping purposes.

4. QUALITY ASSURANCE REQUIREMENTS

4.1 Quality Assurance Program. The design and fabrication of the steam generator shall be based on the quality assurance requirements of RDT F 2-2. Quality verification requirements for procurement of RDT materials shall be in accordance with the RDT material standards.

4.2 Quality Assurance Documents. The quality assurance documentation required to be prepared and submitted to the purchaser is listed in 3.11.7 of this standard.

4.3 Nondestructive Examination Requirements. Materials and work in process shall be examined and tested as specified in 4.4, 4.5, and 4.6. Surfaces that are not accessible for examination after final assembly shall be examined prior to the operation which makes them inaccessible.

4.4 Examination of Materials. The steam generator supplier shall re-examine all fluid boundary materials as follows prior to use.

4.4.1 Visual Examination. Materials shall be examined visually for conformance to the dimensional and cleanliness requirements of the applicable RDT materials standards and Ordering Data or purchase specifications.

4.4.2 Nondestructive Examination. The requirements for nondestructive

examination of materials shall conform to the applicable material standards and the additional requirements specified in the Ordering Data.

4.5 Examination During Fabrication.

4.5.1 Controlling Standards for Examination. Examinations of welds, both visual and dimensional, and nondestructive examination shall be in accordance with the requirements of the Code, as supplemented by RDT E 15-2 and RDT F 3-6, and as noted in the Ordering Data.

4.5.2 Visual and Dimensional Examination.

4.5.2.1 General. All items shall be subjected to visual and dimensional examination to verify conformance to approved drawings and the requirements of this standard. Dimensional inspection shall be in accordance with RDT F 3-15. After forming operations, shells or heads shall be 100 percent examined for conformance to prescribed shape and thickness. Nozzles and attachments shall be examined for proper fit to the curvature of the shell surface.

4.5.2.2 Bolting. Bolting for low-temperature service shall be visually and dimensionally examined in accordance with the requirements of RDT M 6-1. High-temperature service bolting shall be examined in accordance with RDT M 6-3.

4.5.2.3 Welds. All welds shall be examined in accordance with the Code, as supplemented by RDT E 15-2, and as noted in the Ordering Data.

4.5.3 Magnetic-Particle or Liquid-Penetration Examination. When surface examination is required in accordance with the Ordering Data, non-magnetic materials shall be examined by liquid-penetrant methods, and ferritic materials may be examined by either liquid penetrant or magnetic-particle methods.

4.5.3.1 Bolting. Bolting (bolts, studs, stud bolts, or nuts) for high-temperature service shall be subjected to liquid-penetrant or magnetic-particle examination in accordance with the requirements of RDT M 6-3, after threading. Bolting for low-temperature service shall be examined by liquid-penetrant or magnetic-particle methods in accordance with the requirements of RDT M 6-1.

4.5.3.2 Welds. Welds shall be examined in accordance with the requirements of the Code, as supplemented by RDT E 15-2, and as noted in the Ordering Data. Liquid-penetrant, magnetic-particle, ultrasonic examination, and radiographic examinations shall be conducted in accordance with RDT F 3-6 and as noted in the Ordering Data. Following nondestructive examination, weld areas shall be thoroughly cleaned in accordance with the requirements of RDT F 5-1 before proceeding to the next weld pass.

4.5.4 Examination of Weld Repairs. Weld repairs shall be examined in accordance with the requirements of the Code, as supplemented by RDT E 15-2, and as noted in the Ordering Data.

4.5.5 Examination of Lifting, Handling, and Shipping Fixtures.

4.5.5.1 Lifting, handling, and shipping fixtures shall be examined as required by RDT F 8-6.

4.6 Testing.

4.6.1 Pressure Testing. The pressure test performed shall be either hydrostatic or pneumatic. Prior to testing, the supplier shall obtain purchaser approval for the test temperature and pressure, the fluid to be used, and the detailed test procedures. The interior surfaces shall be cleaned in accordance with RDT F 5-1 before testing.

