III
RULES FOR CONSTRUCTION
OF NUCLEAR FACILITY
COMPONENTS

Division 1 - Subsection NB
Class 1 Components

ASME Boiler and Pressure Vessel Committee
on Construction of Nuclear Facility Components
XIII, XIII-1300(i)] shall be provided at joints of Categories A and B between sections that differ in thickness by more than one-fourth the thickness of the thinner section. The transition section may be formed by any process that will provide a uniform taper. An ellipsoidal or hemispherical head which has a greater thickness than a cylinder of the same inside diameter may be machined to the outside diameter of the cylinder provided the remaining thickness is at least as great as that required for a shell of the same diameter. A uniform taper is not required for flanged hubs. The adequacy of the transition shall be evaluated by stress analysis. Stress intensity limitations are given in Section III Appendices, Mandatory Appendix XIII, Article XIII-3000. The requirements of this paragraph do not apply to flange hubs.

NB-3362 Bolted Flange Connections

It is recommended that the dimensional requirements of bolted flange connections to external piping conform to ASME B16.5, Steel Pipe Flanges and Flanged Fittings.

NB-3363 Access Openings

Access openings, where provided, shall consist of handhole or manhole openings having removable covers. These may be located on either the inside or outside of the shell or head openings and may be attached by studs or bolts in combination with gaskets or welded membrane seals or strength welds. Plugs using pipe threads are not permitted.

NB-3364 Attachments

Attachments used to transmit support loads shall meet the requirements of NB-3135.

Figure NB-3361-1
Category A and B Joints Between Sections of Unequal Thickness

(a) Taper may be inside or outside
(b) Heads thinner than shell
(c) Tangent line

GENERAL NOTE: Length of taper may include the width of the weld.

NB-3365 Supports

All vessels shall be so supported and the supporting members shall be arranged and attached to the vessel wall in such a way as to provide for the maximum imposed loadings. The stresses produced in the vessel by such loadings and by steady state and transient thermal conditions shall be subjected to the stress limits of this Subsection. Additional requirements are given in NCA-3240 and Subsection NF.

NB-3400 PUMP DESIGN

NB-3410 GENERAL REQUIREMENTS FOR CENTRIFUGAL PUMPS

NB-3411 Scope

NB-3411.1 Applicability. The rules of NB-3400 apply to (a) through (j) below.

(a) pump casings
(b) pump inlets and outlets
(c) pump covers
(d) clamping rings
(e) seal housing and seal glands
(f) related bolting
(g) pump internal heat exchanger piping
(h) pump auxiliary nozzle connections up to the face of the first flange or circumferential joint in welded connections, excluding the connecting weld
(i) piping identified with the pump and external to and forming part of the pressure-retaining boundary and supplied with the pump
(j) mounting feet or pedestal supports when integrally attached to the pump pressure-retaining boundary and supplied with the pump

NB-3411.2 Exemptions. The rules of NB-3400 do not apply to (a) through (c) below.

(a) pump shafts and impellers; shafts may be designed in accordance with Section III Appendices, Nonmandatory Appendix S
(b) nonstructural internals
(c) seal packages

NB-3412 Acceptability

NB-3412.1 Acceptability of Large Pumps. The requirements for the design acceptability of pumps having an inlet connection greater than NPS 4 (DN 100) diameter are given in (a), (b), and (c) below.

(a) The design shall be such that the requirements of NB-3100 and of NB-3200 or Section III Appendices, Mandatory Appendix II (provided the requirements of NB-3414 and the minimum wall thicknesses of NB-3430 are met) are satisfied.

(b) The rules of this subarticle shall be met. In cases of conflict between NB-3100 and NB-3200 or Section III Appendices, Mandatory Appendix II and NB-3400, the requirements of NB-3400 apply.
configuration of a Type F pump casing is a shell with a dished head attached at one end and a bolting flange at the other. The inlet enters through the dished head, and the outlet may be either tangent to the side or normal to the center line of the casing. Variations of these inlet and outlet locations are permitted.

(b) The design of Type F pumps shall be in accordance with this subarticle.

**NB-3442 Special Pump Types — Type J Pumps**

(a) Type J pumps are those that cannot logically be classified with any of the preceding types.

(b) Any design method which has been demonstrated to be satisfactory for the specified Design Conditions may be used.

**NB-3500 VALVE DESIGN**

**NB-3510 ACCEPTABILITY**

**NB-3511 General Requirements**

The requirements for design acceptability for valves shall be those given in this subarticle. These requirements for the acceptability of a valve design are not intended to ensure the functional adequacy of the valve. In all cases, pressure-temperature rating shall be as given in NB-3530 and, except for NB-3512.2(d) and in local regions (Section III Appendices, Mandatory Appendix XIII, XIII-3120), the wall thickness of the valve body shall not be less than that given by NB-3541. The requirements for prevention of nonductile fracture as set forth in NB-3210(d) shall be met. The requirements of NCA-3254(a) for specifying the location of valve boundary jurisdiction may be considered to have been met by employing the minimum limits of NB-1131, unless the Design Specification extends the boundary of jurisdiction beyond these minimum limits. The requirements of NCA-3254(b) for specifying the boundary conditions are not applicable to valve end connections.

CAUTION: Certain types of double-seated valves have the capability of trapping liquid in the body or bonnet cavity in the closed position. If such a cavity accumulates liquid and is in the closed position at a time when adjacent system piping is increasing in temperature, a substantial and uncontrolled increase in pressure in the body or bonnet cavity may result. Where such a condition is possible, it is the responsibility of the Owner or the Owner’s designee to provide, or require to be provided, protection against harmful overpressure in such valves.
NB-3512 Acceptability of Large Valves

Valve designs having an inlet piping connection larger than NPS 4 (DN 100) are acceptable when they satisfy either the standard design rules or one of the alternative design rules.

**NB-3512.1 Standard Design Rules.** The design shall be such that requirements of this subarticle are met. The requirements of NB-3530 through NB-3550 apply to valves of conventional shape having generally cylindrical or spherical bodies with a single neck of a diameter commensurate with that of the main body portion, such as having a neck inside diameter less than twice the main run inside diameter in the neck region.

**NB-3512.2 Alternative Design Rules.** A valve design may not satisfy all of the requirements of NB-3512.1. A design may be accepted provided it meets one of the alternatives listed in (a), (b), (c), or (d) below.

(a) When the valve design satisfies the rules of NB-3530 through NB-3546.2 with thermal stresses neglected, the rules of Section III Appendices, Mandatory Appendix XIII relative to accounting for thermal secondary stresses and fatigue analysis (Section III Appendices, Mandatory Appendix XIII, XIII-3410, XIII-3420, and XIII-3500) shall also be satisfied.

(b) When a valve is exempted from fatigue analysis by the rules of Section III Appendices, Mandatory Appendix XIII, XIII-3510, the design is acceptable, provided that the requirements of (1) or (2) below are met.

(1) The rules of NB-3530 through NB-3546 shall be met. The rules of Section III Appendices, Mandatory Appendix XIII may be substituted for those of NB-3545.2 for evaluating secondary stresses, and NB-3545.3 need not be considered.

(2) The rules of NB-3530 and NB-3541 shall be met. An experimental stress analysis is performed in accordance with Section III Appendices, Mandatory Appendix II, and the rules of Section III Appendices, Mandatory Appendix XIII with respect to primary and secondary stresses resulting from pressure and mechanical loads shall be met. Unless otherwise specified in the Design Specifications, the pipe reactions shall be taken as those loads which produce a stress [NB-3545.2(b)] of 0.5 times the yield strength of the piping in tension for the direct or axial load and a stress of 1.0 times the yield strength of the piping in bending and torsion. Thermal secondary stresses shall be accounted for by either the rules of Section III Appendices, Mandatory Appendix XIII or NB-3545.

(c) When a valve design satisfies the rules of NB-3530 and NB-3541, and when an experimental stress analysis has been performed upon a similar valve in accordance with Section III Appendices, Mandatory Appendix II, and an acceptable analytic method has been established, the results may be used in conjunction with the requirements of Section III Appendices, Mandatory Appendix XIII for pressure and mechanical loads to establish design acceptability. Accommodation of thermal secondary stresses and pipe reactions shall be as given in (b)(2). Requirements for fatigue analysis of either Section III Appendices, Mandatory Appendix XIII or NB-3550 shall be met.

(d) When permitted by the Design Specification, a weld end valve that does not meet all of the requirements of NB-3540 may be designed so that it meets the requirements of NB-3200 for all pressure-retaining parts and those parts defined by NB-3546.3(a), and shall also meet all of the following requirements.

(1) Pressure, thermal, and mechanical effects, such as those resulting from earthquake, maximum stem force, closure force, assembly forces, and others that may be defined in the Design Specification, shall be included in the design analysis. For Level A Service Limits, the pipe reaction effects are to be determined by considering that the maximum fiber stress of the body at the neck is equal to half of its yield stress, or its yield strength in torsion, or its run inside diameter in the neck region.

