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RELAZIONE TECNICA

IC HX EQUIPMENT REQUIREMENTS SPECIFICATION

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NAC-GTD	1	17.6.92	Sections 10, 11 and 12 expanded. Other changes for consistency with the design status.		Bruzzone	Lumini	Brandani

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1. SCOPE

This specification defines the general functional, engineering and construction requirements for the Isolation Condenser Units.

2. APPLICABLE DOCUMENTS, CODES AND STANDARDS

The design of this equipment shall be in accordance with specific codes and regulations as follows:

a) American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, July 1989

- Section II, Material Specifications

  a) Part A - Ferrous Materials
  b) Part B - Nonferrous Materials
  c) Part C - Welding Rods, Electrodes and Filler Metals

- Section III, Division 1 and Division 2 -Subsection NCA Nuclear Power Plant Components; General Requirements

- Section III, Division 1 - Subsection NB - Class 1 Components

- Section III, Division 1 - Subsection NC - Class 2 Components

- Section III, Division 1 - Subsection NF -Component Supports

- Section III, Division 1 - Subsection NG - Core Support Structures

- Section III, Division 1 - Appendices

- Section V, Nondestructive Examination

- Section IX, Welding and Brazing Qualifications

- Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components - Division 1

b) TEMA - Mechanical Standards Class "R" Heat Exchangers

c) 10CFR50 Appendix A "General Design Criteria for Nuclear Power Plants"

d) ANSI/ASME NQA-1-1983 and its Addenda (NQA-1a) Edition. (Quality Assurance Program Requirements for Nuclear Facility)

e) ANSI/ASME NQA-2-1983 Edition. (Quality Assurance Requirements for Nuclear Facility Applications) (1)

f) USNRC Standard Review Plan 3.6.2 MEB 3-1 Rev. 2, June 1987

g) USNRC Regulatory Guide 1.29 - Seismic Design Classification (Rev. 3) - September 1978

h) ANSI Standard B.16.25 "Butt-welding Ends" 1979

i) ANSI Standard N.18.2 "Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants" 1973 (1)

j) ANSI Standard N.18.2a "Revision and Addendum to ANSI n. 18.2 - 1973" 1975

k) ASTM Standard A 262 "Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steel"

3. REFERENCE DOCUMENTS

a) GEMD-66 "Information Package for Companies Developing an IC Heat Exchanger Design"

b) GEAN-103 "HPCI Testing at SIET"

c) ANGE-0104 "HPCI Testing at SIET"

d) ANGE-0093 "Relazione Tecnica: High Pressure Isolation Condenser Modular Solution Design Report"

e) ANGE-0129 "HPCI & PCC Basic Design Requirements"

f) Isolation Condenser P & ID n° 107E5154 rev. A

g) Composite Design Specification A11-5299 n° 23A6723 rev. A

h) Isolation Condenser System Design Specification B32-4010 25A5013 rev. A

i) FEC/9690 PCCS Design Guidelines

j) Pressure Integrity of Nuclear Components Standard Plant A62-4030

k) GEAN 212 - IC and PCC Arrangement - Nov. 18, 1991

l) Containment Configuration Data Book T10-1030 n. 25A5044 1

m) BAR49 - March 1992 - Containment Building Layout

4. EQUIPMENT FUNCTION

The function of the Isolation Condenser System (IC) is to limit reactor pressure to less than the lowest set point of the SRVs for moderately frequent events resulting in reactor isolation.
Furthermore, the ICs, together with the water stored in the RPV, shall conserve sufficient reactor water to avoid automatic depressurization from low reactor water level.
The IC system is not an Engineered Safety Feature (ESF), although it is used to limit the effects of plant transients.
The IC's shall be sized to remove post-reactor isolation decay heat with two out of three IC's operating and to reduce reactor pressure and temperature to safe shutdown conditions with occasional venting of radiolitically generated noncondensable gases to the suppression pool.

5. DESIGN REQUIREMENTS

5.1. General Design Requirements

5.1.1. Each Isolation Condenser Unit shall be designed for 30 MWt capacity and is made of two identical modules.
The IC Unit is located in the pool above the containment roof slab.
The main steam supply line is vertical and feeds two horizontal headers through four 6" pipes.
Steam is condensed inside 2" vertical tubes and is collected in two lower headers.
Two 4" pipes take the condensate to the 6" main drain line.

5.1.2. The Isolation Condenser shall be designed with the minimum number of system actuations for reliability.

5.1.3. The IC Unit shall be designed to remain in site, inside the IC pool, for 60 years.
However the IC tubes can be plugged off, if leaking, and headers shall be removable during plant shutdown for replacement if needed.

5.1.4. The IC pool and venting system shall be designed for IC tube or pipe ruptures, jet reaction and impingement, and steam/condensate flow oscillations.

5.1.5. The IC pool venting and overpressurization protection system shall be sized to prevent pool overpressure.

5.1.6. The IC shall be designed for OBE and SSE conditions. Load combinations for structural design shall consider dead weight, pressure, thermal and mechanical cycling, seismic, dynamic external loads and main made loads. ?

5.1.7. Construction materials for the IC tubes and components shall be compatible with normal operation requirements of the reactor system.
Material to be nuclear grade stainless steel or inconel, or other material which is not susceptible to IGSC (Intergranular Stress Corrosion).

5.2. Classification of Components

The classification of the IC component parts with respect to functional requirements and structural integrity is given in Table III.

5.2.1. Safety Classification

The IC is not to be considered an ESF (Engineered Safety Feature), although it is used to mitigate the effects of the plant transients.
The planned design basis is to follow the design guidelines of Safety Class 1, for parts through the containment boundary and of Safety Class 2, for part outside the containment.

5.2.2. Seismic Category

All Isolation Condenser parts are to be considered of Seismic Category I.

5.2.3. Quality Assurance

The Isolation Condenser must be in accordance with ref. doc. 2.d and 2.e.

Quality Assurance:

- Group A, inside the primary containment up to the steam distributor included.

- Group B, outside the containment, in the IC pool.

5.3. <u>Thermal-hydraulic Design Requirements</u>

5.3.1. Performances

Each isolation condenser shall be designed for 30 MWt heat removal capacity.
To minimize the heat transfer surface and potential heat exchanger overcapacity, the tube drainage shall be sufficient to assure condensing heat transfer rates throughout the tube lengths.

5.3.2. Fouling

The IC design shall account for a **fouling factor** of [redacted] **m²°C/W (0.0006 hr ft²°F/BTU) on the pool side and zero resistance on the primary tube side.**

5.3.3. Tube Plugging

The calculation of the **heat transfer surface area** shall take into account a **margin for tube plugging of 5%.**

5.3.4. Primary Side Pressure Losses

The primary side pressure loss of the IC shall be limited to 20.68 kPa (3 psi) from the steam line penetration to the main drain line penetration (top of drywell top slab), at maximum expected steady state IC condensing capacity (140% of nominal capacity).

5.3.5. Heat Transfer Condensation Coefficient

The heat transfer condensation coefficient inside the tubes has been evaluated with a conservative approch (Dukler analysis, Collier); the average value along the tube length is 8500 $W/m^2 \cdot °C$.

5.3.6. Heat Transfer Surface Area

The IC required heat transfer area has to be evaluated in the following conditions:

- primary side: saturated steam at 7.240 MPa(g) (1050 psig)
- secondary side: pool water temperature at 100°C (212°F).

5.3.7. Thermal Insulation

The acceptable rate of heat loss from an IC heat exchanger and its connected piping is, during stand-by conditions (see paragraph 6.1. below), 0.06 MWt.

5.4. Draining Requirements

The required draining time is less than or equal to [redacted] seconds after the drain valve opening set point is reached. The draining time after complete opening of the valve is required to be [redacted] seconds or less.

5.5. Safety Requirements

5.5.1. Double isolation capabilities shall be provided for the IC coolant boundary and containment boundary.

5.5.2. The IC system shall be isolatable following IC system component failures or impact damage of parts outside the primary containment system. The design shall be compatible with a Leak Detection and Isolation System (LD&IS) that

must be capable of detecting and isolating IC leaks and ruptures.

5.5.3. The isolation condenser system shall include a redundant unit. The units shall be separated such that impact or other damage to one IC unit will not functionally disable to other units.

5.5.4. The ICS loops and PCCS (Passive Containment Cooling System) loops shall be completely independent systems. The pools for the independent loops shall be interconnected and isolatable.

5.5.5. Failure of pressurized IC components whose rupture can release steam into the safety-related pool which contains the PCCS heat exchangers shall be limited at a critical flow through an area equivalent to two 3" pipes plus one 4" pipe or by providing guard pipes (or an enclosure around the components), or by observing the special stress and fatigue usage limits of NRC SRP3.6.2 MEB3-1, or by proof testing using experimental stress analysis cyclic test limits of ASME III, Subarticle II-1500, using the thermal, pressure, vibration and seismic load cycling defined in the paragraph 6.

5.6. Secondary Side Requirements

5.6.1. IC Tubes Location

The location of the IC tubes in the IC pool should be such as to guarantee the required performance within 72 hours minimum from the initiating events. 1

5.6.2. Pool Inventory Loss

The moisture content of the steam leaving the vent pipe shall not exceed 2% of mass flow of the steam generated in the IC/PCCS pool.

5.7. Primary Side Venting Requirements

Free hydrogen and oxygen gas mixture is generated in the reactor by radiolytic decomposition of water. This can become an explosive mixture if the partial pressure of these gases in a steam-gas mixture increases beyond 36% of the total pressure. Approximately 20 lbs. of gas per million lbs. of steam is generated by the reactor. Therefore, at locations in the IC system where steam is condensed by heat losses, there is out-gassing of the hydrogen-oxygen mixture.
An explosive mixture shall be prevented in the system by either continuously venting off the gases, or by catalytically recombining them (applies for locations with a low condensing rate), or by maintaining the temperature of the steam-gas mixture above the saturation temperature of steam at 4% of the total system pressure (by conduction or vent flow).

5.8. Lay-out Requirements

5.8.1. General Arrangement

The isolation condenser shall be located above the drywell outside the primary containment.
The vertical 12" main steam supply line feeds two horizontal headers through an upper distributor and four 6 inches pipes. 1
Steam is condensed inside 2" vertical tubes and is collected in two lower headers from which two 4" line take the condensate to the 6" main drain line and hence to the RPV.

5.8.2. Arrangement Constraints

The location of the isolation condenser units with their associated piping in the IC pool shall be compatible with the present Containmert Building lay-out limitations of Figures 1,2 and 3 and structural requirements for the drywell top slab, i.e.:

1. a maximum pool depth of 4.4 meters; 1

2. the steam supply, vent and drain pipes connecting to the isolation condenser shall be routed through the containment roof slab.

In particular:

a) in the dedicated pool compartments, the position of the IC center with respect to the reactor center line shall be:
x = ± 9438 mm
y = ± 9350 mm

b) geometrical boundaries: 1
- pool bottom elevation = 25300 mm
- bottom elevation of the slab above pool = 31100 mm
- compartment rectangular base of 6175 mm by 5475 mm

c) the IC primary containment penetrations:

- 20" main steam line guard pipe
- 12" main drain line guard pipe and
- 10" vent lines guard pipe

shall be located as shown in figure 2.

6. OPERATING CONDITIONS

6.1. Normal Steady State Conditions

The normal steady state conditions for the IC is the standby condition, during which:
- the condensate return valves on the main drain line are closed;

a) the IC is filled with condensate reactor water up to the elevation of overflow into the steam line. Condensate temperature is about 10 °C (50°F);

b) the steam pipe and the upper distributor above the condensate are filled with main steam at 289°C (552°F) and 7.240 MPa(g) (1050 psig);

c) the pool water is at the same temperature of the condensate inside the tubes (10°C).

6.2. Transient Operating Conditions

The expected transient conditions during the component life which shall be analyzed for their effect upon the IC, are listed in the following subsections:

6.2.1. Normal Operating Transients (Plant Condition 1)

The normal transients to take into account are the steam heatup cycles and cool down cycles.

	Occurrences
a) Heatup Steam heatup cycles starting from cold condition of 10°C, 0 Pa(g) to 289°C, 7.240 MPa(g) (50°F, 0 psig to 552°F, 1050 psig) at 55.5 °C/hr (100°F/hr.) maximum.	525

	Occurrences
b) Cool down Cool down cycles starting from steam saturation temperature of 289°C, 7.240 MPa(g) to 10°C, 0 Pa(g) (552 °F, 1050 psig to 50°F, 0 psig) at 55.5°C/hr. (100°F/hr.) maximum.	390

6.2.2. Upset Conditions (Plant Condition 2)

Occurrences

a) MSIVC (Main Steam Isolation Valves Closure). — 135
The reference transient to be considered is derived from MSIV transient and the Load Rejection Without By-pass. Starting from the stand-by conditions, drain valves are opened and 10°C (50°F) condensate is replaced by 302°C (575°F) steam: thermal equilibrium is reached with 8.619 MPa(g) (1250 psig),302°C (575°F) steam inside tubes and 10°C (50°F) water rising to 100°C (212°F) outside. Reactor pressure decreases afterward, but for mechanical design purposes steam pressure and temperature are assumed to remain constant.
For 134 events the operator closes the drain valves after two hours of operation.
For one event, drain valves are supposed to be closed after 72 hours of operation.
After closure, temperature decreases to 10°C (50°F) at 55.5°C/hr (100°F/hr).

b) OBE (Operating Basic Earthquake) — 10
Dynamic analysis including OBE shall be based on the floor response spectra of Figures 4 and 5.
Ten response cycles are to be taken into account for each occurency.