4.6.1.1 Hydrostatic Testing. The shell, tube bundle, and assembled steam generator shall be subjected to a hydrostatic test in accordance with the Code, as supplemented by RDT E 15-2, or as specified in the Ordering Data. The use of any liquid other than water shall be approved by the purchaser. The sodium and water/steam sides of the steam generator shall be tested independently. Where tube bundles are removable, seal membranes need not be welded until the strength testing of tubes is completed. After successful completion of the hydrostatic test, the unit shall be thoroughly drained and dried. All accessible welds shall then be examined by the magnetic-particle or liquid-penetrant method in accordance with the requirements of the Code or RDT E 15-2. This test shall not be performed prior to initial helium leak test. Hydrostatic test water shall meet RDT F 5-1, Grade B water.

4.6.1.2 Pneumatic Testing. Pneumatic testing of the steam generator sodium side, where complete dryness is mandatory before a sodium fill, is permitted in lieu of hydrostatic testing. Pneumatic testing shall be in accordance with the Code. The supplier shall recommend the testing procedure, for purchaser approval, before the test is conducted. The sodium-side pneumatic test shall be conducted prior to water/steam side hydrostatic test. The temperature of the steam generator material and gas shall be continuously monitored during the test. Temperature corrections shall be made to the test pressure. Upon completion of the pneumatic tests, the tested items shall be protected from contamination by maintaining the sealed condition and the internal environment of test gas, under the reduced (but still positive) pressure specified in the Ordering Data, until the helium leak test is performed.

4.6.2 Helium Leak Testing.

4.6.2.1 The water/steam and sodium sides of the completed steam generator shall be subjected to mass spectrometer helium leak test in accordance with RDT F 3-6. The supplier shall recommend the procedure, for the purchaser approval, before the test is conducted. The acceptance standards for the maximum helium leak rate for the tubes and the entire tube bundle of the steam generator will be specified in the Ordering Data. The source of any detectable leakage below the specified limits shall be identified, where possible, and reported. When applicable, the basis for assuming that a high spectrometer reading is due to a false indication, rather than to an actual leak, shall be explained. Any actual leak shall be repaired in accordance with

requirements specified in this standard.

4.6.2.2 When a pneumatic pressure test is used (4.6.1.2), the helium leak test shall be performed after the pressure test is completed. When a hydrostatic pressure test is used (4.6.1.1), a helium leak test shall be performed before the hydrostatic test.

4.6.2.3 In addition to testing the completed steam generator, each tube circuit, upon completion of welding to its respective tubesheet(s), shall be helium leak tested while it is still accessible for repair. A complete tube circuit is a tube which has been formed to its design configuration, welded to its connecting tubes to make a tube assembly, and this assembly welded to its respective tubesheets. All assembled tube bundles shall be helium leak tested either as complete bundles or in sections, depending upon the tube bundle configuration. The supplier shall propose the method to be employed, for purchaser's approval.

4.6.3 Stress Verification Testing. A stress certification test shall be performed to verify stress calculations and design methods, if specified in the Ordering Data. Before the test is begun, the supplier shall recommend the test procedure and proposed strain gage locations and methods of attachment to the purchaser.

4.6.4 Special Tests. Specific requirements for development testing or verification of analytical techniques will be specified in the Ordering Data, if required. The supplier shall propose, for purchaser approval, any test programs deemed necessary, as the design proceeds.

4.6.5 Rusting. Precautions shall be taken to assure that no rusting of the unit shall result from pressure testing or leak testing.

4.7 Marking Verification. All finished components, spare parts, and special handling fixtures shall be examined to ensure that they are permanently marked for purposes of identification in accordance with 3.8.13.1. Material samples shall be marked for identification, location, and orientation.

4.8 Instrument Calibration. All instrument components shall be calibrated against certified standards having known valid relationships to nationally recognized standards, and in accordance with RDT F 2-2.

5. PREPARATION FOR DELIVERY

5.1 Delivery Requirements. The supplier shall deliver all items to the designated site. The supplier shall submit for the purchaser's approval a packaging and shipping plan presenting the practices, procedures, and instructions to be followed in meeting the requirements of 5.1.1, 5.1.2, and 5.1.3 and any additional requirements specified in the Ordering Data.

5.1.1 Preparation. Upon completion of all shop testing and inspection, the supplier shall prepare all deliverable items for delivery to the designated site. Plans for all disassembly (as required), recleaning (if

necessary), surface preparation, examination, etc. shall be approved by purchaser. Following preparation, all deliverable items shall be packaged in accordance with the requirements of 5.1.2.