(2) In place of using the values of $S_m$ to satisfy the rules of Section III Appendices, Mandatory Appendix XIII, the allowable stress intensity values for ferritic valve body and bonnet materials shall be those allowable stress values given in Section II, Part D, Subpart 1, Table 1A. For materials in Section II, Part D, Subpart 1, Tables 2A and 2B, a reduced allowable stress intensity based on applying a factor of 0.67 to the yield strengths listed in Section II, Part D, Subpart 1, Table Y-1 shall be used.

(3) The adequacy of the stress analysis of the body and bonnet shall be verified by experimental stress analysis conducted in accordance with the requirements of Section III Appendices, Mandatory Appendix II, II-1100 through II-1400. Individual tests shall be made to verify the adequacy of the stress analysis of internal pressure effects and pipe reaction effects. Tests shall be made on at least one valve model of a given configuration, but a verified analytical procedure may then be applied to other valves of the same configuration, although they may be of different size or pressure rating. The geometrical differences shall be accounted for in the extrapolation stress analysis. The analytical procedure shall have verified capability of providing this extrapolation.

(4) A Design Report shall be prepared in sufficient detail to show that the valve satisfies all applicable requirements.
**NB-3553  Fatigue Usage**

The application of a valve conforming to **NB-3512.1** is acceptable for cyclic loading conditions provided its fatigue usage $I_t$ is not greater than 1.0 as evaluated in (a), (b), and (c) below.

(a) Consider fluid temperature changes not excluded by **NB-3552** to occur instantaneously. Provided that these changes occur in one direction and recovery is at temperature change rates not in excess of 100°F/hr (56°C/h), the fatigue usage factor may be found by:

$$I_t = \sum \frac{N_{ri}}{N_i}$$

where $N_{ri}$ is the required or estimated number of fluid temperature step changes $\Delta T_{fi}$ and $N_i$ is found from Section III Appendices, Mandatory Appendix I, Figures I-9.1 and I-9.2.

(b) If both heating and cooling effects are expected at change rates exceeding 100°F/hr (56°C/h), the number of cycles are to be associated by temperature ranges $\Delta T_i$. For example, assuming the following variations are specified:

- 20 variations: $\Delta T_1 = 250°F$ (140°C) heating
- 10 variations: $\Delta T_2 = 150°F$ (80°C) cooling
- 100 variations: $\Delta T_3 = 100°F$ (56°C) cooling

Lump the ranges of variation so as to produce the greatest effects as follows:

- 10 cycles $\Delta T_{f1} = 250 + 150 = 400°F$
  $$(140 + 80 = 220°C)$$
- 10 cycles $\Delta T_{f2} = 250 + 100 = 350°F$
  $$(140 + 56 = 196°C)$$
- 90 cycles $\Delta T_{f3} = 100°F$ (56°C)

(c) Pressure fluctuations not excluded by **NB-3552** are to be included in the cyclic load calculations. The full range of pressure fluctuation from the normal condition to the condition under consideration shall be represented by $\Delta p_i$ in **NB-3554**.

**NB-3554  Cyclic Stress Calculations**

A valve conforming to **NB-3512.1** shall be qualified by the procedure of (a) through (d) below.

(a) The following criterion shall be met by the greatest temperature range:

$$Q_d \left[ \frac{\Delta p_{f(\max)}}{p_2} \right] + G_0 C_2 C_4 \Delta T_{f(\max)} < 3S_m$$

where $\Delta T_{f(\max)}$ is the largest lumped temperature range obtained using the methods of **NB-3553(b)**, and $\Delta p_{f(\max)}$ is the largest range of pressure fluctuation associated with $\Delta T_{f(\max)}$.

(b) Calculate:

$$S_n(\max) = Q_d \left[ \frac{\Delta p_{f(\max)}}{p_2} \right] + G_0 C_2 C_4 \Delta T_{f(\max)}$$

Provided that $S_n(\max) \leq 3S_m$, calculate the fatigue stresses for each cyclic loading condition as follows:

$$S_i = \frac{4}{3} Q_d \left[ \frac{\Delta p_i}{p_2} \right] + G_0 (C_3 C_4 + C_5) \Delta T_i$$

Determine the allowable number of cycles $N_i$ for each loading condition by entering Section III Appendices, Mandatory Appendix I, Figures I-9.1 and I-9.2, and determine the fatigue usage by **NB-3553(a)**.

(c) If $S_n(\max)$ is greater than $3S_m$ but less than $3mS_m$, the value of $S_i/2$ to be used for entering the design fatigue curve is to be found by multiplying $S_i$ by $K_e$, where:

$$K_e = 1.0 + \left( \frac{1 - n}{n(m - 1)} \right) \left( \frac{S_n}{3S_m} - 1 \right)$$

and where the values of the material parameters $m$ and $n$ are as given in Section III Appendices, Mandatory Appendix XIII, Table XIII-3450-1.

(d) If $S_n(\max)$ is greater than $3mS_m$, use $K_e = 1/n$.

**NB-3560  DESIGN REPORTS**

**NB-3561  General Requirements**

The certified Design Reports listed in this paragraph meet the requirements of **NCA-3550** for the Design Report.

**NB-3562  Design Report for Valves Larger Than NPS 4 (DN 100)**

A Design Report shall be prepared in sufficient detail to show that the valve satisfies the requirements of **NB-3512**. For a valve designed in accordance with **NB-3512.1**, the Design Report shall show that the applicable requirements of **NB-3530, NB-3541** through **NB-3546.2**, and **NB-3550** have been met. It is not necessary to write a special Design Report based on specified Design Pressure and Design Temperature when they are within the pressure–temperature rating and when supplementary information or calculations are also provided, as necessary, to complete the report for a specific application, such as the thermal cyclic duty evaluation of **NB-3550**. A report submitted demonstrating a design for loadings more severe than the specified loadings is also acceptable.

**NB-3563  Design Report Requirements for NPS 4 and Smaller (≤ DN 100) Valves**

For valves whose inlet piping connection is nominally NPS 4 (DN 100) or smaller, the Design Report shall include details to show that the requirements of **NB-3513** have been met.
where the outlet flange is an extension of the bonnet, the bonnet design shall conform to all rules of body design. The body shall be designed in accordance with the rules of NB-3540 through NB-3550. The design adequacy of the inlet and outlet flanges shall be determined using the rules of NB-3658. Flanges shall conform to the applicable pressure–temperature ratings of NB-3531.1 and shall meet the interface dimensions of ASME B16.5.

**NB-3594.2 Bonnet (Yoke).** The bonnet (yoke) may be analyzed using classic bending and direct stress equations, with appropriate free body diagrams. The general primary membrane stress intensity and the general primary membrane plus primary bending stress intensity shall be determined and shall not exceed the stress limits of NB-3592.2.

**NB-3594.3 Nozzle.** The nozzle shall be analyzed in accordance with the applicable rules of NB-3540 and NB-3550, with a basic analytical model configuration as shown in Figure NB-3594.3-1. The sections of the nozzle where dimensions are limited by the flow capacity and the operational control requirements may be considered as simple cylindrical sections. The minimum wall thickness of these sections shall be determined in accordance with NB-3324.1. These requirements are not applicable to the transition region to the seat contacting area of the nozzle, defined by $L$ in Figure NB-3594.3-1, provided dimension $L$ is less than the nominal wall thickness $t_1$.

**NB-3594.4 Body-to-Bonnet Joint.** The body-to-bonnet joint shall be analyzed in accordance with NB-3546.1.

**NB-3594.5 Disk.** The valve disk shall satisfy the requirements of NB-3546.2.

**NB-3594.6 Spring Washer.** The average shear stress shall not exceed $0.65\sigma_m$. The primary bending stress intensity shall not exceed the stress limits of NB-3592.2.

**NB-3594.7 Spindle (Stem).** The general primary membrane stress intensity shall not exceed the stress limits of NB-3592.2.

**NB-3594.8 Adjusting Screw.** The adjusting screw shall be analyzed for thread shear stress in accordance with the method of ASME B1.1 and this stress shall not exceed $0.65\sigma_m$. The general primary membrane stress intensity of the adjusting screw shall not exceed the stress limits of NB-3592.2, based on the root diameter of the thread.

**NB-3594.9 Spring.** The valve spring shall be designed so that the full lift spring compression shall be no greater than 80% of the nominal solid deflection. The permanent set of the spring (defined as the difference between the free height and height measured a minimum of 10 min after the spring has been compressed solid three additional times after presetting at room temperature) shall not exceed 0.5% of the free height.

**NB-3595 Design Report**

**NB-3595.1 General Requirements.** A Design Report shall be prepared in sufficient detail to show that the valve satisfies the rules of this subsubarticle and data sheet NCA-3550.

**NB-3600 PIPING DESIGN**

**NB-3610 GENERAL REQUIREMENTS**

**NB-3611 Acceptability**

The requirements for acceptability of a piping system are given in the following subparagraphs.