6.2.3. Emergency Conditions (Plant Condition 3)

The events to take into account are:

a) SRV unwanted opening. — $< 10^{-2}$/yr (*)
Starting from the stand-by conditions, one minute rise to 302°C (575°F), 8.619 MPa(g) (1250 psig) with condensate remaining at 10°C (50°F). 3.3 minute depressurization to 1.103 MPa(g) (160 psig).

then exponentially to 0.1 MPa(g) (15 psig).
10 minutes total time.

	Occurrences
b) ATWS (Anticipated Transient Without Scram) Reactor isolation with delayed scram: starting from the stand-by conditions, 0.5 minute steam pressure increase to 10.342 MPa(g) (1500 psig). Thermal equilibrium is reached at constant pressure with steam at 314.5°C (598°F) and condensate still at 10°C (50°F). Then, temperature decreases to 10°C (50°F) at 55.5°C/hr. (100°F/hr).	$< 10^{-2}$/yr (*)

6.2.4. Faulted Conditions (Plant Condition 4)

a) Large LOCA Transient enveloped by the SRV unwanted opening.	$< 10^{-4}$/yr (*)
b) SSE (Safe Shutdown Earthquake) Dynamic analysis including SSE shall be based on the floor response spectra of Figures 6 and 7.	$< 10^{-4}$/yr (*)

(*) Assume one occurrence defining maximum loads (not to be included for fatigue usage evaluations).

6.2.5. Test Conditions

The following test condition transients shall be considered in the stress and fatigue analysis of the IC:

	Occurrences
a) Primary Side Hydrostatic Test	
Test pressure = 1.25 design pressure Test temperature= RT_{NDT}+60°F(ASME III App.G)	10 (*)
b) Tube Leakage Test	
(test requirements to be defined)	(later)
c) Others	(later)

(*) Heavy requirement that it is possible to reduce according to ASME XI IWA-5000.

7. MECHANICAL DESIGN REQUIREMENTS

7.1. Code design requirements

- Parts of the HPIC through the containment boundary: ASME Section III Class 1.
- Component parts beyond the isolation valves: ASME Section III Class 2.

7.2. Thermal Stress and Fatigue Evaluation

A thermal stress and fatigue evaluation shall be performed in accordance with ASME Code Section III rules using the special design stress and fatigue usage limits defined for the applicable materials (see appendicies 3, 10 and 20).

7.3. Design Conditions

- Design Pressure	8.619 MPa(g)	(1250 psig)
- Design temperature	302°C	(575°F)

7.4. Support Reactions

The support foot reactions are those forces, at the point of attachment of the external support, that each support foot shall sustain without exceeding the stress intensity limits of ASME III, Class II.
The umbrella reactions for each foot shall be evaluated and are to be used in the IC design.

7.5. Fracture Mechanics Analysis

A fracture mechanics analysis of the IC component ferritic steel parts (steam pipe, steam distributor) shall be performed in accordance with Appendix G of ASME Section III.

7.6. Flow Induced Loads

The IC shall be designed to minimize the effect of flow induced loads. The potential for flow induced vibration damage shall be assessed at the exchange tube bundle and at weld attachment locations between tubes and headers. Potentiality for vibrations arise from:

- The primary steam and condensate flow inside tubes.
- The secondary flow outside the exchange tubes, due to natural circulation of the IC pool water.

Experimental evidence of absence of induced vibrations might be considered satisfactory.

7.7. Nozzle Loads

Nozzle loads are those forces, at the point of attachment of piping to the IC headers, resulting from differential thermal growth, seismic and LOCA conditions.
The preliminary nozzle loads at the IC interfaces with the piping lines inside the primary containment are assumed to be as defined in table IV.
Additionally the thermal stresses caused by pipe-material differences or size discontinuity shall be included.

7.8. Dynamic Analysis Criteria

The Floor Response Spectrum method shall be used. The response spectra shown in Figures 4 and 5 apply for dynamic loads resulting from combination of OBE and DPV/SRV loads (upset condition).
The response spectra shown in Figures 6 and 7 apply for dynamic loads resulting from combination of SSE, DPV/SRV and LOCA loads (faulted condition).
A three directional dynamic excitation shall be considered.
The total three directional response is to be calculated using the square root at the sum of the squares of the modal contributions.

7.9. Blowdown Analysis

7.9.1. Pipe Rupture Criteria

The IC and its component parts shall be designed to withstand the loads induced by a LOCA event.
A hydraulic and structural analysis are to be performed to evaluate the pressure loads, condensation loads and other dynamic loads which may derive from a postulated pipe rupture.
Postulated rupture to take into account are, in accordance with the applicable document (paragraph 2.).

a) Sudden complete circumferential pipe failure with flow from both ends. Pressurized IC components larger than 2 inch diameter, such as pipes, tube sheets, heads and plenums whose rupture can release steam into the IC pool, may be used in the IC pool if:

   i. guard pipes are provided around the pressurized IC component (the guard pipes may be vented into the

IC pool water through quencher-type orifices which assure steam condensation);

or:

ii. the stresses and fatigue usage of the pressurized IC component do not exceed special limits established by the US NRC SRP 3.6.2., Branch Technical Position MEB 3-1;

or:

iii. the pressurized IC components has been proof-tested using experimental stress analysis cyclic tests in accordance with ASME Code Section III, Article II-1000, Subarticle II-1500. The number of operational cycles upon which this experimental cyclic testing shall be based is defined in the above item.

b) Sudden failure of guard pipe pipes and transition pieces that extend the containment boundary only if guard pipe design does not meet the special limits established by US NRC SRP 3.6.2., Branch Technical Position MEB 3-1.

c) The multiple failure of a group of closely spaced heat exchanger tubes (cascading tube failure). The number of failed tubes and the break flow area is to be determined using the following principles:

i. There is the sudden circumferential failure of one tube.

ii. The tubes surrounding the broken tube can be used to limit consequential damage if the tubes are held together by tube stays.

iii. The consequential damage caused by the first tube failure (Item i.) is limited to longitudinal splitting of surrounding tubes without shear-off if tube stays are provided (see Item ii.). Also, the tube materials and welded joints used must be qualified for the environmental conditions, without IGSC (Intergranular Stress Corrosion), and without high fatigue usage, and must not be susceptible to brittle fracture type failure. The resultant consequential break flow area is equivalent to flow from both ends of a split tube multiplied by the number of surrounding tubes that can be impacted by the first broken tube.

7.9.2. Fatigue Analysis Criteria

Fatigue evaluation shall take into account:

a) Mechanical and thermal cycling occuring during normal and upset transients.

b) Flow and condensation induced vibration that occurs during:

- two hours of operation with 302°C (575°F) steam inside tubes and 50°F water on the outside during 134 envelope upset transients;

- 72 hours of operation at the same conditions for one upset transient;

c) 10 response acceleration cycles for each of the 10 dynamic load excitation cycles taking into account OBE and DPV/SRV events.

d) All the test condition transients.

7.9.3. IC Compartment Design

Compartments that contain the IC units and supply pipe shall be designed to withstand the pressure caused by an assumed pipe rupture within the compartment: the vent area limits the pool pressure to 34.5 KPa(g) (5 psig).
The maximum assumed rupture have an area equivalent to two 3" pipes plus one 4" pipe.

7.10. <u>Loading Conditions</u>

The IC and its component parts shall be designed to with stand the loads resulting from the combinations defined in table II.

8. MAINTENANCE REQUIREMENTS

- The IC heat exchangers shall be readily inspectable, repairable and replaceable in the IC pool.
- Removal for routine inspection should not be necessary but difficulties of removal shall be however minimized (i.e. cutting/reweld shall be also minimized).
- The water in the IC pool compartment shall be removable without emptying the entire IC pool.

9. SERVICE REQUIREMENTS

9.1. Water Chemistry

The IC shall be designed to operate satisfactorily with the water chemistry indicated in Table I.

9.2. Instrumentation

Process instrumentation and controls shall be provided to monitor the IC during all normal and off-normal operating conditions.

10. CONTROLS, TESTS INSPECTIONS AND INSERVICE INSPECTION REQUIREMENTS

10.1 General

Applicable Non Destructive examination methods are: Ultrasonic (UT), Radiographic (RT), Magnetic Particle (MT), Liquid Penetrant (PT), Eddy Current (ET), Visual Examination (VT), Leak Testing.
Before NDE begins, the Supplier shall prepare NDE procedures and drawings or sketches detailing the essential variables of the applicable method. The procedures shall be consistent with applicable Codes and Standard and shall be submitted to the Customer for approval.
In addition for the requirements of ASME Code Section III NC, the following requirements apply.

10.2 Procurement Controls

Controls shall be performed consistent with procurement specification requirements. The following specific requirements apply. 1

10.2.1 Headers and Headers Covers

Forgings shall be examined according to ASME Code, Sec. V Art. 23, SA-745 "Standard practice for ultrasonic examination of austenitic steel forgings" with the following additional requirements.

10.2.1.1 Preparation for forgings

The headers hollow forgings shall be UT examined after heat treatment and after rough-machining to provide cylindrical surfaces for radial examination; the ends of forgings shall be machined perpendicular to the axis of the forgings for the axial examination.
The headers covers forgings shall be UT examined after heat treatment and after rough-machining to provide faces flat and parallel to one another.
The surface roughness of exterior finish shall not exceed 250 micro in. (6.3 micron).
The UT shall be performed prior to drilling holes, tapers, grooves or machining sections to contour extruded nozzles.

10.2.1.2 UT Procedure

The headers hollow forgings shall be radially and axially scanned using straight beam techique.

In addition the hollow forgings shall be examined by angle beam technique from the outside diameter in two perpendicular directions.
The headers covers forgings shall be UT examined using a straight beam from at least one flat face and radially from the circumference.
If radial penetration is not possible due to attenuation or to curved shape of the cover, angle beam examination directed radially may be subsistuted in place of radial straight beam.

10.2.1.3 Quality Level

The applicable quality level for straight beam examination shall be SA-745 par. 12.1.1.1 (a) QL-1, for angle beam examination shall be SA-745 Par. 12.1.2.1 QA-1.

10.2.1.4 Acceptance Criteria

Acceptance criteria for straight beam examination shall be in accordance with SA-745 Par. 12.1.1.1, for angle beam examination shall be in accordance with SA-745 Par. 12.1.2. 1

10.2.2 Steam Distributor and Distributor Cover

Forging shall be examined according to ASME Code, Sec. V Art. 23, SA-388 "Recommended Practice for Ultrasonic Testing and Inspection of Heavy Steel Forgings" with the following additional requirements.

10.2.2.1 Preparation of forging

The forging for distributor shall be UT examined after heat treatment and after rough-machining to provide cylindrical surfaces for radial examination; the ends of the forging shall be machined perpendicular to the axis of the forgings for the axial examination.
The surface roughness of exterior finish shall not exceed 250 micro in. (6.3 micron).
The UT shall be performed prior to drilling holes, tapers, grooves and machining the final external contour.

10.2.2.2 UT Procedure

The forging for distributor shall be radially and axially scanned usign straight beam technique.
In addition the forging shall be examined by angle beam technique two perpendicular directions.

10.2.2.3 Reference Standards

Reference Standards for Straight Beam examination shall be flat bottom holes with diameter of 0.4 mm for each 6 mm of section thickness or fraction thereof to a max. of 3 mm. Reference Standards for Angle Beam examination shall be notch 3% of section thickness (or 6 mm whichever is larger) in depth, 60 degrees V-shaped and 25 or less long. The section thickness is the thickness after final machining.

10.2.2.4 Acceptance Criteria

Acceptance criteria shall be in accordance with ASME Code Sec. III, Div. 1 - NB-2542.2

10.2.3 Pipes

Pipes for main steam line, feed lines and drain lines shall be Ultrasonic examined after final heat treatment and before bending according to ASME Code Sec. III, Div. 1 NC-2550 with the following additional requirements. (1)

10.2.3.1 The surface roughness of exterior finish shall not exceed 250 micro in. (6.3 micron).

10.2.3.2 Pipes shall be examined in two circumferential directions, as defined in NC-2552.1, and in two axial directions.