5.1.2 Packaging and Packing. The steam generator and any other deliverable item subject to deterioration, corrosion, or damage shall be packaged in a manner to preserve them. All sealing, packaging, packing, and identification marking shall be in accordance with RDT F 7-2 and as specified in the Ordering Data. Packaging shall be adequate to protect the item while at the supplier's facilities, during transportation to the designated site, and at the designated site. The center of gravity of the loaded shipping container shall be marked on the external surface of the shipping container.

Supplier handling, preservation, packaging, and storage procedures shall be prepared for purchaser approval in accordance with RDT F 2-2. These procedures shall include instructions for removing all items from packaging.

5.1.3 Shipping. The supplier shall be responsible for the delivery of all items covered by this standard to the delivery point. These responsibilities include, but are not limited to, the following:

5.1.3.1 Routing. The supplier shall recommend routing to the designated site for all materials and components for which he is responsible. When approved by the purchaser, the supplier shall make all arrangements necessary to ship those materials and components in accordance with the terms of the contract and requirements of this standard.

5.1.3.2 Shipping Instructions. The supplier shall prepare and submit suitable instructions to the carrier for handling, shipping, in-transit storage, unloading and storing of all major items for which the supplier has delivery responsibility.

5.1.3.3 Loading. Required shipping position, supports, and crating shall be determined by the supplier. The supplier shall provide supervision for loading the components onto the transporting vehicle. All handling equipment shall be designed to prevent any damage to components during handling and shipping operations.

5.1.3.4 Documentation. The supplier shall identify all technical documentation; e.g., instructions, drawings, reports, and manuals which are to be shipped with the deliverable items.

5.1.4 Handling. All handling, lifting, supporting, and shipping fixtures not specified by purchaser drawings shall comply with RDT F 8-6 and the following requirements:

5.1.4.1 Handling Fixtures. All special lifting or handling fixtures shall be designed for a static load in accordance with RDT F 8-6.

5.1.4.2 Ductility of Lifting Devices. Lifting, handling, and shipping fixtures and lifting attachments, provided with the components, fab-

ricated from ferritic materials shall be sufficiently ductile to permit safe handling and shipment at an ambient temperature of minus 10°F. If shipment is scheduled for the winter months (October through March, inclusive) and the anticipated ambient temperature may be less than minus 10°F, the manufacturer shall take special precautions to prevent brittle fracture of the material. All welds shall be heat treated as necessary to comply with the above requirements.

5.1.4.3 Lifting Points. Lifting points shall be as approved by the purchaser at each stage of the fabrication.

5.1.4.4 Upending. If the component to be handled requires upending, points of attachments for chain falls, trunnions, or other features shall be provided so that upending can be done in a safe, controlled manner.

5.1.4.5 Proof Testing. Proof tests shall be performed on, and documented for, all critical lifting, handling, supporting, and shipping fixtures prior to use on components to assure safe handling of these components. If painted, these items shall be stripped to base metal prior to testing by a suitable method which will not interfere with the interpretation of the nondestructive examination required by this standard.

6. NOTES AND ORDERING DATA CHECKLIST

6.1 Notes.

6.1.1 Special or novel design features may require performance testing where the state-of-the-art is such that analyses alone cannot provide verification. Confirmation testing can be recommended only after these analytical areas have been identified. The purchaser and supplier shall together determine the need for and the extent of specific performance verification tests.

6.1.2 The purchaser will provide a pressure relief system designed to relieve the buildup of pressure caused by a small water-to-sodium leak or by a faulty control system intended for maintaining inert gas pressure. A second pressure-relief system will be provided by the purchaser to relieve the sodium-side when the relief capacity of the first pressure-relief system is exceeded.

6.2 Compliance. Ordering Data for the steam generator will be certified by a qualified registered professional engineer, representing the purchaser, to be correct and complete with respect to the specified functions and operating conditions in compliance with Section III of the Code.

6.3 Heat Exchanger Specification Sheet. Figure 1 is an example of a specification sheet used in the procurement of heat exchangers. This sheet has been prepared and recommended for use by TEMA. For purposes of this standard, this sheet may be used as shown, or modified as required, in the procurement of sodium-heated steam generators.