**NB-3611.1 Stress Limits.** The design shall be such that the stresses will not exceed the limits described in NB-3630 except as provided in NB-3611.2.

**NB-3611.2 Acceptability When Stresses Exceed Stress Limits.** When the stresses as determined by the methods given in NB-3630 exceed the limits thereof, the design can be accepted, provided it meets the requirements of NB-3200.

**NB-3611.3 Conformance to NB-3600.** In cases of conflict between NB-3100 and NB-3600, the requirements of NB-3600 shall apply.

**NB-3611.4 Dimensional Standards.** For the applicable year of issue of all dimensional standards referred to in NB-3600, see Table NCA-7100-1.

**NB-3611.5 Prevention of Nonductile Fracture.** The requirements for prevention of nonductile fracture as set forth in NB-3210(d) shall be met.

**NB-3612 Pressure–Temperature Ratings**

**NB-3612.1 Standard Piping Products.**

(a) When standard piping products are used, the pressure ratings given as functions of temperature in the appropriate standards listed in Table NCA-7100-1 shall not be exceeded. In addition, the requirements of NB-3625 shall be met. When established pressure ratings of standard products do not extend to the upper temperature limits for the material, the ratings between those established and the upper temperature limit may be determined in accordance with NB-3649.

(b) When the adequacy of the pressure design of a standard product is established by burst tests, the manufacturer of the product shall maintain a record of burst tests conducted to ensure adequacy of product and shall certify. Such records shall be available to the purchaser.

**NB-3612.2 Piping Products Without Specific Ratings.** If piping products are used for which methods of construction are not covered by this Subsection, the manufacturer of the product shall use methods of construction that will be as safe as otherwise provided by the rules of this Subsection. When products are used for
limitations for Service Limit C specified in Article NB-3000 are not exceeded for each of the components in the protected system.

NB-7400  SET PRESSURES OF PRESSURE RELIEF DEVICES

NB-7410  SET PRESSURE LIMITATIONS FOR EXPECTED SYSTEM PRESSURE TRANSIENT CONDITIONS

The stamped set pressure of at least one of the pressure relief devices connected to the system shall not be greater than the Design Pressure of any component within the pressure-retaining boundary of the protected system. Additional pressure relief devices may have higher stamped set pressures, but in no case shall these set pressures be such that the total system pressure exceeds the system limitations specified in NB-7310.

NB-7420  SET PRESSURE LIMITATION FOR UNEXPECTED SYSTEM EXCESS PRESSURE TRANSIENT CONDITIONS

The establishment of the stamped set pressure shall take into account the requirements of NB-7320.

NB-7500  OPERATING AND DESIGN REQUIREMENTS FOR PRESSURE RELIEF VALVES

NB-7510  SAFETY, SAFETY RELIEF, AND RELIEF VALVES

NB-7511  General Requirements

NB-7511.1  Spring-Loaded Valves. Valves shall open automatically by direct action of the fluid pressure as a result of forces acting against a spring.

NB-7511.2  Balanced Valves.

(a) Balanced valves, whose operation is independent of back pressure, may be used if means are provided to verify the operability of the balancing device.

(b) Balanced safety valves for steam service shall additionally have a redundant back pressure balancing device.

NB-7511.3  Antisimmer Type Valves. Valves which are fitted with antisimmer devices that serve to raise the set pressure of the valve during normal operation of the system may be used, provided:

(a) the design is such that the valve opens automatically and discharges its certified capacity at 110% of the system design pressure in the event any item of the auxiliary loading device should fail;

(b) the operating signal and energy source provisions are such that the valve reverts to its normal set pressure in the event of any failure of signal or loss of energy source;

(c) the auxiliary loading force imposed on such valves does not raise the set pressure of the valve by more than 10%;

(d) the auxiliary loading force that augments the force exerted by the valve spring is automatically unloaded at a pressure not greater than the set pressure of the valve.

NB-7512  Safety Valve Operating Requirements

NB-7512.1  Antichattering and Lift Requirements.

Safety valves shall be constructed to operate without chattering and to attain rated lift at a pressure which does not exceed the set pressure by more than 3% or 2 psi (15 kPa), whichever is greater.

NB-7512.2  Set Pressure Tolerance.

(a) The set pressure tolerance plus or minus shall not exceed the following: 2 psi (15 kPa) for pressures up to and including 70 psi (480 kPa), 3% for pressures from 70 psi (480 kPa) to 300 psi (2 MPa), 10 psi (70 kPa) for pressures over 300 psi (2 MPa) to 1,000 psi (7 MPa), and 1% for pressures over 1,000 psi (7 MPa). The set pressure tolerance shall apply unless a greater tolerance is established as permissible in the Overpressure Protection Report (NB-7200) and in the safety valve Design Specification (NCA-3250).

(b) Conformance with the requirements of (a) shall be established for each production valve by test. Steam valves shall be tested on steam.

NB-7512.3  Blowdown.

Safety valves shall be adjusted to close after blowing down to a pressure not lower than 95% of the set pressure unless a different percentage is specified in the safety valve Design Specification (NCA-3250) and the basis for the setting is covered in the Overpressure Protection Report (NB-7200). The adjustment shall be determined by test or by proration from the Certificate Holder’s blowdown test data.

NB-7513  Safety Relief and Relief Valve Operating Requirements

Safety relief and relief valves shall be constructed to attain rated lift at a pressure that does not exceed the set pressure by more than 10% or 3 psi (20 kPa), whichever is greater.

NB-7513.1  Set Pressure Tolerance.

(a) The set pressure tolerance plus or minus from the set pressure of safety relief and relief valves shall not exceed 2 psi (15 kPa) for pressures up to and including 70 psi (480 kPa) and 3% for pressures over 70 psi (480 kPa) to 300 psi (2 MPa), 10 psi (70 kPa) for pressures over 300 psi (2 MPa) to 1,000 psi (7 MPa), and 1% for pressures over 1,000 psi (7 MPa). The set pressure tolerance shall apply unless a greater tolerance is established as permissible in the Overpressure Protection Report (NB-7200) and in the safety valve Design Specification (NCA-3250).

(b) Conformance with the requirements of (a) shall be established for each production valve by test. Steam valves shall be tested on steam, air or gas valves on air...
or gas, and liquid valves on liquid. Alternative fluids may be used as the test media if the requirements of NB-7550 have been met.

**NB-7513.2 Blowdown.** Safety relief and relief valves shall be adjusted to close after blowing down to a pressure not lower than that specified in the valve Design Specification (NCA-3250), and the basis for the setting shall be covered in the Overpressure Protection Report (NB-7200). The adjustment shall be determined by test or by proration from the Certificate Holder’s blowdown test data.

**NB-7514 Credited Relieving Capacity.**

The credited relieving capacity of safety, safety relief, and relief valves shall be based on the certified relieving capacity. In addition, the capacity can be prorated as in NB-7700.

**NB-7515 Sealing of Adjustments.**

Means shall be provided in the design of all valves for sealing all adjustments or access to adjustments that can be made without disassembly of the valve. For a pilot-operated pressure relief valve, an additional seal shall be provided to seal the pilot and main valve together. Seals shall be installed by the Certificate Holder at the time of initial adjustment. Seals shall be installed in a manner to prevent changing the adjustment or disassembly of the valve without breaking the seal. The seal shall serve as a means of identifying the Certificate Holder making the initial adjustment.

**NB-7520 PILOT-OPERATED PRESSURE RELIEF VALVES.**

**NB-7521 General Requirements.**

Pilot-operated pressure relief valves shall operate independently of any external energy source.

**NB-7522 Operating Requirements.**

**NB-7522.1 Actuation.** The pilot control device shall be actuated directly by the fluid pressure of the protected system.

**NB-7522.2 Response Time.** The Overpressure Protection Report (NB-7200) shall include the effects of divergence between opening (set) and closing (blowdown) pressures of the pilot valve and the pressures at which the main valve attains rated lift and closes. These divergences are caused by the inherent time delay (e.g., response time) between the operation of the pilot and the main valve, and the rate of the system pressure change. The limits for response time shall be specified in the valve Design Specification (NCA-3250).

**NB-7522.3 Main Valve Operation.** The main valve shall operate in direct response to the pilot control device. The valve shall be constructed to attain rated lift under stable conditions at pressures which do not exceed the set pressure by more than 3% or 2 psi (15 kPa), whichever is greater, for steam, and 10% or 3 psi (20 kPa), whichever is greater, for air, gas, or liquid service.

**NB-7522.4 Sensing Mechanism Integrity.** For other than spring loaded direct acting pilot control devices, means shall be provided to detect failure of the pressure-sensing element, such as bellows, when operation of the pilot control device is dependent upon the integrity of a pressure-sensing element.

**NB-7522.5 Set Pressure Tolerance.**

(a) The set pressure tolerance shall apply only to the pilot valve.