10.2.3.3 The reference specimen shall be in accordance with NC2552.3 (a) and (b) with the following additional requirements.

- The reference specimen shall contain two axial standards defects (notches), on the outside and inside surfaces, and two circumferential standard defects (notches), on the outside and inside surfaces.
- Notches shall be 5% of nominal wall thickness (or 0.10 mm whichever is larger) in depth, 60 degrees V-shaped and 25 mm or less long.

10.2.3.4 Repair of defects by welding is not permitted.

10.2.4 Tubes

Tubes shall be UT examined before bending according to ASME Code Sect. III Div. 1 NB-2551.
After bending, tubes shall be PT examined according to ASME Code Sect. III Div. 1 NB-2556.

10.3 Welds Control

Welds control shall be performed in accordance with the prescriptions of ASME Code Sect. III, Div. 1 NB-5000 and consistent with approved procedures.
Additionally:

a) circumferential butt welded joint in piping shall be examined by the radiographic and the liquid penetrant method;

b) tube-to-headers welds shall be surface examined by the liquid penetrant method and volumetric examined by radiographic method;

c) headers to supports full penetration corner welds shall be surface examined by the liquid penetrant method and volumetric examined by ultrasonic method.

d) each layer of the buttering of distributor nozzles for field welds to Inconel 600 piping shall be surface examined by the liquid penetrant method. Volumetric examination by Radiographic method shall be made at site after piping welding. 1

10.4 Assembling Controls

Controls shall be performed during the overall assembling in order to verify that:

- tubes are properly positioned in the corresponding header holes;
- dimensions and tolerances are consistent with approved manufacturing drawings;
- all parts which will become inaccessible, are properly positioned and fixed and/or welded and inspected;
- inner surfaces are properly cleaned.

Before packaging, a final cleanliness control shall be performed at Customer's Personnel presence.
All control Reports shall be part of the Final Manufacturing Report.

10.5 Hydrotest

Hydrostatic tests shall be performed on the IC module and subassemblies in accordance with ASME Code Sect. III.

Final hydrostatic test of the overall unit shall be performed at site.

10.6 Leak Testing

Leak test shall be performed on the IC module in accordance with ASME Code Sect. V Art. 10 APPENDIX V "Helium mass spectrometer test - tracer probe and hood techniques". The component is acceptable when no leakage is detected that exceeds the allowable rate of 1 x 10E-04 std cm^3/sec (1 x 10E-04 millibar liter/sec). (1)

10.7 Visual and Dimensional Examination

The IC and its parts shall be subjected to visual and dimensional examination to verify conformance with the drawing and all of the requirements of this specification which do not involve tests.

10.8 Inservice Inspection Requirements

- ISI amount shall be minimized during the design phase, by reducing eg. the number of welds.
- The IC is an extension of the reactor coolant pressure boundary which is not isolated from the pressure boundary.
  Therefore, ASME Code Sections III, Class II, and Section XI requirements for design and accessibility of welds for in-service inspection apply.
- The IC tubes, the headers and IC pool shall be arranged so IC tubes can be inspected with ultrasonic probes (if needed according to above requirements) or plugged off. This requires that the tubes should be accessible from outside the IC pool or a means provided to isolate one IC pool from another.
- Exchange tubes shall be inspected by the Eddy current method.
- Routine ISI of tube header welds is required (ultrasonic inspection).
- Non-destructive examination for welded part, forged part, and out surface shall be done according to the applicable laws and codes.

11. MATERIAL REQUIREMENTS

Materials listed in Paragraph 11.1 below are acceptables for the application when used in proper relationship with other materials. Chemical analysis of material shall be performed according to ASTM E 38.

11.1 Acceptable Materials

All materials shall be subjected to the requirements of ASME Code (ref. 2.a), Appendix 3 of this document, and the following paragraphs.

11.1.1 Ni-base Alloy

Ni-base Alloy material shall be subjected to the following requirements:

11.1.1.1 Pickling of wetted surfaces is prohibited.

11.1.2 Austenitic Stainless Steel (1)

Austenitic stainless steel material shall be subject to the following requirements:

11.1.2.1 In the final fabrication condition, wrought austenitic stainless steel shall be in the solution heat treated condition. Heat treatment shall be done at 1040/1150 °C metal temperature, followed by an approved cooling process.
Localized heat treatment is not permitted unless qualified for a specific application.

11.1.2.2 Grain size and uniformity shall be controlled in the material to provide adequate UT inspectability, where required.

11.1.2.3 Material shall be tested to verify freedom from sensitization according to ASME A 262 Practice A. (ref. 2.k).

11.1.2.4 Hardness of cold worked raw materials shall not exceed 92 HRB. Hardness shall be controlled during fabrication by process control of bending, cold forming, straightening or other similar operations.

11.1.3 Carbon and Low Alloy Steel Materials

Carbon and Low Alloy Steel Materials shall be subject to the following requirements:

11.1.3.1 Forgings shall be SA-508 Cl. 3. Sulfur content shall be limited to 0.015 %.

11.1.4 Pressure boundary materials

a) Pipes for steam supply line and guard pipe
Pipes material shall be SA-333 Gr. 6 seamless.

b) Forging for distributor and distributor cover
Forgings material shall be SA-508 Cl. 3.

c) Boltings for distributor covers
Bolting material shall be SA-540.

d) Pipes for feed lines
Pipes material shall be SB-167 Nickel-Chromium-Iron Alloy UNS N06600 (Alloy 600).

e) Forging for headers and headers covers
Forging material shall be SB-564 Nickel-Chromium-Iron Alloy UNS N06600 (Alloy 600).

f) Bolting for headers covers
Bolting material shall be SB-637 UNS N07718 (Gr. 718).

g) Tubes
Tubing material shall be SB-163 Nickel-Chromium-Iron Alloy UNS N06600 (Alloy 600).

h) Pipes for Drain Lines
See previous Par. d).

i) Drain "T" forging and drain "T" forging cover
Forgings material shall be SA-182 F304AL with Carbon content not exceeding 0.020%.
Material shall be melted by vacuum furnace followed by electroslag-consumable remelting and furnished in heat-treated conditions according to SA-182 Par. 5.3.
Heat treatment of forging may be performed before machining. Drain "T" forging shall not be machined directly from bar stock.

l) Boltings for "T" forging covers
Boltings for "T" forging cover shall be SA-193 B8.

m) Pipes for main drain line
Pipes material shall be SA-312 TP304L with the Carbon content not exceeding 0.020%.
The tubes shall be seamless, hot finished and in solution heat-treated conditions according SA-312.

n) Pipes for vent line
Pipes material shall be SA-312 TP304L.

o) Vent nozzles
Material for the vent nozzles welded to the headers shall be SB-564 Nickel-Chromium-Iron Alloy UNS N06600 (Alloy 600).

p) Instrumentation nozzles
Material for instrumentation nozzles (2" complete with flange and 1/4" NPT) shall be SA-182 F304L with Carbon content not exceeding 0,020%.

11.1.5 Non-Pressure boundary materials

The material for non-pressure retaining parts shall be in accordance with the applicable ASME or ASTM Specifications.

a) Flow distributor device
Forging material shall be SA-182 F304.

b) Venturi inserts
Forging material shall be SB-564 Nickel-Chromium-Iron Alloy UNS N06600 (Alloy 600). 1

c) Flow distributor plug
Material for the flow distributor plug (to be welded to the drain "T" forging cover) shall be SA-312/240 TP 304.

d) Supports
Material for supports integral attachments shall be SA-240 TP 304.
Material for support beams and plate shall be SA-36, coated for corrosion protection.

f) Flange for guard pipe
Flange material shall be SA-105 protective coated on outside surface.

g) Flanges for drain "T" forgings and vent lines
Flanges material shall be SA-182/240 TP 304.

11.1.6 Protective coating

The outside surfaces of guard pipe, flange item f), and all the support beams and plates which will be exposed to pool water, shall be protective coated to avoid corrosion. Coating shall be compatible with 100°C water temperature.

Inorganic Zinc coating shall be used, such as CARBOLINE Carbo Zinc 11 FD or AMERON Dimetcote 6, or approved equal.

11.2 Unacceptable Materials

Contamination of the IC with sulphur, lead, low melting point metals, their alloys, and their compounds shall be prohibited during fabrication, testing, shipping or erection. Where a satisfactory substitute material free of such contaminants cannot be found, the use of such substance for processing and fabricating metals at room temperature is permissible providing all surfaces, crevices, blind holes, etc., are throughly cleaned to remove the containment prior to any operation involving elevated temperatures. 1

The Supplier shall submit to the Customer, for approval, a detailed Cleaning Procedure. This procedure shall contain specific informations to assure reliable cleaning process of the materials and components during all stages of manufacturing.

11.3 Gaskets

For distributor cover the gasket shall be of the spiral wound graphite filled type or approved equal.

For headers covers the gaskets shall be metallic O-rings of te self-energized type provided with retainer clips.

For the drain "T" forgings covers the gaskets shall be metallic O-rings.

The O-rings shall be manufactured, worked, tested, inspected and certified according to the production standards of a qualified manufacturer.

Material shall be Alloy 718 or Alloy X-750.

12. **FABRICATION REQUIREMENTS**

12.1. General

Manufacturing technology in process of work of the IC unit shall be high level.

The principal manufacturing documents are listed below. The following list is for guidance purpose and is not necessarily comprehensive.

- Planning
- Engineering schedule
- Procurement and Fabrication Drawings
- Fabrication plan and description of the activity
- Procurement Specifications
- Control Specifications
- Manufacturing procedure Specifications
- Welding Specifications and Welding Procedure Specification
- Welding book
- Final Manufacturing Report to be submitted to the Customer after completion of the IC and before its shipping to te plant site.
- Technical Manual.

1

12.2 Fabrication

Manufacturing procedures shall meet the general requirements listed in Table III and the prescriptions detailed hereinafter.

12.2.1 Material Procurement

Material procurements shall be carried out to meet the prescription of Par. 11. and according to the relevant specifications, approved, if required, by the Customer.

12.2.2 Thermal cutting

12.2.2.1 Austenitic Stainless Steel and Nickel-Chromium-Iron Alloy

Thermal cutting of pressure retaining materials and weld preparation shall be made by plasma cutting process only. No other type of thermal cutting is admitted. After cutting, a minimum of 1.0 mm of material shall be removed by machining or griding.

12.2.2.2 Carbon Steel, Carbon Manganese and Low Alloy Steel

Preheat temperature for thermal cutting shall not be lower than the one specified for the welding of the same material and thickness.
After thermal cutting operations, including arc-air and oxygen cutting, on all pressure retaing materials and all weld preparations, a minimum of 1.0 mm of material shall be removed by machining or griding.

12.2.3 Welding

Welding procedures and weld procedure / operator qualifications shall be consistent with ASME Code Section IX.
Special precautions shall be taken for Inconel 82 buttering of SA-508 Cl. 3 distributor nozzles ends, to avoid adverse effects on material properties: welding procedure shall be submitted to Customer for approval.

12.2.4 Heat Treatment

Heat treatment shall be in accordance with Appendix 3.
The values of the main parameters of these treatment shall be reported to the Customer.

12.2.5 Repair Welding

a) Repair to welds - They may proceed without prior Customer approval, provided that the repair procedures are consistent with welding specification requirements and that the repair is properly recorded.
Weld repairs shall not be done more than twice.

b) Repair to base material - No repair to base material shall proceed without prior Customer approval.

12.2.6 Surface Protection

The Surface Protection Procedure shall contain specific informations to assure reliable surface protection of the materials and components during all stages of manufacturing.
The surface protection treatment shall be provided for manufacturing time, according to the prior program to be established by the Supplier.

Exposure of austenitic stainless steel to substances containing chloride or fluoride ions is to be avoided.
Where manufacturing or inspections processes necessitate exposure to chloride or fluoride ions, all finished surfaces that may have been so exposed shall be thoroughly cleaned with approved cleaners or solvent to ensure freedom from contaminants.
Surface cleanliness should be tested in accordance with Supplier Surface Protection Procedure.
Grit blasting shall not be performed on surfaces in contact with water.
The Supplier Surface Protection Procedure shall contain detailed information on surface protective coating of carbon and low-alloy steel in contact with water according to the functional requirements of the component. ⟨1⟩

12.2.7 Cleaning

Manufacturing and welding procedures shall include precautions against contamination by such items: mercury, lead, zinc, cadmium or other low melting point metals.
All surfaces shall be cleaned prior to heat treatment.
Welding procedures shall prevent the contamination of the deposited weld metal by a temperature sensitive crayon.
No cleaning of not formed austenitic stainless steel material by acid pickling shall be performed.
Water used for cleaning or testing the component shall be grade B in quality according to the applicable procedure.
Cleaning procedures, solvent specifications and packaging procedures shall be submitted to the Customer for approval.