Figure 1

HEAT EXCHANGER SPECIFICATION SHEET

1				JOB NO.	
2	CUSTOMER			REFERENCE NO.	
3	ADDRESS			PROPOSAL NO.	
4	PLANT LOCATION			DATE	
5	SERVICE OF UNIT			ITEM NO.	
6	SIZE	TYPE	(HORIZ.) (VERT.)	CONNECTED IN	
7	SQ. FT. SURF./UNIT (GROSS) (EFF.)	SHELLS/UNIT		SQ. FT. SURF./SHELL (GROSS) (EFF.)	
8	PERFORMANCE OF ONE UNIT				
9		SHELL SIDE		TUBE SIDE	
10	FLUID CIRCULATED				
11	TOTAL FLUID ENTERING				
12	VAPOR				
13	LIQUID				
14	STEAM				
15	NON-CONDENSABLES				
16	FLUID VAPORIZED OR CONDENSED				
17	STEAM CONDENSED				
18	GRAVITY				
19	VISCOSITY				
20	MOLECULAR WEIGHT				
21	SPECIFIC HEAT		BTU/LB-° F		BTU/LB-° F
22	THERMAL CONDUCTIVITY		BTU/HR-FT-° F		BTU/HR-FT-° F
23	LATENT HEAT		BTU/LB		BTU/LB
24	TEMPERATURE IN		° F		° F
25	TEMPERATURE OUT		° F		° F
26	OPERATING PRESSURE		PSIG		PSIG
27	NO. PASSES PER SHELL				
28	VELOCITY		FT/SEC		FT/SEC
29	PRESSURE DROP		PSI		PSI
30	FOULING RESISTANCE (MIN.)				
31	HEAT EXCHANGED-BTU/HR		MTD CORRECTED-° F		
32	TRANSFER RATE—SERVICE		CLEAN		
33	CONSTRUCTION OF ONE SHELL				
34	DESIGN PRESSURE		PSI		PSI
35	TEST PRESSURE		PSI		PSI
36	DESIGN TEMPERATURE		° F		° F
37	TUBES	NO.	O.D.	BWG	LENGTH PITCH
38	SHELL	I.D.	O.D.		SHELL COVER (INTEG) (REMOV)
39	CHANNEL OR BONNET				CHANNEL COVER
40	TUBESHEET—STATIONARY				TUBESHEET-FLOATING
41	BAFFLES—CROSS	TYPE			FLOATING HEAD COVER
42	BAFFLES—LONG	TYPE			IMPINGEMENT PROTECTION
43	TUBE SUPPORTS				
44	TUBE TO TUBESHEET JOINT				
45	GASKETS				
46	CONNECTIONS-SHELL SIDE	IN	OUT		RATING
47	CHANNEL SIDE	IN	OUT		RATING
48	CORROSION ALLOWANCE—SHELL SIDE		TUBE SIDE		
49	CODE REQUIREMENTS				TEMA CLASS
50	REMARKS				
51					
52					
53					
54					

6.4 Ordering Data Checklist. The detailed data and conditions necessary to design, fabricate, examine, test, and deliver a sodium-water steam generator in accordance with this standard are included in the Ordering Data. These subjects are also listed below in the Ordering Data Checklist. The list includes topics to which the standard makes specific references, as well as other supplemental information which will be defined by the purchaser.

	Item	Refer to Paragraph
	General Design Requirements	
1.	Description	3.1.1
2.	Type	3.1.1
3.	Function	3.1.1
4.	Design basis including design life	3.1.1
5.	Inservice inspection requirements	3.1.3.1
6.	Cover gas specifications	3.1.6
7.	Quantity of residual sodium allowed after drainage	3.1.7.2
8.	Limits on size and weight	3.1.8
9.	Heatup rates	3.1.9.2
10.	Insulation requirements	3.1.9.3
11.	Trace heater requirements	3.1.9.3
12.	Environmental conditions	3.1.11
	Thermal and Hydraulic Design Requirements	
13.	Operating conditions	3.2.1.1, 3.2.2.1, 3.3.1, 3.3.3.1, 3.3.3.2, 3.3.4, 3.3.5, 3.6
14.	Load range	3.2.1.1, 3.2.2.1, 3.2.2.2, 3.3.1, 3.3.3.1, 3.3.3.2, 3.3.4, 3.3.5
15.	Thermal transients	3.2.1.1, 3.2.2.1, 3.2.10, 3.3.1, 3.3.3.1, 3.3.3.2, 3.3.4, 3.3.5, 3.11.1.1, 3.11.2