(b) The set pressure tolerance plus or minus shall not exceed the following: 2 psi (15 kPa) for pressures up to and including 70 psi (480 kPa), 3% for pressures over 70 psi (480 kPa) for liquid valves and 3% for pressures over 70 psi (480 kPa) up to and including 300 psi (2 MPa), 10 psi (70 kPa) for pressures over 300 psi (2 MPa) up to and including 1,000 psi (7 MPa), and 1% for pressures over 1,000 psi (7 MPa) for steam, air, and gas valves. The set pressure tolerance as stated shall apply unless a greater tolerance is established as permissible in the Overpressure Protection Report (NB-7200) and in the valve Design Specification (NCA-3250).

(c) Conformance with the requirements of (b) above shall be established for each production valve by test. Steam valves shall be tested on steam, air or gas valves on air or gas, and liquid valves on liquid. Alternative fluids may be used as the test media if the requirements of NB-7550 have been met.

**NB-7522.6 Blowdown.**

(a) The blowdown requirements shall only apply to the pilot valve.

(b) Pilot-operated valves shall be adjusted to close after blowing down to a pressure not lower than 95% of the set pressure for steam, unless a different percentage is specified in the valve Design Specification (NCA-3250) and the basis for the setting is covered in the Overpressure Protection Report (NB-7200). For all other fluids, pilot-operated valves shall be adjusted to close after blowing down to a pressure not lower than that specified in the valve Design Specification (NCA-3250), and the basis for the setting shall be covered in the Overpressure Protection Report (NB-7200).

(c) Conformance with the requirements of (b) above shall be established for each production valve by test or by proration from the Certificate Holder’s blowdown test data. Alternative fluids may be used as the test media if the requirements of NB-7550 have been met.

**NB-7523 Credited Relieving Capacity.**

The credited relieving capacity of pilot-operated pressure relief valves shall be based on the certified relieving capacity. In addition, the capacity may be prorated as permitted in NB-7700.
NB-7524 Sealing of Adjustments
The sealing requirements of NB-7515 shall apply.

NB-7530 POWER-ACTUATED PRESSURE RELIEF VALVES

NB-7531 General Requirements
Power-actuated pressure relief valves which depend upon an external energy source, such as electrical, pneumatic, or hydraulic systems, may be used provided the requirements of NB-7530 are met.

NB-7532 Operating Requirements

NB-7532.1 Actuation. Power-actuated pressure relief valves shall be actuated in response to signals from protected system fluid pressure-sensing devices.

NB-7532.2 Response Times.
(a) The opening response time is the time delay between the time the pressure sensor recognizes a predetermined system pressure and the time the power-actuated pressure relief valve attains its certified capacity.
(b) The closing response time is the time delay between the time the pressure sensor recognizes a predetermined system pressure and the time the power-actuated pressure relief valve is fully closed.
(c) The Overpressure Protection Report (NB-7200) shall include an analysis of the effect that opening and closing time responses have on the overpressure protection for the system.
(d) Each production valve shall be tested to verify that the stipulated response time in the Design Specification (NCA-3250) for the valve has been met.

NB-7532.3 Main Valve Operation. The main valve shall provide rated flow under stable system conditions at pressures which do not exceed the opening actuation pressure by more than 3% or 2 psi (15 kPa) whichever is greater for steam, and 10% or 3 psi (20 kPa) whichever is greater for air, or gas, or liquid service.

NB-7532.4 Sensors, Controls, and External Energy Sources.
(a) The sensors, controls, and external energy sources for valve operation shall have redundancy and independence at least equal to that required for the control and safety protection systems associated with the system being protected.
(b) The pressure sensors shall be capable of controlling the opening actuation pressure to within a tolerance of ±1% when the automatic control is in use.
(c) When automatic control is in use, the valve closing actuation pressure shall be controlled to a pressure not lower than 95% of the opening actuation pressure unless a different percentage is specified in the Design Specification (NCA-3250) and the basis for the closing actuation pressure is covered in the Overpressure Protection Report (NB-7200).

NB-7533 Certified Relieving Capacity
The power-actuated pressure relief valve certified relieving capacity and the proration of capacity shall be as determined by NB-7700.

NB-7534 Credited Relieving Capacity

NB-7534.1 Expected System Pressure Transient Conditions. For expected system pressure transient conditions, the relieving capacity with which these valves are credited shall be not more than:
(a) the certified relieving capacity of the smaller one when two valves are installed;
(b) one-half of total certified relieving capacity when three or more valves are installed.

NB-7534.2 Unexpected System Excess Pressure Transient Conditions. For unexpected system excess pressure transient conditions, the credited relieving capacity with which these valves are credited shall be not more than:
(a) the certified relieving capacity of the valve with the smaller certified capacity when two valves are installed;
(b) the certified relieving capacity of all except the valve with the largest certified capacity when three through ten valves are installed;
(c) the certified relieving capacity of all except two valves of the largest certified capacity when more than ten valves are installed.

NB-7535 Sealing of Adjustments
Means shall be provided for the sealing of all adjustments which affect valve operation. Seals shall be installed by the owner or his designee. Steam valves shall be tested on steam, gas or air valves on gas or air, and liquid valves on liquid. Alternative fluids may be used as the test media if the requirements of NB-7550 have been met.

NB-7540 SAFETY VALVES AND PILOT-OPERATED PRESSURE RELIEF VALVES WITH AUXILIARY ACTUATING DEVICES

NB-7541 General Requirements
Safety valves and pilot-operated pressure relief valves with auxiliary actuating devices that operate independently of the self-acting mechanism of the valve may be used provided the requirements of NB-7510 or NB-7520, as applicable, are met, except as modified below.
ENDNOTES

1 Any postweld heat treatment time that is anticipated to be applied to the material or item after it is completed shall
be specified in the Design Specification. The Certificate Holder shall include this time in the total time at temperature
specified to be applied to the test specimens.

2 In addition to providing a basis for acceptance standards for material, the test data are designated to be used as a
basis for establishing inservice operation and for use in fracture prevention evaluation [NB-3210(d) and Section III
Appendices, Nonmandatory Appendix G].

3 The requirements for impact testing of the heat-affected zone [NB-4335.2] may result in reduced test temperatures
or increased toughness requirements for the base material.

4 The methods given in the Appendix of SFA-5.9, Specification for Corrosion Resisting Chromium and
Chromium-Nickel Steel Welding Rods and Bare Electrodes, shall be used to establish a welding and sampling method
for the pad, groove, or other test weld to ensure that the weld deposit being sampled will be substantially free of
base metal dilution.

5 The volumetric examinations required by this paragraph need only be conducted from one surface.

6 The direction of ultrasonic examinations referenced is the direction of sound propagation.

7 Lowest service temperature is the minimum temperature of the fluid retained by the component or, alternatively,
the calculated volumetric average metal temperature expected during normal operation, whenever pressure within
the component exceeds 20% of the preoperational system hydrostatic test pressure.

8 Communicating chambers are defined as portions of the vessel which intersect the shell or heads of a vessel and form
an integral part of the pressure-retaining closure, e.g., sumps.

9 Side plates of a flat-sided vessel are defined as any of the flat plates forming an integral part of the pressure-retaining
enclosure.

10 The severity and frequency of specified fluid temperature variations may be such that the period of calculated pres­
sure integrity is less than plant design life. In such cases it is the responsibility of the Certificate Holder to state these
conditions in the Design Report (NB-3560).

11 Special features such as wear surfaces or seating surfaces may demand special alloys or proprietary treatments. The
absence of such materials from Section II, Part D, Subpart 1, Tables 2A and 2B shall not be construed to prohibit their
use and such materials do not require approval under Section III Appendices, Mandatory Appendix IV (NB-2121).

12 Normal service is defined as service, other than startup and shutdown, resulting in specified Service Loadings for
which Level A Limits, Level B Limits, or Testing Limits are designated.

13 t equals nominal wall thickness.

14 Welds that are exposed to corrosive action should have a resistance to corrosion that is not substantially less than
that of the cladding. The use of filler metal that will deposit weld metal which is similar to the composition of the
cladding material is recommended. If weld metal of different composition is used, it should have properties compa­
rible with the application.

15 An intermediate postweld heat treatment for this purpose is defined as a postweld heat treatment performed on a
weld within a temperature range not lower than the minimum holding temperature range subjected during the final postweld heat treatment.

16 A radiographic examination [NB-5111(a)] is required; a preservice examination [NB-5111(b)] may or may not be
required for compliance to the Design Specification [NCA-3211.19(b)].
III
RULES FOR CONSTRUCTION
OF NUCLEAR FACILITY
COMPONENTS

Division 1 - Subsection NC

Class 2 Components

ASME Boiler and Pressure Vessel Committee
on Construction of Nuclear Facility Components
NC-2126.2 Welded Finned Tubes. Welded finned tubes may be made from P-No. 1 and P-No. 8 tubular products (pipe or tubing) that conform to one of the specifications for tubes listed in Section II, Part D, Subpart 1, Table 1A, and to all of the special requirements of this Article which apply to that product form. Heat transfer fins shall be of the same P-Number as the tube and shall be attached by a machine welding process, such as the electric resistance welding or the high frequency resistance welding process. In addition, the following requirements shall apply:

(a) The heat transfer fins need not be certified material. The material for the heat transfer fins shall be identified and suitable for welding; however, Certified Material Test Reports are not required.