TABLE 1
WATER QUALITY
(See Notes 1 & 2)

REACTOR WATER QUALITY PARAMETER	SYSTEM DESIGN
Chloride (ppb)	20.0
Sulfate (ppb)	20.0
Conductivity** at 25°C (µS/cm)	0.25
Silica (ppb as SiO_2)	100
pH at 25°C min	7.0
max	8.0 (8.6*)
CORROSION PRODUCT METALS (ppb)	
Fe Insoluble	20.0
Soluble	
Cu Total	2.0
All Other Metals	8.0
Sum	30.0

**Does not include an incremental conductivity value of 0.8 µS/cm at 25°C due to carbon dioxide from air in water stored in tanks open to the atmosphere.

*Operating values change to these values during plant shuntdown. Otherwise, operating and shutdown design values are the same.

Note 1: The values given are for reactor water quality during reactor operation and shutdown except as noted by asterisk.

Note 2: IC pool water quality is the same as reactor water quality at shutdown design values.

Note 3: Pool water is demineralized and filtered and will contain no biological material or biocides.

TABLE II

TABLE COMBINATION CRITERIA

PLANT CONDITION	LOAD COMBINATION	SERVICE LEVEL
-	Deadweight, Design Pressure Design Temperature, OBE	Design
1	Deadweight, Normal Condition Transients	A (normal)
2	Deadweight, Upset Condition Transient, OBE	B (upset)
3	Deadweight, Emergency Condition Transients	C (emergency)
4	Deadweight, SSE, Faulted Condition (1)	D (faulted)
-	Test Deadweight, Test Pressure	Test

Note:(1) The response spectrum used for dynamic analysis takes into account building response to SSE and LOCA loads.
Other pipe rupture loads are to be combined by means of the SRSS method.

TABLE III

IC CLASSIFICATION

COMPONENT PARTS	ANSI SAFETY CLASSIFICAT.	ASME CODE CLASSIFICAT.	Q.A. GROUP	SEISMIC CATEGORY
Through primary containment	CLASS 1	CLASS 1	A	1
Outside primary containment	CLASS 2	CLASS 2	B	1

TABLE IV

PRELIMINARY NOZZLE LOADS FOR HPIC DESIGN

LOAD (note 1)	Plant Condition		
	1 and 2	3	4
Axial or Shears Transverse (LBS)	0.050 Ap Syp	0.055 Ap Syp	0.070 Ap Syp
Bending Moments (IN-LBS)	0.25 Zp Syp	0.30 Zp Syp	0.35 Zp Syp
Torsional Moment (IN-LBS)	0.25 Zp Syp	0.30 Zp Syp	0.35 Zp Syp

NOTE 1: The six component of nozzle loads are assumed to be applied simultaneously.

Where:

Ap = Cross sectional area of pipe metal, (in^2)
Syp = Tensile yield strength of pipe material at design temperature, (lb/in^2). When pipe material is not specified, yield shall be taken as 30,000 psi.
Zp = Section modulus of pipe, (in^3).

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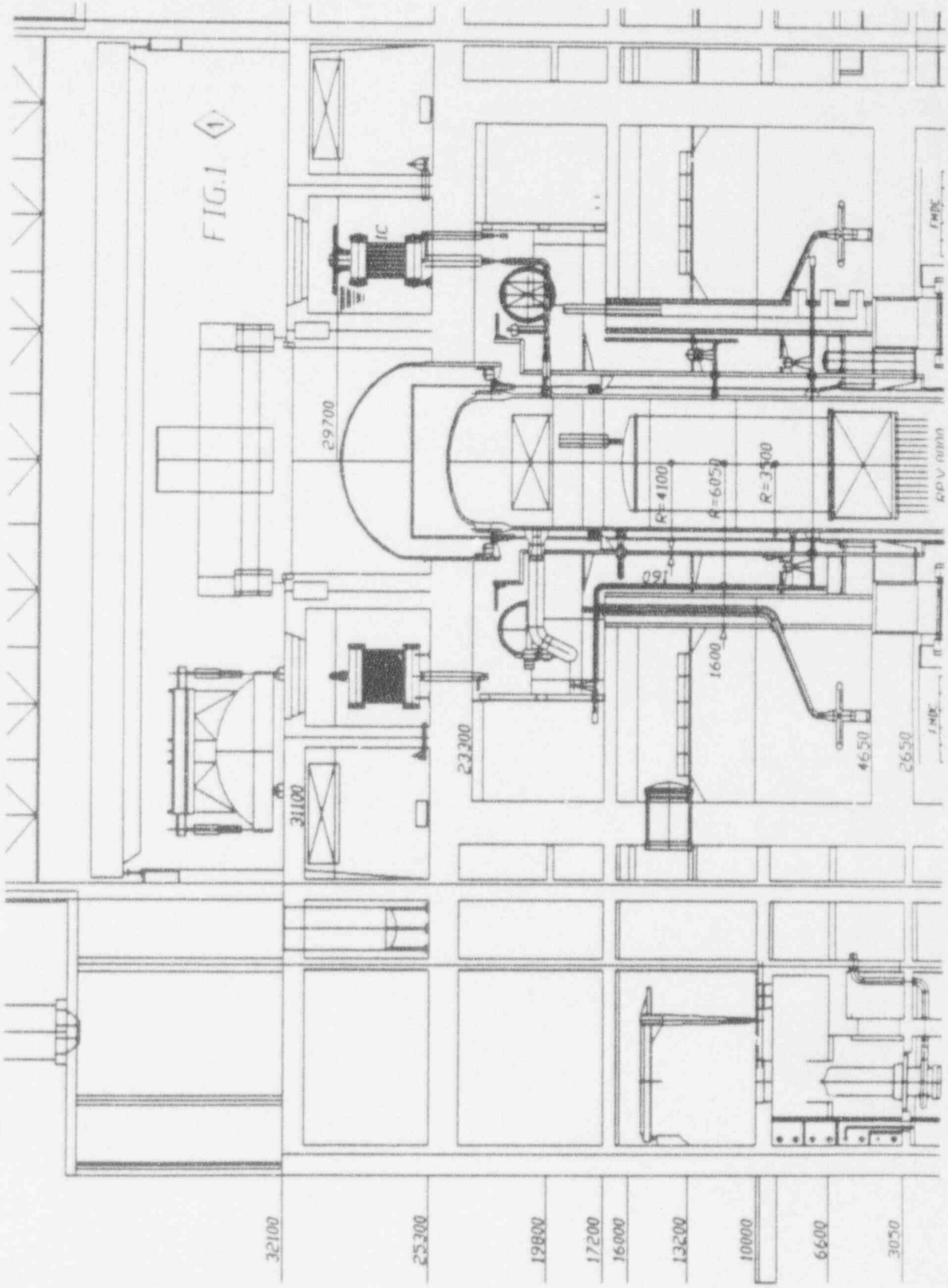
Progetto project	Identificativo document no.	Rev. rev.	Pagina page
SBWR	SBW 5280 TNIX N014 000	1	40



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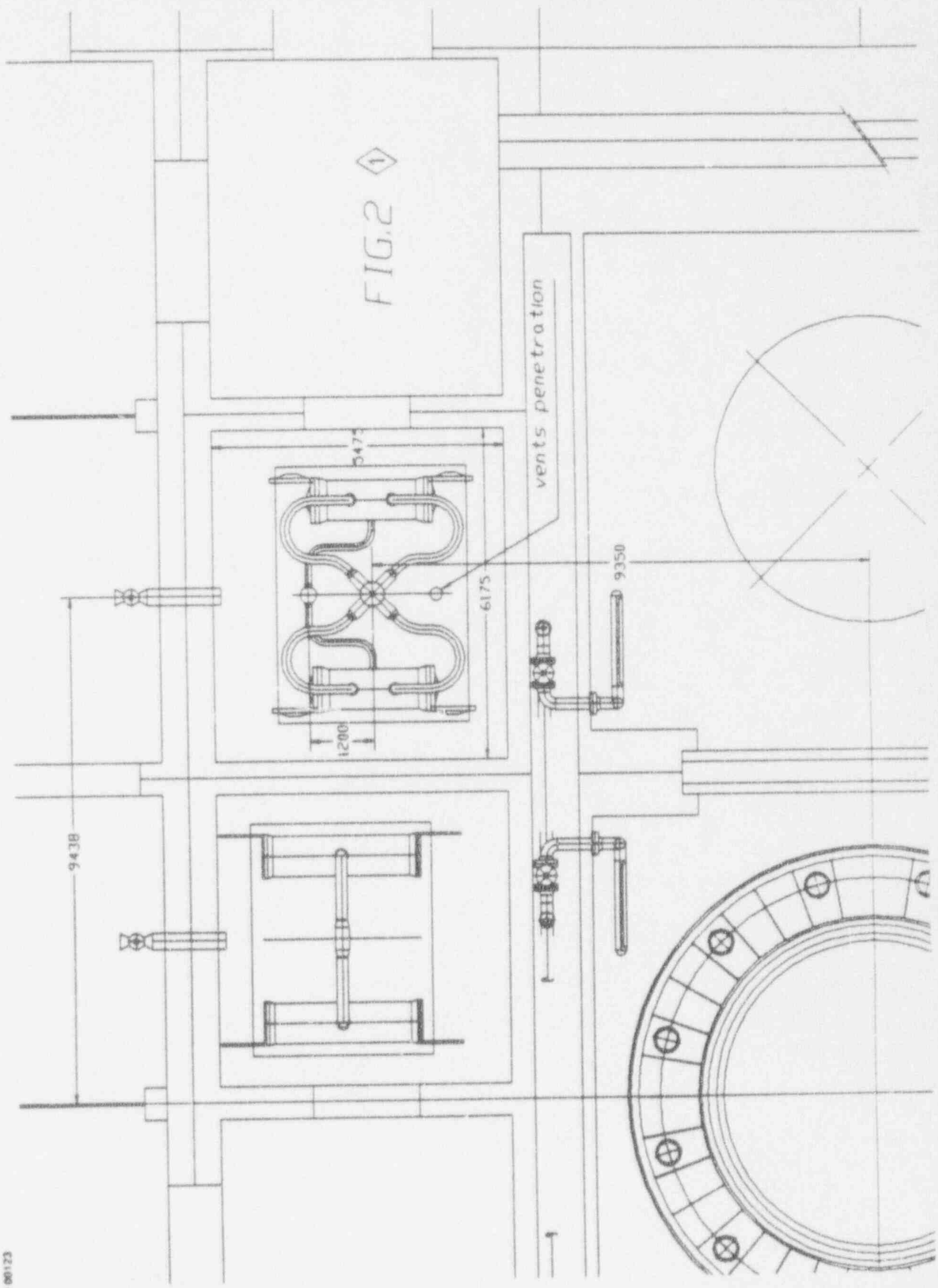