	Item	Refer to Paragraph
16.	Natural circulation conditions	3.2.2.2, 3.3.1
17.	Drainability requirements	3.2.1.1
18.	Sodium purity	3.2.3
19.	Boiler water purity	3.2.4
20.	Feedwater purity	3.2.4
21.	Number of tubes and their distribution that may be plugged at the time of delivery	3.2.5.1
22.	Water/steam-side pressure drop	3.2.6
23.	Sodium side pressure drop	3.2.6
24.	Sodium side fouling	3.2.7
	Structural Design Requirements	
25.	Seismic loads	3.3.2
26.	Vibration testing	3.3.3.2
27.	Nozzle loads and time dependent response characteristics	3.3.6
28.	High temperature design criteria	3.3.8.2
29.	Shell protection requirements	3.3.9
30.	Sodium-water reaction	3.3.10
31.	Corrosion allowance criteria	3.3.12
	Connections, Accesses, and Appurtenances	
32.	Insulation supports and thermal requirements	3.4.3
33.	SG movement limitations	3.4.5.2
34.	Foundation and support structures design information and interface responsibility	3.4.6.1
35.	Piping connections requirements	3.4.7
36.	Bolt screw thread specifications	3.4.8

	Item	Refer to Paragraph
37.	Preheating system support requirement	3.4.9
	Instrumentation	
38.	Instrument listings	3.5.1.1
39.	Sodium level indication	3.5.2
40.	Pressure gages	3.5.3
41.	Temperature instrumentation	3.5.4
42.	Flow instrumentation	3.5.5
43.	Water-to-sodium leak detection	3.5.6
44.	External leak detection	3.5.7
	Operating Conditions	
45.	Definitions of normal, upset, emergency and faulted conditions	3.6
	Materials of Construction	
46.	General requirements	3.7.1
47.	Material samples	3.7.3
	Fabrication	
48.	Tube plug welding time period	3.8.2.2
49.	Tube plug demonstration criteria	3.8.2.2
50.	Tube-to-tube sheet and tube-to-tube welds qualification samples and data	3.8.2.4
51.	Heat treatment - approval, requirements and number of record copies	3.8.3
52.	Surface finish requirements	3.8.5
53.	Cleanliness control and cleaning requirements	3.8.9
54.	Identification of subcomponents	3.8.13.2
55.	Nameplate information	3.8.13.3

	Item	Refer to Paragraph
	Installation and Field Services Requirements	
56.	Services to be rendered	3.9.1
57.	Storage requirements	3.9.3
58.	Handling equipment requirements	3.9.4
59.	Installation requirements	3.9.6, 3.9.7
	Safety	
60.	Water/steam-side pressure relief design parameters	3.10.1
61.	Sodium-side pressure relief requirements	3.10.2
62.	Water-side isolation requirements	3.10.3.1
63.	Sodium removal requirements	3.10.3.2
	Reports and Documentation	
64.	Interim report requirements	3.11.2
65.	Periodic and progress report intervals	3.11.3
66.	Final report illustration requirements	3.11.4
67.	Time and approval requirements including number of copies required for reports, procedures, and other documents	3.11.5, 3.11.6, 3.11.7.2
68.	Operations and maintenance manual photographs	3.11.8
69.	Time, number of copies and approval requirements of drawings	3.12
70.	Number of tube plugs to be supplied	3.12.6
	Quality Assurance Requirements	
71.	Material visual examination requirements	4.4.1
72.	Material nondestructive examination requirements	4.4.2
73.	Controlling standards for examination during fabrication	4.5.1

	Item	Refer to Paragraph
74.	Visual and dimensional examination requirements for welds	4.5.2.3
75.	Liquid-penetration and magnetic-particle examination criteria	4.5.3, 4.5.3.2
76.	Examination of weld repairs	4.5.4
	Testing	
77.	Hydrostatic testing specifications	4.6.1.1
78.	Pressure to be maintained after pneumatic testing	4.6.1.2
79.	Helium leak testing acceptance standards	4.6.2
80.	Stress verification testing requirements	4.6.3
81.	Special test requirements	4.6.4
	Preparation for Delivery	
82.	Delivery requirements	5.1
83.	Packaging and packing requirements	5.1.2
	Notes and Ordering Data	
84.	Checklist compliance	6.2