(b) The machine welding process used to weld the heat transfer fins to the tubular material shall be performed in accordance with a Welding Procedure Specification.

(c) The procedure qualification shall require that a minimum of 12 cross-sections through the weld zone shall be examined at 5× minimum magnification. There shall be no cracks in the base material or weld; and the weld penetration shall be limited to 20% of the nominal tube wall thickness.

(d) For P-No. 1 material, the weld that attaches the fins to the tubing shall be heat treated after welding to a minimum temperature of 1,000°F (540°C).

(e) The fin is not considered to provide any support to the tube under pressure loading.

NC-2128 Bolting Material

(a) Material for bolts and studs shall conform to the requirements of one of the specifications listed in Section II, Part D, Subpart 1, Table 3. Material for nuts shall conform to SA-194 or to the requirements of one of the specifications for nuts or bolting listed in Section II, Part D, Subpart 1, Table 3. Refer to Section II, Part D, Subpart 1, Table 4 for bolting material for vessels designed to the requirements of NC-3200.

(b) The use of washers is optional. When used, they shall be made of wrought material with mechanical properties compatible with the nuts with which they are to be employed.

NC-2130 CERTIFICATION OF MATERIAL

All materials used in the construction of components shall be certified as required in NCA-3862 and NCA-3861. Certified Material Test Reports are required for pressure-retaining material except as provided by NCA-3861. A Certificate of Compliance may be provided in lieu of a Certified Material Test Report for all other material. Copies of all Certified Material Test Reports and Certificates of Compliance applicable to material used in a component shall be furnished with the material.

NC-2140 WELDING MATERIALS

For the requirements governing the materials to be used for welding, see NC-2400.

NC-2150 MATERIAL IDENTIFICATION

The identification of pressure-retaining material shall meet the requirements of NCA-4256. Material for small items shall be controlled during manufacture and installation of the component so that they are identifiable as acceptable material at all times. Welding and brazing materials shall be controlled during the repair of material and the manufacture and installation so that they are identifiable as acceptable until the material is actually consumed in the process (NC-4122).

NC-2160 DETERIORATION OF MATERIAL IN SERVICE

Consideration of deterioration of material caused by service is generally in Section NC-3211. It is the responsibility of the Owner to select material suitable for the conditions stated in the Design Specifications (NCA-3250), with specific attention being given to the effects of service conditions upon the properties of the material.

NC-2170 HEAT TREATMENT TO ENHANCE IMPACT PROPERTIES

Carbon steels, low alloy steels, and high alloy chromium (Series 4XX) steels may be heat treated by quenching and tempering to enhance their impact properties. Postweld heat treatment of the component at a temperature of not less than 1,100°F (595°C) may be considered to be the tempering phase of the heat treatment.

NC-2180 PROCEDURES FOR HEAT TREATMENT OF MATERIAL

When heat treating temperature or time is required by the material specification and the rules of this Subsection, the heat treating shall be performed in temperature-surveyed and temperature-calibrated furnaces or the heat treating shall be controlled by measurement of material temperature by thermocouples in contact with the material or attached to blocks in contact with the material or by calibrated pyrometric instruments. Heat treating shall be performed under furnace loading conditions such that the heat treatment is in accordance with the material specification and the rules of this Subsection.

NC-2190 NON-PRESSURE-RETAINING MATERIAL

(a) Material in the component support load path and not performing a pressure-retaining function (see NC-1130) welded to pressure-retaining material shall meet the requirements of Article NF-2000.
NC-3120 SPECIAL CONSIDERATIONS

NC-3121 Corrosion

Materials subject to thinning by corrosion, erosion, mechanical abrasion, or other environmental effects shall have provision made in the Design Specifications for these effects by indicating the increase in the thickness of the base metal over that determined by the design equations (NC-2160). Other suitable methods of protection may be used. Material added or included for these purposes need not be of the same thickness for all areas of the component if different rates of attack are expected for the various areas.

NC-3122 Cladding

The rules of this paragraph apply to the design of clad components constructed of material permitted in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3.

NC-3122.1 Stresses. Except as permitted by NC-3214, no structural strength shall be attributed to the cladding.

NC-3122.2 Design Dimensions. The dimensions given in (a) and (b) below shall be used in the design of the component:

(a) for components subjected to internal pressure, the inside diameter shall be taken at the nominal inner face of the cladding;
(b) for components subjected to external pressure, the outside diameter shall be taken at the outer face of the base metal.

NC-3123 Welds Between Dissimilar Metals

In satisfying the requirements of this subarticle, caution shall be exercised in construction involving dissimilar metals having different chemical compositions, mechanical properties, and coefficients of thermal expansion in order to avoid difficulties in service.

NC-3124 Ductile Behavior Evaluation

The use of material below the temperature established by the methods of NC-2331(a) may be justified by methods equivalent to those contained in Section III Appendices, Nonmandatory Appendix G.

NC-3125 Configuration

Accessibility to permit the examinations required by the Edition and Addenda of Section XI as specified in the Design Specification for the component shall be provided in the design of the component.

NC-3130 GENERAL DESIGN RULES

NC-3131 General Requirements

The design shall be such that the rules of this Article are satisfied for all configurations and loadings, using the maximum allowable stress values $S$ of Section II, Part D, Subpart 1, Tables 1A, 1B, and 3 in the various equations and including the use of the standard products listed in Table NCA-7100-1. Use of the maximum allowable stress values of Section II, Part D, Subpart 1, Tables 1A, 1B, and 3 does not apply to vessels designed to the rules of NC-3200.

NC-3131.1 Design Reports.

(a) The N Certificate Holder is required to provide a Design Report as part of the responsibility for achieving structural integrity of the component. The Design Report shall be certified when required by NCA-3550.

(b) The Certificate Holder for construction of a vessel conforming to the design requirements of NC-3200 shall provide a Design Report conforming to the requirements of NC-3211 and NC-3223.2.

NC-3131.2 Proof Test to Establish Maximum Design Pressure. When the configuration of a component is such that the stresses resulting from internal or external pressure cannot be determined with adequate accuracy by the rules of this Article, the maximum Design Pressure shall be determined by proof testing in accordance with the rules of NC-6900 except for piping as otherwise provided in this Article. This procedure does not apply to vessels designed to the requirements of NC-3200.

NC-3132 Dimensional Standards for Standard Products

Dimensions of standard products shall comply with the standards and specifications listed in Table NCA-7100-1 when the standard or specification is referenced in the specific design subarticle. However, compliance with these standards does not replace or eliminate the requirements for stress analysis when called for by the design subarticle for a specific component.

NC-3133 Components Under External Pressure

NC-3133.1 General. Rules are given in this paragraph for determining the thickness under external pressure loading in spherical shells, cylindrical shells with or without stiffening rings, and tubular products consisting of pipes, tubes, and fittings. Charts for determining the stresses in shells and hemispherical heads are given in Section II, Part D, Subpart 3. For vessels designed to NC-3200, see NC-3240.

NC-3133.2 Nomenclature. The symbols used in this paragraph are defined as follows:

$$A = \text{factor determined from Section II, Part D, Subpart 3, Figure G and used to enter the applicable material chart in Section II, Part D, Subpart 3. For the case of cylinders having } D_o/T \text{ values less than 10, see NC-3133.3(b).}$$
Step 3. From the intersection obtained in Step 2, move horizontally to the right and read the value of factor \( B \). This is the maximum allowable compressive stress for the values of \( T \) and \( R \) used in Step 1.

Step 4. For values of \( A \) falling to the left of the applicable material/temperature line, the value of \( B \) shall be calculated using the following equation:

\[
B = \frac{AE}{2}
\]

Step 5. Compare the value of \( B \) determined in Step 3 or 4 with the computed longitudinal compressive stress in the cylindrical shell or tube, using the selected values of \( T \) and \( R \). If the value of \( B \) is smaller than the computed compressive stress, a greater value of \( T \) must be selected and the design procedure repeated until a value of \( B \) is obtained which is greater than the compressive stress computed for the loading on the cylindrical shell or tube.

NC-3133.7 Conical Heads. The required thickness of a conical head under external pressure shall not be less than that determined by the rules of (a), (b), and (c) below.

(a) When one-half of the included apex angle of the cone is equal to or less than 22 1/2 deg, the thickness of the cone shall be the same as the required thickness of a cylindrical shell, the length of which equals the axial length of the cone or the axial distance center to center of stiffening rings, if used, and the outside diameter of which is equal to the outside diameter at the large end of the cone or section between stiffening rings.

(b) When one-half of the included apex angle of the cone is greater than 22 1/2 deg and not more than 60 deg, the thickness of the cone shall be the same as the required thickness of a cylindrical shell, the outside diameter of which equals the largest inside diameter of the cone measured perpendicularly to the cone axis, and the length of which equals an axial length that is the lesser of either the distance center to center of stiffening rings, if used, or the largest inside diameter of the section of the cone considered.