FIG.2
1
vents penetration
9350
6175
1200
9438

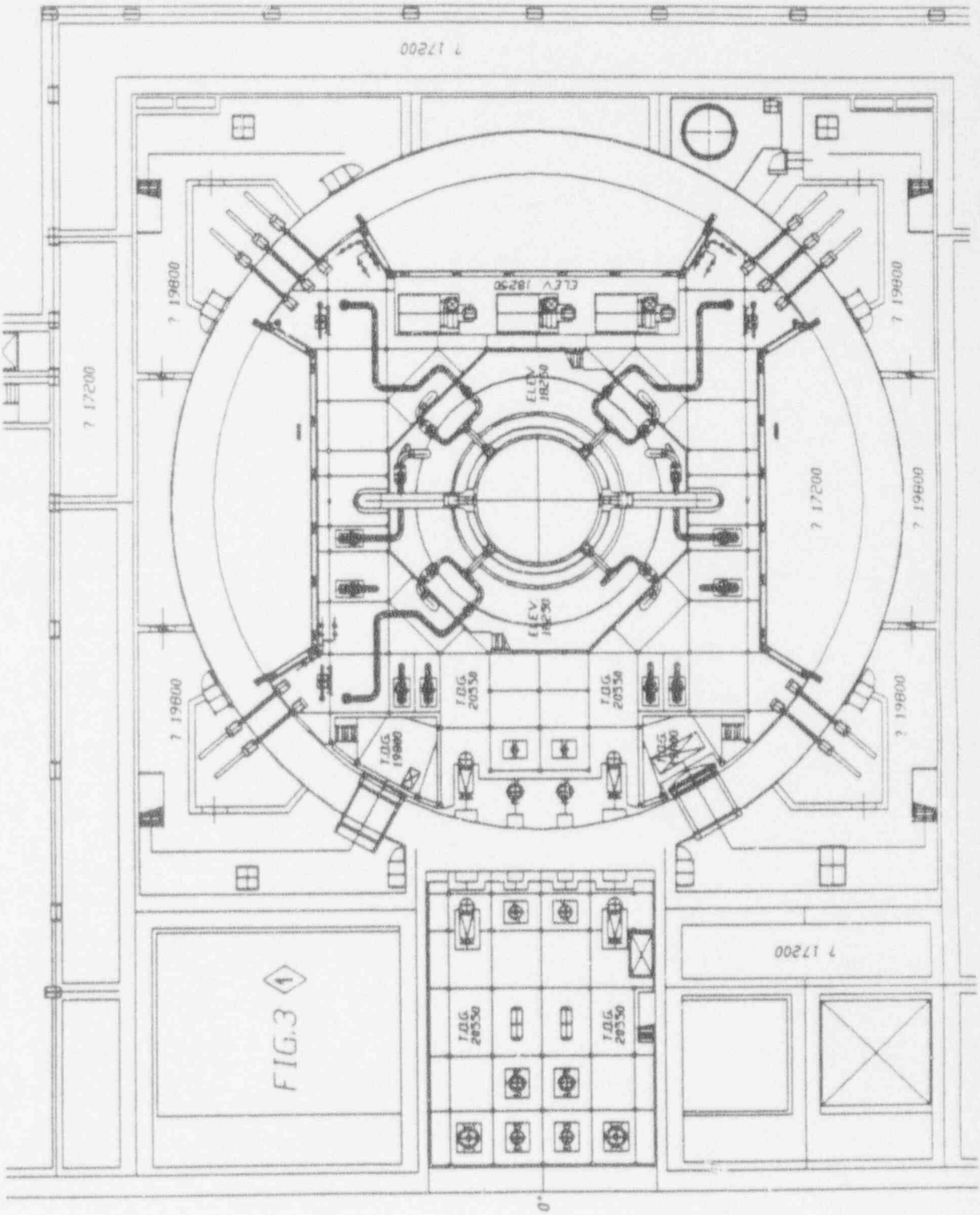


FIG.3
1
ELEV 18250
T.O.G. 20550
T.O.G. 19800
17200
19800
0°

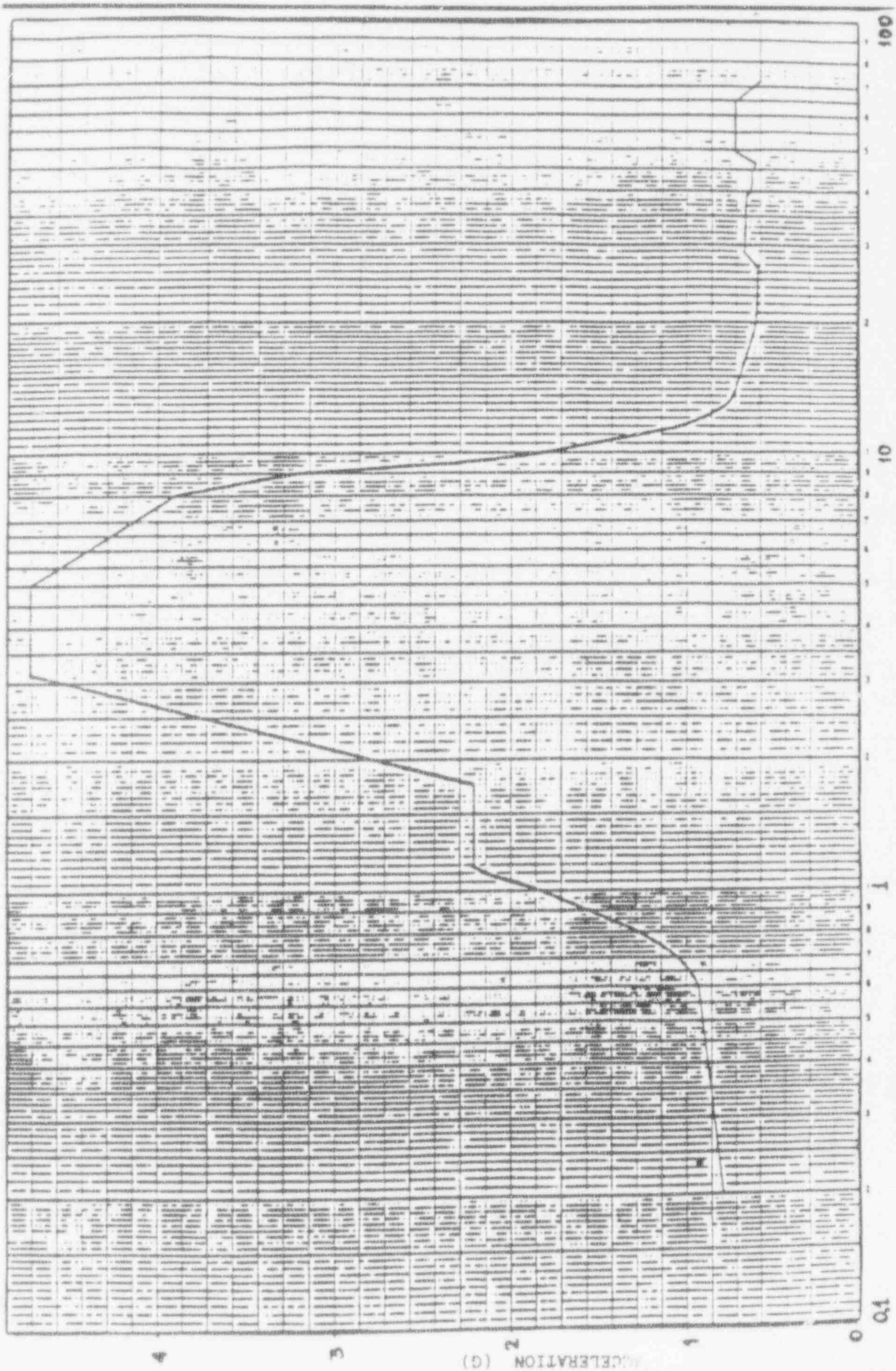


FIGURE 4

SERVICE LEVEL B (UPSET) DYNAMIC LOAD RESPONSE SPECTRA - HORIZONTAL

FIGURE 5

SERVICE LEVEL B (UPSET) DYNAMIC LOAD RESPONSE SPECTRA - VERTICAL

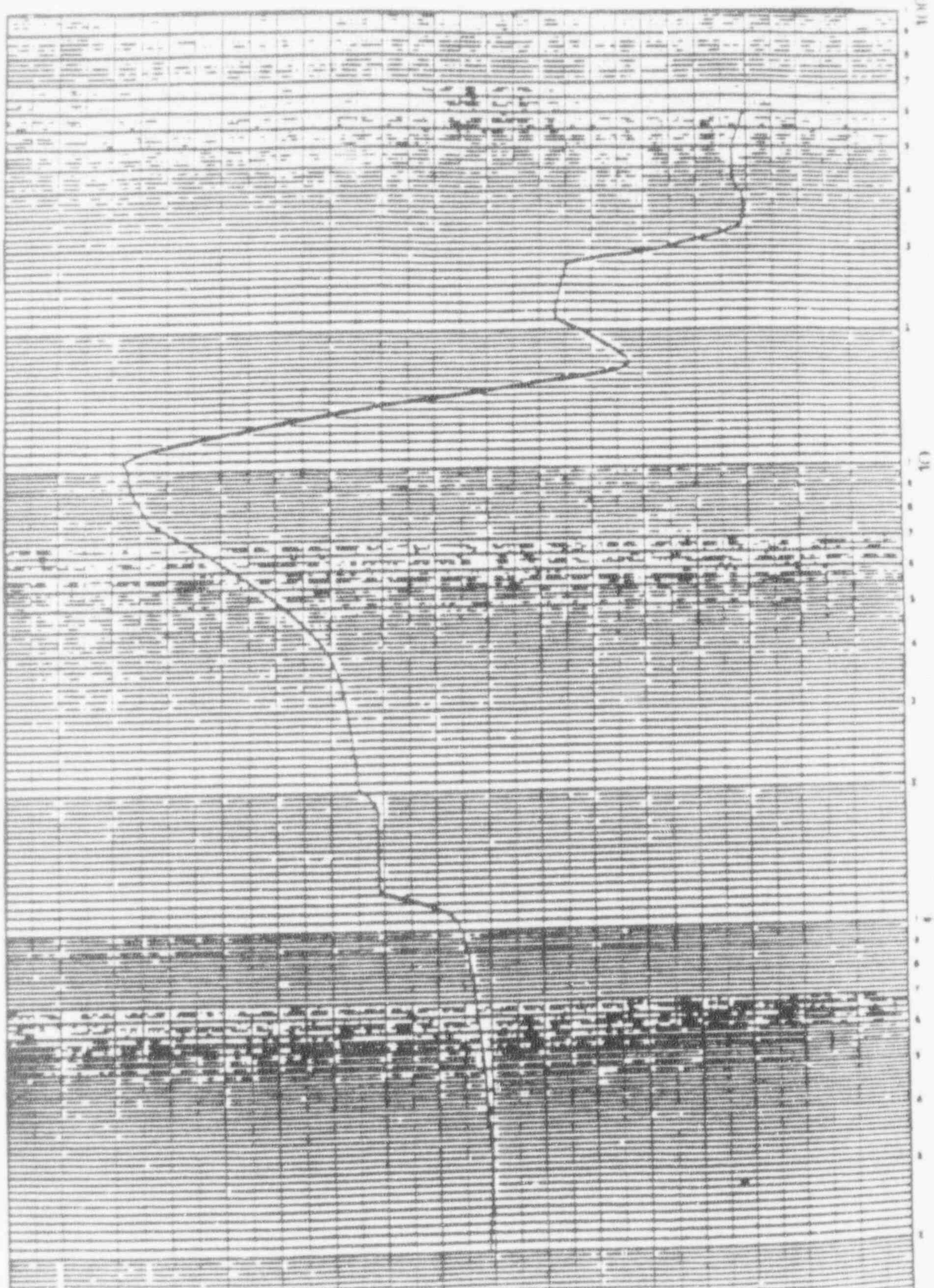


FIGURE 6

SERVICE LEVEL D (FAULTED) DYNAMIC LOADING - HORIZONTAL

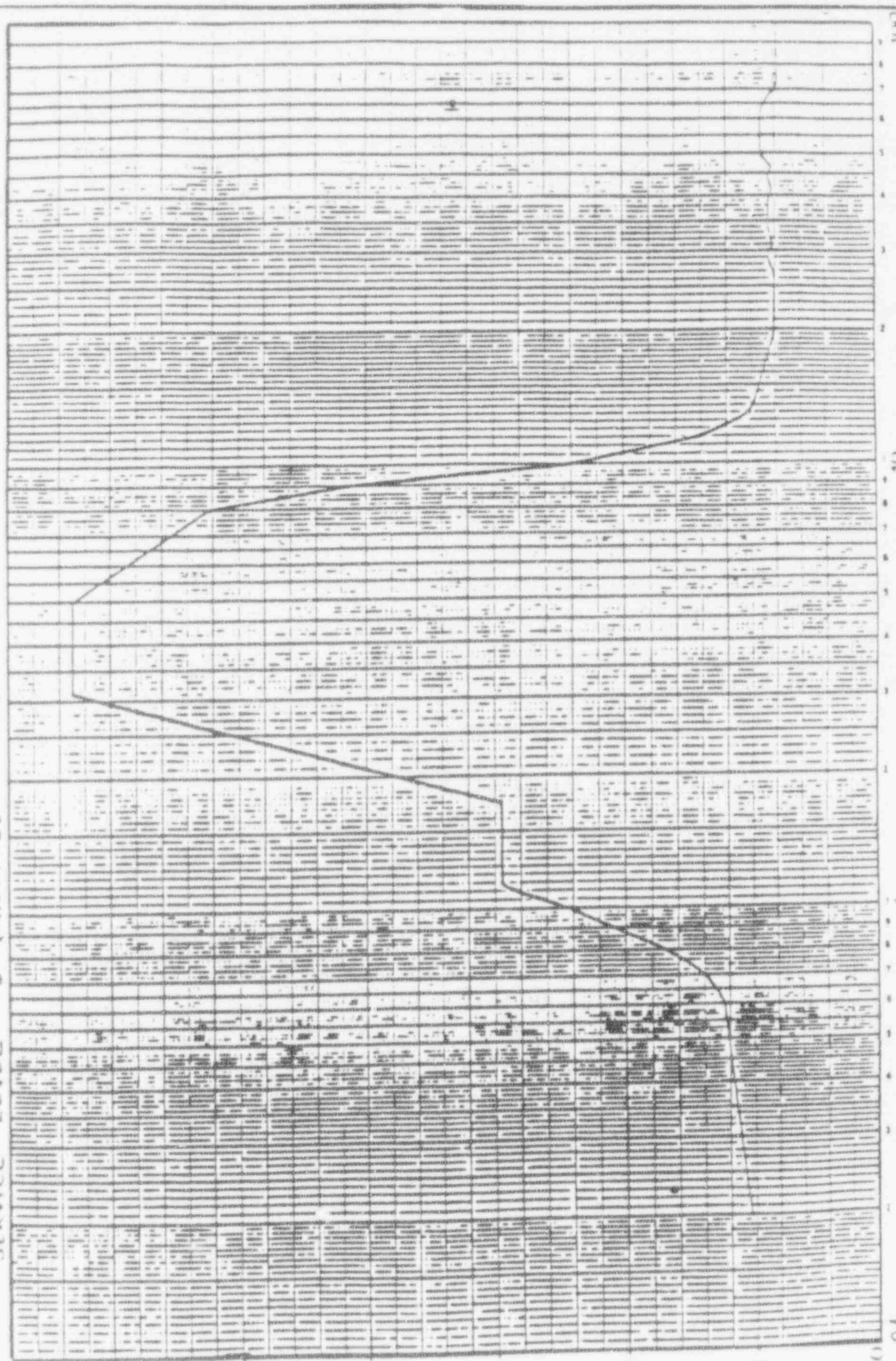
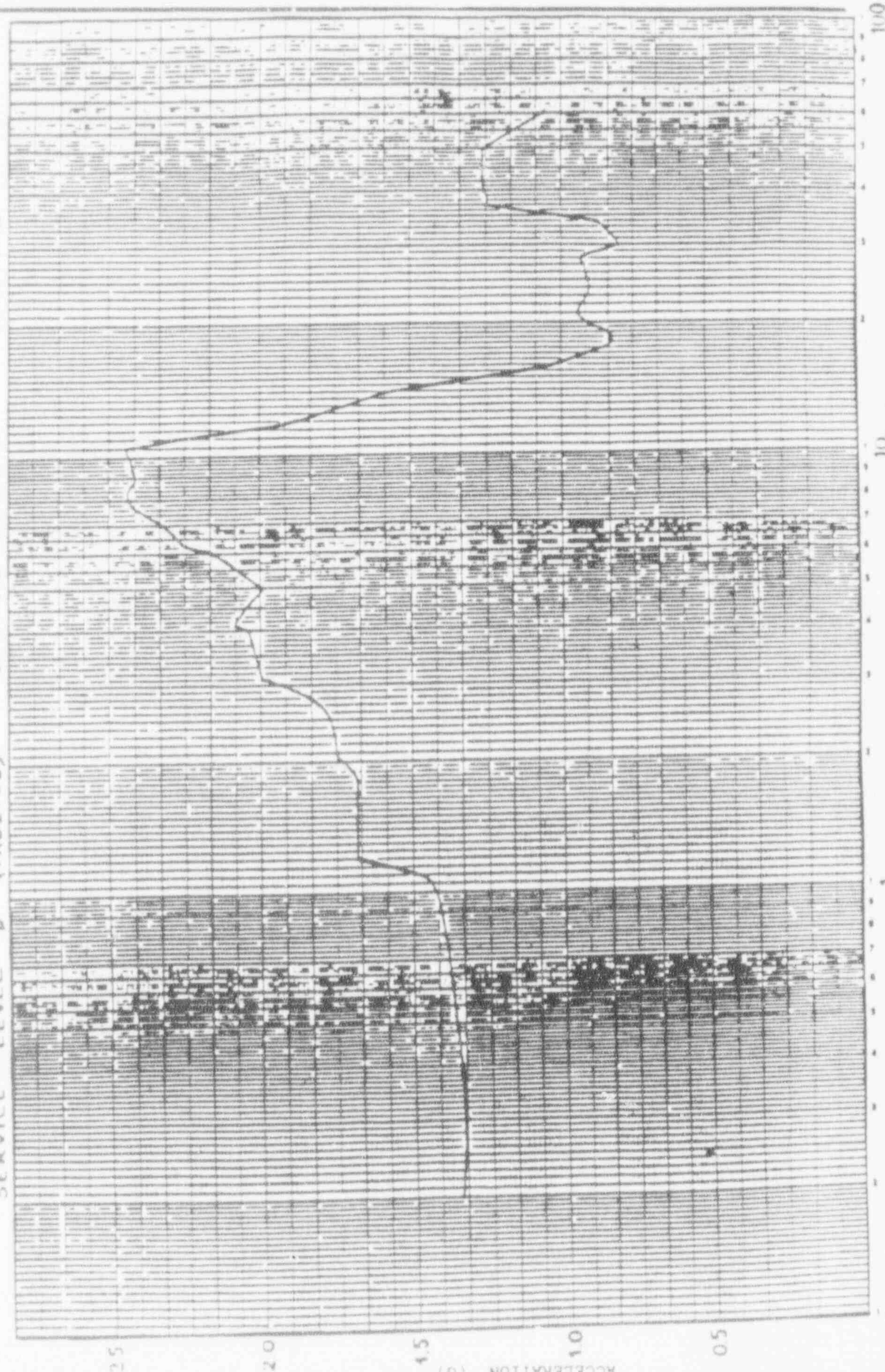


FIGURE 7

SERVICE LEVEL D (FAULTED) DYNAMIC LOADING - VERTICAL



APPENDIX 3

SBWR MATERIALS REQUIREMENTS

FOR ISOLATION CONDENSER

April 4, 1991

3.2 Wrought Austenitic Stainless Steels

3.2.1 Requirements of this section shall apply to all wrought austenitic stainless steel (such as Types 304 and 316) components exposed to water or steam environment at temperatures over 100°C, unless specified otherwise.

3.2.2 All materials shall be purchased to specifications prepared for SBWR service. If the components cannot be solution heat treated after welding or other heat treating operation, unless qualified, the carbon content of the material shall not exceed 0.020%.

3.2.3 Solution Heat Treatment of Austenitic Stainless Steels

a. In the final fabrication condition, wrought austenitic stainless steel parts shall be in the solution heat treated condition. The recommended solution heat treatment is heating to the temperature range of 1040° to 1150°C with a hold time designed to achieve full solutionizing while minimizing grain growth. Heat treatment shall immediately be followed by quenching or cooling below 205°C such that sensitization is avoided. For crevice applications Type 316L is preferred to Type 304L and for parts for service even at or below 100°C, solution heat treatment and water quenching must be done. Alternate method of quenching such as air quench, are allowed provided the process is qualified and controlled with sensitization tests required in this specification.

b. Localized heat treatment of austenitic stainless steel is not permitted unless qualified for a specific application.

3.2.4 Sensitization

3.2.4.1 Welding of wrought Type 300 series austenitic stainless steel is considered to cause sensitization. Sensitized wrought austenitic stainless steel shall not be used. Austenitic stainless is considered to be sensitized if it has been heated within the temperature range between 430°C and 980°C regardless of the subsequent cooling rate. When heated above 430°C, the austenitic stainless steel material shall be solution heat treated in accordance with Paragraph 3.2.3. Type 316(NG) or Type 316L and Type 304(NG) or Type 304L material with 0.020 percent maximum carbon is exempt from this requirement during welding provided it is in a solution heat treated condition prior to welding.

3.2.5 Austenitic Stainless Steel Pipe or Tubing. Wrought austenitic stainless steel pipe or tubing shall be Type 304(NG), Type 304L, Type 316(NG) and Type 316L to an applicable SBWR materials specification. For parts that cannot be solution heat treated after welding, only Type 304L or Type 304(NG) for non-creviced parts, or Type 316(NG) or Type 316L for creviced parts with 0.020 percent maximum carbon material shall be used. Other stainless steels qualified for SBWR service such as Type 347 Modified are also acceptable.

3.2.5.1 Cold bending or forming shall be controlled such that hardness in the final fabricated condition shall not exceed Rockwell B 90 for Type 304(NG) and Type 304L and Rockwell B 92 for Type 316(NG) and Type 316L. Hardness values

shall be reported on the Materials Test Report. Brinell hardness equivalent to Rockwell B may be used.

3.2.5.2 Induction Bending of Pipe. Induction bending of pipe shall be qualified based on the bend radius and the pipe diameter for components to be bent to bend radii of 5D and less. Each heat of material shall be qualified by bending a test piece and subjecting it to high sensitivity U.T. examination and destructive examination for microfissures.

3.2.6 Welding Materials for Austenitic Stainless Steel. Filler metals for welding austenitic stainless steels shall be selected to be compatible with the base metal(s) to be welded. Filler metal shall be procured in accordance with applicable ASME Code Requirements. Acceptable filler metal Types are 308L, 309L, 309MoL, 316L and 316LC.

3.2.6.1 Ferrite Control

3.2.6.1.1 For all stainless steel welding materials including consumable inserts for components which operate above 100°C the ferrite content shall be not less than 5% (or 5 FN) for each individual reading, and the average shall be not less than 8%. Maximum ferrite content shall not exceed 20%. Ferrite content shall be determined on undiluted weld deposits. Ferrite measurements shall be made in accordance with the magnetic measurement requirements described in ASME Section III, Paragraph NB2433.

3.2.7 Austenitic Stainless Steel Welds

3.2.7.1 Heat Input Controls. Welding heat input controls are required for all welds including repair welds, overlay/cladding welds, weld bead straightening, and joining carbon or low alloy steel to stainless steel. Austenitic stainless steel components solution heat treated after welding are exempt from these requirements.

a. For manual GTAW and SMAW, heat input shall be limited by weaving and welding technique controls. Non-weaving (stringer bead) welding techniques shall be used where possible. Weaving and technique shall be controlled to meet the equivalent of heat input limits of paragraph 3.2.7.1.b.

b. For automatic (or machine) welding and manual welding with processes other than GTAW or SMAW, welding heat input shall not exceed 44,000 joules/cm calculated according to the following formula:

$$\text{Heat Input} = \frac{\text{Voltage}^{(1)}\ (\text{Volts}) \times \text{Current}^{(2)}\ (\text{Amps}) \times 60}{\text{Travel Speed (cm per Minute)}}$$

NOTES:

(1) This heat input is based on the voltage at the arc. Voltage may, however, be measured at the welding power supply. If the heat input limit is exceeded when voltage is measured at the welding power supply, the voltage

may be reduced by an amount equal to the voltage drop between the power supply and the arc. This voltage drop shall be determined by direct measurement for each power supply, welding process, and cable combination.

(2) For pulsing current applications, the weighted average current, according to the formula below shall be used to calculate the heat input.

$$\text{Weighted Average Current} = \frac{(\text{High Pulse Current} \times \text{High Pulse Time}) + (\text{Low Pulse Current} \times \text{Low Pulse Time})}{\text{High Pulse Time} + \text{Low Pulse Time}}$$

3.2.7.2 The maximum interpass temperature shall be 180°C for all stainless steel welds. (See Appendix 10.)

3.2.7.3 Socket welds and seal welds shall use the GTAW process (with filler metal added) for at least the root layer(s). Protective gas back purging is not required.

3.2.8 Intergranular Attack (IGA) shall be controlled per the requirements of GE specification E50YP11 for all wrought austenitic stainless steel which during operation is wetted with water at temperatures above 100°C. IGA control shall be applied to raw material and subsequently after any heat treatment above 815°C and any pickling operations. Where a minimum depth of 0.8 mm of material will be removed from all wetted surfaces after the final heat treatment, no IGA control is required. Results are to be noted in the Materials Test Report.

3.2.9 All solution heat treated wrought material for service above 100°C shall be tested for sensitization per the requirements of GE specification E50YP20. As a minimum, one specimen representing each heat treat lot shall be tested for sensitization. The material tested shall be heat treated with the lot it represents. The Materials Test Report for the material shall note the results of these tests.

3.3.6 Reporting Ferrite in Welding Materials. The ferrite content and the method used for its determination shall be reported in the Material Test Report for austenitic stainless steel weld metal and castings.

3.4 Grinding Controls

3.4.1 These requirements shall apply to final fabricated surfaces to be exposed to reactor water. Abrasive grinding of stainless steel heat-affected zones shall be minimized to the extent possible. Care shall be taken to confine grinding to the weld metal only and limit grinding of the adjacent base metal to that required to meet the fabrication and examination requirements of the ASME Code, this specification, the equipment requirement specification, or support drawing. Grinding abrasives and wire brushes for stainless steel and nickel-chrome-iron alloy shall not have been used previously on materials other than stainless steel or nickel-chrome-iron alloy. For wrought austenitic stainless steel surface to be exposed to reactor water, if any grinding is done and not followed with solution heat treatment, the surface shall be polished to remove the grinding marks to obtain a final surface finish of 0.8 mm of finer.

3.5 Wrought Ni-Cr-Fe Alloy 600 and Weld Metal Alloys 82 and 182

3.5.1 This section describes the design and processing requirements for Ni-Cr-Fe alloys. The requirements are applicable to wetted components exposed to temperatures over 100°C.

3.5.1.1 High Stress Corrosion Cracking (SCC) resistance is obtained by using improved nickel base alloys as follows:

a. Base material for welded structure:

Alloy 600 with Niobium modified chemistry (1-4%)

b. Weld metal:

Alloy 82 or 182 with Niobium as follows:

Alloy 82: 2-3% Nb
Alloy 182: 2.5-4.5% Nb

3.5.2 Design Limitations for Wrought Alloy 600

3.5.2.1 Design limitations for wrought Alloy 600 for both solution annealed and the improved heat-treatment (885°C) are listed below. Requirements for Niobium modified Alloy 600 are also included.