(c) When one-half of the included apex angle of the cone is greater than 60 deg, the thickness of the cone shall be the same as the required thickness for a flat head under external pressure, the diameter of which equals the largest inside diameter of the cone (NC-3325).

NC-3133.8 Tubes and Pipes When Used as Tubes. The required wall thickness for tubes and pipes under external pressure shall be determined in accordance with Figure NC-3133.8-1.

NC-3135 Attachments

(a) Except as in (c) and (d) below, attachments and connecting welds within the jurisdictional boundary of the component as defined in NC-1130 shall meet the stress limits of the component.

(b) The design of the component shall include consideration of the interaction effects and loads transmitted through the attachment to and from the pressure-retaining portion of the component. For vessels designed to NC-3200, thermal stresses, stress concentrations, and restraint of the pressure-retaining portion of the component shall be considered.

(c) Beyond 2\( t \) from the pressure-retaining portion of the component, where \( t \) is the nominal thickness of the pressure-retaining material, the appropriate design rules of Article NF-3000 may be used as a substitute for the design rules of Article NC-3000 for portions of attachments which are in the component support load path.

(d) Nonstructural attachments shall meet the requirements of NC-4435.

NC-3200 ALTERNATIVE DESIGN RULES FOR VESSELS

NC-3210 GENERAL REQUIREMENTS

NC-3211 Basis for Use

NC-3211.1 Scope.

(a) This subarticle contains design rules for vessels which may be used as an alternative to the design rules in NC-3300. When these requirements are met for design, the stress intensity values of Section II, Part D, Subpart 1, Tables 2A, 2B, and 4 may be used.

(b) These requirements provide specific design rules for some commonly used vessel shapes under pressure loadings and, within specified limits, rules for treatment of other loadings. Simplified rules are also included for the approximate evaluation of design cyclic service life. Rules are not given which cover all details of design.

(c) When complete rules are not provided or when the vessel designer chooses, a complete stress analysis of the vessel or vessel region shall be performed considering all the loadings of NC-3212 and the Design Specifications. This analysis shall be done in accordance with Section III Appendices, Mandatory Appendix XIII for all applicable stress categories. Alternatively, an experimental stress analysis shall be performed in accordance with Section III Appendices, Mandatory Appendix II.

(d) When these alternative design rules are used, the special requirements of NC-4260, NC-5250, NC-6221, and NC-6222 shall be met.

(e) A Design Report shall be prepared by the Certificate Holder showing compliance with this subarticle. This Design Report shall meet the requirements of NCA-3550 for a Design Report (Section III Appendices, Nonmandatory Appendix C).

NC-3211.2 Requirements for Acceptability.

(a) The design shall be such that the NC-3100 and this subarticle are satisfied. In cases of conflict, the requirements of this subarticle shall govern.

(b) The design shall be such that stress intensities do not exceed the limits given in NC-3216.
wall. All stud bolted attachments require a detailed fatigue analysis in accordance with the requirements of Section III Appendices, Mandatory Appendix XIII unless the conditions of NC-3219 are met. Attachments shall conform reasonably to the curvature of the shell to which they are to be attached. The fabrication requirements of NC-4267 and the examination requirements of NC-5250 shall be met.

**NC-3264.2 Attachment Materials.** Materials welded directly to pressure parts shall meet the requirements of NC-2190.

**NC-3264.3 Design of Attachments.** The effects of attachments, including external and internal piping connections, shall be taken into account in the design. Attachments shall meet the requirements of NC-3135.

**NC-3264.4 Design of Supports.**

(a) All vessels shall be so supported and the supporting members so arranged and attached to the vessel as to provide for the maximum imposed loadings. Wind and earthquake loads need not be assumed to occur simultaneously.

(b) All supports should be designed to prevent excessive localized stresses due to temperature changes in the vessel or deformations produced by the internal pressure.

(c) Horizontal vessels supported by saddles shall provide bearing extending over at least one-third of the shell circumference.

(d) Additional requirements for the design of supports are given in NCA-3240 and Subsection NF.

**NC-3264.5 Types of Attachment Welds.** Welds attaching non-pressure parts or stiffeners to pressure parts shall meet the requirements of NC-4267.

**NC-3264.6 Stress Values for Weld Material.** Attachment weld strength shall be based on the nominal weld area and the design stress intensity values in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4 and stress criteria in NC-3200 for the weaker of the two materials joined, or, where weaker weld metal is permitted, the design stress intensity values of the weld metal multiplied by the following reduction factors: 0.5 for fillet welds NC-3264.5; 0.75 for partial penetration groove or partial penetration groove plus fillet welds NC-3264.5; 1.0 for complete weld penetration. The nominal weld area for fillet welds is the throat area; for groove welds, the depth of penetration times the length of weld; and for groove welds with fillet welds, the combined throat and depth of penetration, exclusive of reinforcement, times the length of weld.

(a) Attachment Welds — Evaluation of Need for Fatigue Analysis. In applying Condition AP or BP of NC-3219.3, fillet welds and partial penetration welds are considered non-integral attachments, except that the following welds need not be considered:

(1) welds for minor attachments

(2) welds for supports which may be considered integral as covered by Conditions A and B of NC-3219.2

---

### Table NC-3266-1

<table>
<thead>
<tr>
<th>Size of Pipe Connection, NPS (DN)</th>
<th>Threads Engaged</th>
<th>Min. Plate Thickness Required, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ (15)</td>
<td>6</td>
<td>0.43 (11)</td>
</tr>
<tr>
<td>¼ (20)</td>
<td>6</td>
<td>0.43 (11)</td>
</tr>
<tr>
<td>1 (25)</td>
<td>6</td>
<td>0.61 (16)</td>
</tr>
<tr>
<td>1 ¼ (32)</td>
<td>6</td>
<td>0.61 (16)</td>
</tr>
<tr>
<td>1 ½ (40)</td>
<td>6</td>
<td>0.61 (16)</td>
</tr>
<tr>
<td>2 (50)</td>
<td>8</td>
<td>0.70 (18)</td>
</tr>
</tbody>
</table>
NC-3300 VESSEL DESIGN

NC-3310 GENERAL REQUIREMENTS

Class 2 vessel requirements as stipulated in the Design Specifications (NC-3250) shall conform to the design requirements of this Article.

NC-3320 DESIGN CONSIDERATIONS

NC-3321 Stress Limits for Design and Service Loadings

Stress limits for Design and Service Loadings are specified in Table NC-3321-1. The symbols used in Table NC-3321-1 are defined as follows:

\[ S = \text{allowable stress value given in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3.} \]
\[ \sigma_b = \text{bending stress. This stress is equal to the linear varying portion of the stress across the solid section under consideration. It excludes discontinuities and concentrations and is produced only by pressure and other mechanical loads.} \]
\[ \sigma_L = \text{local membrane stress. This stress is the same as } \sigma_m, \text{ except that it includes the effect of discontinuities.} \]
\[ \sigma_m = \text{general membrane stress. This stress is equal to the average stress across the solid section under consideration. It excludes discontinuities and concentrations and is produced only by pressure and other mechanical loads.} \]

Typical examples of locations for which \( \sigma_b, \sigma_L, \text{ and } \sigma_m \) are applicable are shown in Table NC-3321-2.

### Table NC-3321-1

<table>
<thead>
<tr>
<th>Service Limit</th>
<th>Stress Limits [Note (1)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design and Level A</td>
<td>( \sigma_m \leq 1.0S )</td>
</tr>
<tr>
<td></td>
<td>( (\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.5S )</td>
</tr>
<tr>
<td>Level B</td>
<td>( \sigma_m \leq 1.10S )</td>
</tr>
<tr>
<td></td>
<td>( (\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.65S )</td>
</tr>
<tr>
<td>Level C</td>
<td>( \sigma_m \leq 1.5S )</td>
</tr>
<tr>
<td></td>
<td>( (\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.8S )</td>
</tr>
<tr>
<td>Level D</td>
<td>( \sigma_m \leq 2.0S )</td>
</tr>
<tr>
<td></td>
<td>( (\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 2.4S )</td>
</tr>
</tbody>
</table>

**GENERAL NOTE:** See NC-3321 for definitions of symbols.

**NOTE:** (1) These limits do not take into account either local or general buckling that might occur in thin-wall vessels.

NC-3322 Special Considerations

The provisions of NC-3120 apply.

NC-3323 General Design Rules

The provisions of NC-3130 apply except as modified by the rules of this subarticle. In case of conflict, this subarticle governs the design of vessels.

NC-3324 Vessels Under Internal Pressure

**NC-3324.1 General Requirements.** Equations are given for determining the minimum thicknesses under internal pressure loading in cylindrical and spherical shells and ellipsoidal, torispherical, toriconical, conical, and hemispherical heads. Provision shall be made for any of the other loadings listed in NC-3111 when such loadings are specified.

**NC-3324.2 Nomenclature.** The symbols used in this paragraph and Figure NC-3324.2-1 are defined as follows:

\[ D = \text{inside diameter of the head skirt; inside length of the major axis of an ellipsoidal head; or inside diameter of a conical head at the point under consideration, measured perpendicular to the longitudinal axis} \]
\[ D_o = \text{outside diameter of the head skirt; outside length of the major axis of an ellipsoidal head; or outside diameter of a conical head at the point under consideration, measured perpendicular to the longitudinal axis} \]
\[ D_1 = \text{inside diameter of the conical portion of a toriconical head at its point of tangency to the knuckle, measured perpendicular to the axis of the cone} \]
\[ D/2h = \text{ratio of the major to the minor axis of ellipsoidal heads, which equals the inside diameter of the skirt of the head divided by twice the inside height of the head and is used in Table NC-3324.2-1} \]
\[ h = \text{one-half of the length of the minor axis of the ellipsoidal head or the inside depth of the ellipsoidal head measured from the tangent line, head bend line} \]
\[ K = \text{a factor in the equations for ellipsoidal heads depending on the head proportion, } D/2h \text{ (Table NC-3324.2-1)} \]
\[ L = \text{inside spherical or crown radius for torispherical and hemispherical heads} \]
\[ L = K_1 D \text{ for ellipsoidal heads in which } K_1 \text{ is obtained from Table NC-3332.2-1} \]
\[ L_o = \text{outside spherical or crown radius} \]
\[ P = \text{Design Pressure} \]
\[ R = \text{inside radius of the shell course under consideration before corrosion allowance is added} \]
\[ r = \text{inside knuckle radius} \]
\[ R_o = \text{outside radius of the shell course under consideration} \]
III Appendices, Nonmandatory Appendix A using the appropriate equations for the casing shape or by methods permitted in Section III Appendices, Mandatory Appendix XIII.

Pumps with an "A" dimension greater than 20 in. (500 mm) or nozzles larger than NPS 4 (DN 100) discharge are permitted. Design of these larger pumps must be performed in accordance with Section III Appendices, Mandatory Appendix II, Experimental Stress Analysis, or Section III Appendices, Mandatory Appendix XIII, Design Based on Stress Analysis. If the design is qualified by analysis, the analysis shall be certified in accordance with NCA-3551.1.

**NC-3441.2 Design of Type B Pumps.** Type B pumps are those having horizontally split casings with double suction as illustrated in Figure NC-3441.2-1. Any design method that has been demonstrated to be satisfactory for the specified design conditions may be used.

**NC-3441.3 Design of Type C Pumps.** Type C pumps are those having double volutes and radially split casings with a single suction as illustrated in Figures NC-3441.3-1 and NC-3441.3-2. The splitter is considered a structural part of the casing. Casing design shall be in accordance with the requirements of this subarticle and with those given in (a) through (e) below.

(a) **Casing Wall Thickness.** Except where specifically indicated in these rules, no portion of the casing wall shall be thinner than the value of \( t \) determined as follows:

\[
 t = \frac{(0.5PA)}{S}
\]

where

- \( A = \) scroll dimension inside casing as shown in Figure NC-3441.3-2, in. (mm)
- \( P = \) Design Pressure, psig (MPa gage)
To determine the case stresses, establish the load $H_D$, the tensile stress $\sigma_{tx}'$, and the bending stress $\sigma_{b}'$ for Section $X$ and for Section $(Y + Z)$

$$\sigma_{tx}'_{comb} = \frac{H_{Dx} + H_{D(Y + Z)}}{\sigma_{tx}' + \sigma_{b}'(Y + Z)}$$

$$\sigma_{b}'_{comb} = \frac{H_{Dx} + H_{D(Y + Z)}}{\sigma_{b}' + \sigma_{b}'(Y + Z)}$$

The allowable limit for $\sigma_{tx}'_{comb}$ is $S_c$. The total stress is $\sigma_{tx}'_{comb} + \sigma_{b}'_{comb}$. The allowable limit for total stress is $1.5S_c$.

(-a) The above procedure will generally show some bolt stresses in excess of the indicated allowable values. Under these circumstances it is permissible to average bolt stresses between adjacent bolts. Such averaged stresses shall not exceed the specified allowables.

NC-3441.8 Design of Type H Pumps. Type H pumps are those having axially split, barrel-type casings (Figures NC-3441.8-1 and NC-3441.8-2) and radially split covers. The axially split casing shall be designed in accordance with the rules of NC-3441.7 for Type G pumps. The radially split cover shall be designed in accordance with the rules of NC-3437.

NC-3441.9 Design of Type K Pumps. Type K pumps are vertical pumps of one or more stages having a radially split casing as illustrated in Figures NC-3441.9-1 and NC-3441.9-2. The basic configuration is a casing consisting of a barrel and a head joined by bolted flanges. There is an inner assembly consisting of internal chambers of the head, one or more bowls, column sections, and a suction bell, all joined by flanges and arranged so that the external surfaces of these parts are subjected to inlet pressure. These pumps may be furnished with or without column(s) and with or without lateral restraints between the inner assembly and outer casing.

(a) Casing. The barrel and head of the casing shall be designed in accordance with the requirements of NC-3400 and with those given in (1) through (3) below.

(1) Barrel. The Design Pressure for the barrel shall be the pump inlet pressure or as otherwise stated in the Design Specification (NCA-3250), but in no case shall it be less than the maximum pressure at the pump inlet under any Service Condition. The static head shall be included in the selection of the Design Pressure.

(2) Head

(-a) The external walls of the head, which form the pressure boundary, shall be designed for the pressures specified in (-b) and (-c) below. The Design Pressure for the internal chambers shall be as specified under the inner assembly rules.

(-b) The Design Pressure for the portions of the head that form the pressure boundary between the outlet pressure and the atmosphere shall be the outlet pressure or as otherwise stated in the Design Specification, but in no case shall it be less than the maximum pressure at the pump outlet under any Service Condition.

(-c) The Design Pressure for the portions of the head that form the pressure-containing boundary between the inlet pressure and the atmosphere shall be the inlet pressure or as otherwise stated in the Design Specification, but in no case shall it be less than the maximum pressure at the pump inlet under any Service Condition.
(d) The minimum distance, X, between the bottom of the hole and the nozzle opening shall be greater than or equal to the greater of the minimum, nozzle, wall thickness or 50% of the hole diameter as shown [Figure NC-3441.10-1, sketch (c)].

NC-3442 Special Pump Types
(19) NC-3442.1 Design of Type J Pumps (Centrifugal).
(a) Type J pumps are those that cannot logically be classified with any of the preceding types of centrifugal pumps.
(b) It is not planned to establish rules for Type J pumps. Any design method that has been demonstrated to be satisfactory for the specified Design Conditions may be used.

NC-3442.2 Design of Reciprocating Pumps. See NC-3450.

NC-3450 DESIGN OF CLASS 2 RECIPROCATING PUMPS

NC-3451 Scope
(a) These rules cover the strength and pressure integrity of the structural parts of the liquid end [Figure NC-3451(a)-1], whose failure would violate the pressure boundary. Such parts include
(1) liquid cylinder and valve chambers
(2) valve covers
(3) liquid cylinder heads
(4) stuffing boxes
(5) packing glands
(6) manifolds
(7) piping and nozzles normally identified with the pump and furnished by the pump supplier
(8) related bolting
(9) external and internal integral attachments to the pressure-retaining boundary
(b) These rules do not apply to the plunger or piston, nonstructural internals, including valves, valve seats, gaskets, packing, and cylinder mounting bolting. Hydrostatic testing of packing glands is not required.

NC-3452 Acceptability
The pressure boundary parts shall be capable of withstanding the specified Design Pressures, and the design shall be such that the requirements of NC-3100 are satisfied in addition to these rules.

NC-3453 Material and Stresses
Material and allowable stresses shall conform to the requirements of Article NC-2000.

NC-3454 Design Requirements
NC-3454.1 Design of Welded Construction.
(a) Design of welded construction shall be in accordance with NC-3350.

(b) Partial penetration welds, as shown in Figure NC-4244(e)-1 sketch (c-3) and Figure NC-4266(d)-1 sketches (a) and (b), are allowed for nozzles such as vent and drain connections and openings for instrumentation. Nozzles shall not exceed NPS 2 (DN 50). For such nozzles, all reinforcement shall be integral with the portion of the shell penetrated. Partial penetration welds shall be of sufficient size to develop the full strength of the nozzles.

NC-3454.2 Piping. Piping located within the pressure-retaining boundary of the pump, and identified with the pump, shall be designed in accordance with NC-3600.

NC-3454.3 Liquid End. Any design method that has been demonstrated to be satisfactory for the specified design may be used.

NC-3454.4 Fatigue. The liquid cylinder and pressure-retaining bolting are exposed to significant fatigue loadings that shall be considered in the design. Any design method that has been demonstrated to be satisfactory for the specified design may be used.