3.5.2.2 Uncreviced Case. The Stress Rule Index (SRI) as defined in Paragraph 3.2.10 shall not exceed 1.0. Sustained stress is defined in Paragraph 1.6.e.2.

3.5.2.3 Creviced Case

a. The SRI value for unstabilized Alloy 600 shall not exceed 0.80. For Alloys of Nb modified chemistry SRI values of 1.0 is permitted (See Table 3).

b. Crevices in regular Alloy 600 components shall be eliminated by redesign, sealing, or repairing using a non flux welding process. If a crevice cannot be avoided, Niobium modified Alloy 600 may be used.

c. There shall be no heat treat oxide film on surfaces which form wetted crevices.

3.5.3 Design Limitations for Regions Containing Wrought Alloy 600 Heat Affected Zone and Weld Filler Metals With and Without Niobium Modification

3.5.3.1 Uncreviced Case

a. The SRI value shall not exceed 1.0. For all welded components including weld repairs all accessible surfaces in the final repair condition shall be liquid penetrant examined. Where the back side of the joint cannot be thus examined, the root and the second layer shall be radiographed. The

examination techniques and the acceptance criteria the ASME Code shall apply. The penetrameter thickness shall be based on root weld thickness

b. Welds which by design cannot be inspected to demonstrate acceptance by the standards of paragraph 3.5.3.1a. shall have an SRI value not to exceed 0.80.

3.5.3.2 Creviced Case. For alloys without the addition of Nb, components shall not have weld metal or weld heat affected zones in crevice areas. If a crevice cannot be avoided by design, Nb modified Ni-base alloys can be used. For Nb modified alloys 600, 82 and 182, SRI values shall not exceed 1.0.

3.5.3.3 For use of Nb modified Alloy 600, high N82 and high N182 alloys, the design limitations for the creviced case are the same as for the non-creviced case (See Table 3).

TABLE 3. STRESS RULES FOR ALLOYS 600, 82, AND 182

Alloy	Uncreviced		Creviced		Not Known -- (Cannot Examine the Back Side)
	Wrought	Welded	Wrought	Welded	
Alloy 600 for solution annealed, or solution annealed plus 850°C heat treated	SRI ≤ 1.0	SRI ≤ 1.0	SRI ≤ 0.80	Not Allowed	SRI ≤ 0.80
Alloy 600 Nb Modified	SRI ≤ 1.0	SRI ≤ 1.0	SRI ≤ 1.0	SRI ≤ 1.0	SRI ≤ 1.0
Regular Alloy 82	-	SRI ≤ 1.0	-	Not Allowed	SRI ≤ 0.80
Nb Modified Alloy 82	-	SRI ≤ 1.0	-	SRI ≤ 1.0	SRI ≤ 1.0
Nb Modified Alloy 182	-	SRI	-	SRI ≤ 1.0	SRI ≤ 1.0

3.5.4 The SRI calculation shall be performed for the most highly stressed component in an assembly. If acceptable (per Table 3), all other joints in the assembly may also be considered acceptable.

3.5.5 For any fired furnace heating of nickel-chrome-iron at temperatures above 650°C the sulfur content of the fuel and atmosphere shall be known. Where an oil fired furnace is used, each lot of oil, defined as one shipment from one source of supply shall be analyzed and shall be limited to 0.5 weight

percent sulfur, maximum. Where a gas fired furnace is used, the gas shall be analyzed at least once a month. The sulfur content of the gas shall be less than 10 grains per standard cubic meter of fuel gas. For gas furnaces where a full muffle furnace is not used, the burners shall be adjusted to yield an oxidizing flame. When furnace is used to carburize or when carbon monoxide (CO) is used as a reducing medium, the furnace shall be completely purged of all CO before heat treating nickel-chrome-iron. The above control on sulfur content need not apply if all surfaces have at least 1.6 mm removed after heat treatment.

3.5.6 Allowable welding materials are regular Alloy 82 and Nb modified Alloys 82 and 182, per the requirements of applicable ASME Code Section. All welding materials shall be Ni-Cr-Fe alloy per SFA-5.14 ERNi-Cr-3. If submerged arc welding process is used, the as-deposited chemistry shall comply with the requirement of SFA 5.14. For welding preheat and interpass temperature controls, see Appendix 10.

3.5.7 Processing Requirements

3.5.7.1 Heat Treatment Controls

3.5.7.1.1 Heat Treatment. Nb modified Alloy 600 is an acceptable material. The regular Alloy 600 is acceptable either as solution anneal (S.A.) or as S.A. plus 850°-885°C modified heat treated. The solution annealing is to be done at 1075° ± 25°C followed with water quench. the 850-885°C heat-treating may be followed with air cool.

3.5.7.2 Acid Cleaning Controls. After each pickling operation on Alloys 600/82/182, the treatment shall be followed by neutralizing and rinsing, or by removal of 0.75 mm minimum from all pickled surfaces by machining. No pickling is allowed after final machining. Alloy 600, purchased from the mill without special surface treatment requirements, is normally acid pickled, and surface removal is required as described above. Nitric acid cleaning ('Passivation' for free iron removal) is permitted, but no hydrofluoric acid or other reducing acids may be in the 'passivation' bath.

3.5.7.3 Basic (Caustic) Cleaning Controls. Caustic cleaning may be used for parts with no crevices.

3.5.7.4 Intergranular Attack (IGA) and Pitting Controls

3.5.7.4.1 Parts and raw materials shall be examined for intergranular attack unless a minimum of 0.75 mm of metal is removed from all as-received surfaces during fabrication.

3.5.7.4.2 Material subjected to any heat treatment or pickling operation at any time during fabrication shall be examined for IGA per Paragraph 3.5.7.4.3 unless a minimum of 0.75 mm of metal is subsequently removed from all surfaces. See Paragraph 3.5.7.2 for further pickling controls.

3.5.7.4.3 Metallographic examination at 200 to 400 X magnification shall be performed on unetched cross sections of specimens to measure the depth of IGA. Prior to mounting the metallographic sample shall be prepared so as to

preserve the edges of the cross section during metallographic polishing. IGA shall be measured on a cross section perpendicular to and from the surface where IGA occurs.

3.5.7.4.4 The depth of pitting shall be measured inward from the original surface, as described above, for IGA.

3.5.7.4.5 Completed parts or components shall not have IGA or pitting in excess of 0.025 mm deep.

3.6 Plain Carbon Steel Materials

3.6.1 Requirements of this section shall apply to all ASME Code Class I & II piping systems and components as well as to the balance of plant equipment.

3.6.2 All materials shall be purchased to ASME Code specifications. The materials shall be high quality, consistent with the design requirements.

3.6.3 All forms of materials (piping, plate, forging, casting, fitting) shall be intrinsically tough grades. The material must achieve charpy impact energy absorption tested per ASME Code, Section III and Section II SA specification. The Section III impact test requirements are specified in paragraph NB2300/NC2300.

3.6.4 To achieve the required quality, toughness, and other mechanical properties, the material must be manufactured to the quality requirements of the ASME Code specifications. Melting practice, chemistry control, impurity limits, and the heat treatment requirements of the applicable specification shall be met. Specific requirements in addition to the above are as follows:

a. The stock material shall be produced by a fine grain melting practice, and shall be silicon plus aluminum killed.

b. The ferritic and the austenitic grain size shall be 5 or finer on the average, as measured by the applicable JIS or equivalent.

c. In addition to the chemical composition per the applicable specification, sulfur and phosphorus shall be controlled not to exceed 0.030% each.

d. The material shall be heat treated to achieve uniform mechanical properties including charpy impact energy requirements of the ASME Code specifications for high toughness grades. All hot forming shall be followed by re-heat treatment. Specimens shall be taken and testing performed in a manner that demonstrates the actual properties of the material after hot forming and final heat treatment.

3.6.5 Fatigue crack initiation design rules are presented in Appendix 20, to be used as a design guide.

3.6.6 Carbon Steel Welds

3.6.6.1 For preheat and interpass temperature controls, see Appendix 10.

3.6.6.2 Welding Materials. Welding electrodes and bare rod materials shall be in compliance with the applicable JIS filler metal specifications. Welding materials for shielded metal arc welding of the pressure retaining parts shall be limited to the low hydrogen type.

3.6.7 Bolting. Bolts shall have a protective coating to prevent atmospheric corrosion in accordance with the approved material and procedure.

3.6.8 Sequence of Examination. (Pressure-Retaining Ferritic Steel) Acceptance radiographic, magnetic particle, liquid penetrant examination shall be performed following the final heat treatment for properties.

3.6.9 Method of Surface Examination. For completed components, the selection of either magnetic particle testing or liquid penetrant examination, or a combination of both, to be used to disclose surface defects in pressure retaining carbon and low alloy steel components, shall be established based on the specific application of the selected technique.

APPENDIX 10

PREHEAT AND INTERPASS TEMPERATURE CONTROLS

APPENDIX 10

10.1 PREHEAT AND INTERPASS TEMPERATURE CONTROLS

10.1.1 Preheat and interpass temperature for all welding including temporary attachments and plate edge repairs shall be in accordance with Table 10-1. Preheating techniques shall ensure that the full thickness (T) of the weld joint preparation and adjacent base material is at the specified temperature for the distance of 'T' or 150 mm whichever is least. 'T' is defined as the material thickness of the thickest material being joined. In no case shall the distance 'T' on the adjacent base material be less than 50 mm.

10.1.2 Maintenance of Preheat

10.1.2.1 Preheat shall be maintained until post weld heat treatment for low alloy steel materials except that preheat may be dropped to room temperature for the following cases:

a. Temporary Attachments and Plate Edge Repairs. Preheat shall be carefully controlled to ensure that the required size area has been heated. Preheat temperature shall be maintained during welding and for one hour after welding has been completed. If the welding procedure has been qualified for drop of preheat, then preheat may be dropped following the one hour hold.

b. Weld Overlay. For stainless steel or Ni-Cr-Fe weld overlay on low alloy steel head and shell courses made to fine grain practice, preheat may be dropped to room temperature after a post weld intermediate heat treat of 230°C to 290°C for eight hours if the overlay weld procedure is qualified for drop of preheat.

c. Arc-air Gouging. Preheat shall be maintained during gouging and for one hour afterwards. Preheat for other thermal cutting processes may be dropped following cutting.

10.1.2.2 Loss of preheat for any welding shall be reported with corrective action taken in each instance.

10.1.3 In case of welding to predeposited stainless or nickel-chrome-iron weld overlay (weld buildup or cladding) on carbon or low alloy steels requiring preheat, the following restriction shall apply:

a. Welds to weld overlay thicknesses 3 mm and over may not require preheat or post weld heat treatment if the specific procedure to be used has been qualified to show that the heat affected zone does not reach the base material. In those cases, all of the welding parameters affecting heat input shall be recorded in the procedure and no increase in the amount of the heat input above qualification values shall be used for production welds.

TABLE 10-1 PREHEAT AND INTERPASS TEMPERATURE REQUIREMENTS FOR WELDING AND THERMAL CUTTING (P-NUMBERS AS DEFINED IN THE ASME CODE, SECTION IX).

Thickness	Minimum Preheat Temperature	Heat Interpass Temperature
I. CARBON STEEL MATERIALS		
WELDS TO P1 MATERIALS TO BE LEFT IN THE AS WELDED CONDITION		
19 mm and Less	15°	260°C
Over 19 mm	100°C	260°C
WELDS TO P1 MATERIAL WHICH ARE LATER POST WELD HEAT TREATED		
25 mm and Less	15°c	260°C
Over 25 mm	100°C	260°C
THERMAL CUTTING OF P1 MATERIAL		
50 mm and Less	15°C	260°C
Over 50 mm	65°C	260°C
II. STAINLESS STEEL AND NICKEL-CHROME-IRON MATERIALS		
P8 AND P43		
P8, Stainless	None	180°C
P43, Ni-Cr-Fe		205°C

APPENDIX 20

FATIGUE CRACK IMITATION DESIGN RULES

FOR CARBON STEEL

APPENDIX 20 - FATIGUE CRACK INITIATION DESIGN RULES FOR CARBON STEEL

20.1 Scope. Fatigue design rule evaluation shall be conducted on all ASME Code carbon steel pipes and safe ends for which fatigue analysis is performed. The rules specifically apply to circumferential girth butt welds and to piping and safe ends exposed to reactor coolant at any purity and oxygen content at temperatures of 245°C or higher.

20.2 Applicability and Exemptions. The rules are exempted in certain cases. A flow chart shown in Figure 20-1 defines applicability rules. Applicability of these rules and the exemptions to their use are described in the following.

20.2.1 Elbows, tees, and valve bodies designed and analyzed per the stress index method of the ASME Code procedure are exempted from fatigue design rules analysis; these components already have large safety margins.

20.2.2 Transients have total cycle times of ten seconds or less and no tensile hold time are exempted from fatigue design rules analysis provided that the oxygen content of the water does not exceed 0.3 ppm.

20.2.3 All transients where the metal temperature does not exceed 175°C are exempted from fatigue design rules application.

20.2.4 All systems containing only air or gases, with the exception of steam/water mixtures, are exempted from fatigue design rules applications.

20.2.5 The design rules apply where tensile loading occurs and where conditions are not otherwise exempted by the rules of this paragraph. The stress range shall be defined by the maximum principal stress range for the non-exempted condition.

20.2.6 In situations where the calculated primary plus secondary stress intensity limits are exceeded, a plastic analysis may be performed. In such cases, the fatigue design rules are applicable only when the simplified elastic-plastic analysis per ASME Code is used.

20.3 Application of Fatigue Design Rules to Carbon Steel Piping and Safe Ends

20.3.1 The design rules consist of four factors that supplement the present Code fatigue design procedures, and are categorized as follows:

a. A new set or fatigue strength reduction factors for butt welds only (K_f)

b. A notch factor (K_n) based on the Neuber analysis to account for the effects of local yielding.

c. A mean stress correction factor (K_m).

d. An environmental correction factor (K_{en}).

FATIGUE DESIGN RULE APPLICABILITY FOR CARBON STEEL PIPING AND SAFE ENDS

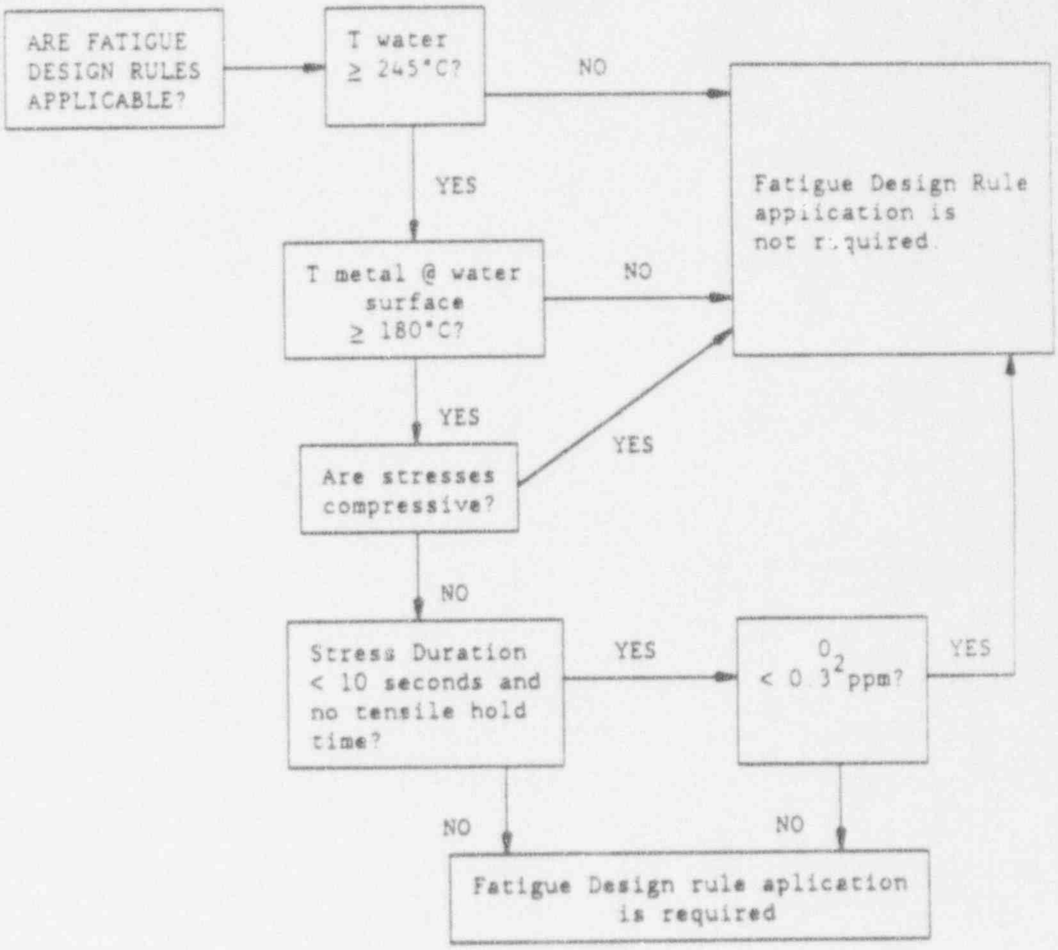


FIGURE 20-1 FLOW CHART TO DETERMINE WHERE THE FATIGUE DESIGN RULES APPLY

With the inclusion of these four factors for piping fatigue analysis, the peak stress amplitude is given by

$$S_a = 1/2 K_f K_n K_m K_{en} K_\epsilon S_n$$

Where S_n = range of alternating primary + secondary stresses calculated using conventional ASME Code.

and K_ϵ = plastic strain correction factor (based on simplified elastic-plastic analysis) specified in ASME Code.

20.3.2 The specific form of each of the four new factors follows:

A. Fatigue Strength Reduction Factor (K_f)

1. Piping Analysis

Fatigue evaluation of piping components is typically performed using the stress index values from the applicable code. However, for the fatigue stress rule evaluation, the stress indices specified in Table 3 shall be used. These values are the same as those specified in the ASME Code except that the K_2 stress index for girth butt welds is somewhat higher. In computing the other factors for piping, the K_2 value shall be used as the fatigue strength reduction factor K_f.

2. Notches

For notches in carbon steel components, the fatigue strength factor is determined as follows:

For Notches:

$$K_f = 1 + \sqrt{\frac{K_t - 1}{1 + \frac{\sigma'}{\sigma}}}$$

where:

K_t = theoretical stress concentration factor of the notch

σ' = material constant = 0.48 mm. for carbon steel

σ = notch root radius (mm)

B. Notch Factor (K_n)

The notch correction factor K_n depends on the ratio $S_n/3S_m$ where S_m is the ASME Code allowable design stress intensity value for carbon steel

For K_nm, there are cases to consider, as follows:

$$K_n = 1 \qquad \text{for } 0 \leq \frac{S_n}{3S_m} \leq \frac{1}{K_f}$$

$$K_n = 1 + \frac{(K_f^{(0.67)} - 1)\left(K_f\left(\frac{S_n}{3S_m}\right) - 1\right)}{(K_f - 1)} \qquad \text{for } \frac{1}{K_f} < \frac{S_n}{3S_m} < 1$$

$$K_n = K_f^{(0.67)} \qquad \text{for } \frac{S_n}{3S_m} > 1$$

C. <u>Mean Stress Correction Factor</u> (K_m)

The mean stress correction factor K_m depends on the type of loading being considered, as follows:

For fully reversed load cycling (tension-compression):

$$K_m = 1$$

For load-controlled cycling at any R-ratio:

$$K_m = \sqrt{\frac{2}{(1-R)}}$$

where:

R	=	S_{min}/S_{max} and
S_{min}	=	minimum net section stress for the stress cycling being analyzed, and
S_{max}	=	maximum net section stress for the stress cycle being analyzed

For deflection controlled cycling from an initial zero deflection to a maximum deflection and return:

$$K_m = \sqrt{2} \qquad \text{for } 0 \leq \frac{S_n}{3S_m} \leq \frac{1}{K_f}$$

$$K_m = 1.1 + \frac{0.32\,(2 - \frac{S_n}{3S_m})}{(2 - \frac{1}{K_f})} \quad \text{for } \frac{1}{K_f} < \frac{S_n}{3S_m} < 2$$

$$K_m = 1.1 \quad \text{for } \frac{S_n}{3S_m} \geq 2$$

D. Environmental Correction Factor (K_{en})

The environmental correction factor, K_{en} depends on the ratio $S_n/3S_m$ (1-R) as well as two empirical constants H and H', as follows:

$$K_{en} = 1 \quad \text{for } 0 \leq \frac{S_n}{3S_m\,(1-R)} < 0.35$$

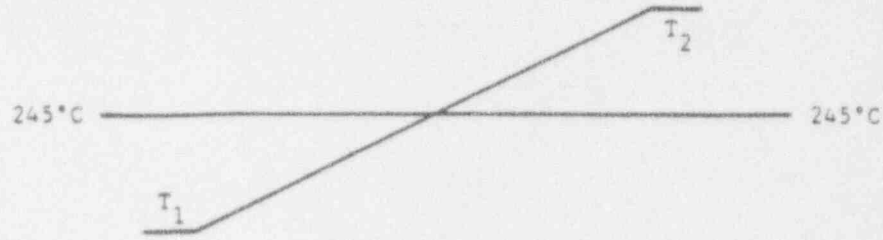
$$K_{en} = 1 + H\left(\frac{S_n}{3S_m\,(1-R)} - 0.35\right) \quad \text{for } 0.35 < \frac{S_n}{3S_m\,(1-R)} < 1$$

$$K_{en} = H' \quad \text{for } \frac{S_n}{3S_m\,(1-R)} \geq 1$$

The constants H and H' have the following values:

Constant	Air	Water Environment	
		0.1 to 0.3 ppm oxygen	> 0.3 ppm or Unknown
H	1.0	2.0	3.5
H'	1.0	2.3	3.3

The environmental correction factor, K_{en}, is applicable only when the water temperature equals or exceeds 245°C during the entire fatigue cycle. If a temperature transient occurs from a T_1 less than 245°C to a T_2 greater than 245°C, then the following applies:



For thermal transients where the temperature crosses the transient point as shown in the figure above, the following multiplier shall be used on the K_{en} factor only:

$$M = 1/K_{en} \text{ for } T2 < 245°C \quad ,$$

$$M = \left(\frac{245°C - T_1}{T_2 - T_1} \right) \frac{1}{K_{en}} + \frac{T_2 - 245}{T_2 - T_1} \text{ for } T_2 > 245°C$$

This equation assigns the environmental factor only to that part of the stress range which occurs during the time when T > 245°C.

20.3.3 If the fatigue usage factor requirements for a specific component cannot be achieved using the range of maximum stresses in the fatigue stress rule criterion, then reanalysis of the component using only the maximum principal tensile stresses (substituted for the maximum range of stresses) can be conducted.

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TABLE 3. STRESS INDICES FOR USE WITH EQUATIONS IN ASME CODE NB-3650

(Not Applicable for $D_o/t > 100$)

Piping Products and Joints	Internal Pressure			Moment Loading			Thermal Loading		
	B_1	C_1	K_1	B_2	C_2	K_2	B_3	C_3	K_3
Straight pipe remote from welds or other discontinuities	0.5	1.0	1.0	1.0	1.0	1.0	1.0	---	1.0
Girth butt weld between straight pipe or between pipe and butt welding components									
(a) flush	0.5	1.0	1.1	1.0	1.0	1.1	1.0	0.5	1.1
(b) as welded t > 3/16" (and δ/t < 0.1)	0.5	1.1	1.2	1.0	1.0	*	1.0	0.5	1.7
(c) as welded t < 3/16" (or δ/t > 0.1)	0.5	1.1	1.2	1.0	1.4	2.5	1.0	0.5	1.7
Girth fillet weld to socket weld fittings, slip on flanges, or socket welding flanges	0.75	2.0	3.0	1.5	2.1	2.0	1.8	1.0	3.0
Longitudinal butt welds in straight pipe									
(a) flush	0.5	1.0	1.1	1.0	1.0	1.1	1.0	---	1.1
(b) as welded t > 3/16"	0.5	1.1	1.2	1.0	1.2	1.3	1.0	---	1.2
(c) as welded t < 3/16"	0.5	1.4	2.5	1.0	1.2	1.3	1.0	---	1.2
Tapered transition joints per NB-4425 and Fig. NB-4233-1									
(a) flush or no girth weld closer than √rt	0.5		1.2	1.0		1.1	6	1.0	1.1
(b) as welded	0.5		1.2	1.0		*	6	1.0	1.7
Branch connections per NB-3643	1.0	2.0	1.7				1.8	1.0	1.7
Curved pipe or butt welding elbows per ANSI B16.9, ANSI B16.28 or MSS SP48	1.0	$\frac{2R-r}{2(R-r)}$	1.0			1.0**	1.0	0.5	1.0
Butt-welding tees per ANSI B16.9 or MSS SP48	1.0	1.5	4.0			1.0**	1.0	0.5	1.0
Butt-welding reducers per ANSI B16.9 or MSS SP48	1.0			1.0			1.0	0.5	1.0

* $K_2 = 1 + 2\,\delta/t$

where t = nominal pipe thickness

** The calculated peak stress shall not be less than that obtained if the butt weld equations