NC-3454.5 Earthquake Loadings. The effects of earthquake shall be considered in the design of pumps. The stresses resulting from these earthquake effects shall be included with the stresses resulting from pressure or other applied loads.

NC-3454.6 Corrosion. In designs where corrosion of material is a factor, allowances shall be made.

NC-3454.7 Bolting. Bolting in axisymmetric arrangements involving the pressure boundary shall be designed in accordance with the procedure described in Section III Appendices, Mandatory Appendix XI.

NC-3500 VALVE DESIGN
NC-3510 GENERAL REQUIREMENTS
NC-3511 Design Specification
Design and Service Conditions (NCA-3242) shall be stipulated in the Design Specification (NCA-3250). The requirements of NCA-3254(a) for specifying the location of valve boundary jurisdiction may be considered to have been met by employing the minimum limits of NC-1131, unless the Design Specification extends the boundary of jurisdiction beyond these minimum limits. The requirements of NCA-3254(b) for specifying the boundary conditions are not applicable to valve end connections.

CAUTION: Certain types of double-seated valves have the capability of trapping liquid in the body or bonnet cavity in the closed position. If such a cavity accumulates liquid and is in the closed position at a time when adjacent system piping is increasing in temperature, a substantial and uncontrolled increase in pressure in the body or bonnet cavity may result. Where such a condition is possible, it is the responsibility of the Owner or his designee to provide, or require to be provided, protection against harmful overpressure in such valves.
NC-3595.8 Adjusting Screw. The adjusting screw shall be analyzed for thread stress in accordance with the method of ASME B1.1, and this stress shall not exceed 0.65. The general membrane stress of the adjusting screw shall not exceed the stress limits of NC-3592.2, based on the root diameter of the thread.

NC-3595.9 Spring. The valve spring shall be designed so that the full lift spring compression shall be no greater than 80% of the nominal solid deflection. The permanent set of the spring (defined as the difference between the free height and the height measured a minimum of 10 min after the spring has been compressed solid three additional times after presetting at room temperature) shall not exceed 1.0% of the free height.

NC-3596 Design Reports

NC-3596.1 General Requirements. The manufacturer shall certify compliance with the requirements of this subarticle in accordance with the provisions of NCA-3570.
The stress intensification factors and flexibility factors in Table NC-3673.2(b)-1 shall be used unless specific experimental or analytical data exist that would warrant lower stress intensification factors or higher flexibility factors.

(c) Flexibility factors are identified herein by \( k \) with appropriate subscripts. The general definition of a flexibility factor is:

\[
 k = \frac{\theta_{ab}}{\theta_{nom}}
\]

where

\[
\theta_{ab} = \text{rotation of end } a, \text{ with respect to end } b, \text{ due to a moment load } M \text{ and in the direction of the moment } M
\]

\[
\theta_{nom} = \text{nominal rotation assuming the component acts as a beam with the properties of the nominal pipe. For an elbow, } \theta_{nom} \text{ is the nominal rotation assuming the elbow acts as a curved beam}
\]

The flexibility factor \( k \) is defined in detail for specific components in Table NC-3673.2(b)-1.

(d) Stress intensification factors are identified herein by \( i \). The definition of a stress intensification factor is based on fatigue bend testing of mild carbon steel fittings and is:

- **(U.S. Customary Units)**
  \[
  iS = 245,000N^{-0.2}
  \]

- **(SI Units)**
  \[
  iS = 1700N^{-0.2}
  \]

where

\[
i = \text{stress intensification factor}
\]

\[
N = \text{number of cycles to failure}
\]

\[
S = \text{amplitude of the applied bending stress at the point of failure, psi (MPa)}
\]

(e) For piping products or joints not listed in Table NC-3673.2(b)-1, flexibility or stress intensification factors shall be established by experimental or analytical means.

(f) Experimental determination of flexibility factors shall be in accordance with Section III Appendices, Mandatory Appendix II, II-1900. Experimental determination of stress intensification factors shall be in accordance with Section III Appendices, Mandatory Appendix II, Article II-2000.

(g) Analytical determination of flexibility factors shall be consistent with the definition above.

(h) Analytical determination of stress intensification factors may be based on the empirical relationship

\[
i = \frac{C_2K_2}{2}, \text{ but not less than 1.0}
\]

where \( C_2 \) and \( K_2 \) are stress indices for Class 1 piping products or joints from NB-3681(a)-1, or are determined as explained below.

Analytical determination of stress intensification factors shall be correlated with experimental fatigue results. Experimental correlation may be with new test data or with test data from similar products or joints reported in literature. Finite element analyses or other stress analysis methods may be used to determine \( C_2 \); however, tests or established stress concentration factor data should then be used to determine \( K_2 \).

(i) For certain piping products or joints the stress intensification factor may vary depending on the direction of the applied moment, such as in an elbow or branch connection. For these cases, the stress intensification factor used in eqs. NC-3653.2(a)(10a), NC-3653.2(b)(10b), and NC-3653.2(c)(11) shall be the maximum stress intensification factor for all loading directions as determined in accordance with (f) or (h) above.

(j) Stress intensification factors determined in accordance with (f) above shall be documented in accordance with Section III Appendices, Mandatory Appendix II, II-2050. The test report may be included and certified with the Design Report (NCA 3551.1 and NCA 3555) for the individual piping system or a separate report furnished (Section III Appendices, Mandatory Appendix II, II-2050).

(k) Stress intensification factors determined in accordance with (h) above shall be documented in a report with sufficient detail to permit independent review. The review shall be performed by an engineer competent in the applicable field of design in accordance with Section III Appendices, Mandatory Appendix XXIII. The report shall be included and certified as part of the design report for the piping system (NCA 3551.1 and NCA 3555).

(l) The total expansion range as determined from NC-3672.3 shall be used in all calculations, whether or not the piping is cold sprung. Expansion of the line, linear and angular movements of the equipment, supports, restraints, and anchors shall be considered in the determination of the total expansion range.

(m) Where simplifying assumptions are used in calculations or model tests, the likelihood of underestimates of forces, moments, and stresses, including the effects of stress intensification, shall be evaluated.

(n) Dimensional properties of pipe and fittings used in flexibility calculations shall be based on nominal dimensions.

(o) When determining stress intensification factors by experimental methods, NC-3653.3(d) shall not apply. The nominal stress at the point under consideration (crack site, point of maximum stress, etc.) shall be used.
methods. Such temporary piping shall be designed to safeguard against rupture or other failure which could become a hazard to health or safety.

NC-3690 DIMENSIONAL REQUIREMENTS FOR PIPING PRODUCTS

NC-3691 Standard Piping Products

Dimensions of standard piping products shall comply with the standards and specifications listed in Table NCA-7100-1.

NC-3692 Nonstandard Piping Products

The dimensions of nonstandard piping products shall be such as to provide strength and performance equivalent to standard products, except as permitted in NC-3641.

NC-3700 ELECTRICAL AND MECHANICAL PENETRATION ASSEMBLIES

NC-3720 DESIGN RULES

(a) The design of the pressure-retaining portion of electrical and mechanical penetration assemblies shall be the same as for vessels (NC-3300).

(b) For closing seams in electrical and mechanical penetration assemblies meeting the requirements of NC-4730(c), the closure head shall meet the requirements of NC-3325 using a factor $C = 0.20$. The fillet weld shall be designed using an allowable stress of $0.5S$.

NC-3800 DESIGN OF ATMOSPHERIC STORAGE TANKS

NC-3810 GENERAL REQUIREMENTS

NC-3811 Acceptability

The requirements for acceptability of atmospheric storage tanks are given in the following subparagraphs.

NC-3811.1 Scope. The design rules for atmospheric storage tanks cover vertical cylindrical flat bottom above ground welded tanks at atmospheric pressure. These tanks may contain liquids such as refueling water, condensate, borated reactor coolant, or liquid radioactive waste. Such tanks may be within building structures, depending upon the liquid to be contained, or they may be above grade exposed to atmospheric conditions.

NOTE: These rules do not limit storage tanks from being installed below grade or below ground, provided the tanks are not subject to external pressure resulting from earth or fill.

NC-3811.2 Design Requirements. The design rules for atmospheric storage tanks shall conform to the design requirements of NC-3100 and NC-3300 except as they may be modified by the requirements of this subarticle. As an alternative, the design rules of NC-3200 may be used as a replacement of the requirements of NC-3800. The specific design requirements shall be stipulated in the Design Specifications.

NC-3812 Design Report

The Certificate Holder manufacturing a storage tank is responsible for achieving structural integrity of the tank. The Design Report shall be certified when required by NCA-3550.

NC-3820 DESIGN CONSIDERATIONS

NC-3821 Design and Service Loadings

(a) Loadings shall be identified as Design or Service, and if Service, they shall have Level A, B, C, or D Service Limits designated (NCA-2142).

(b) The provisions of NC-3110 shall apply.

(c) The stress limits given in NC-3821.5 shall be met.

NC-3821.1 Design Pressure. The Design Pressure shall be atmospheric.

The limitation of the Design Pressure to atmospheric is not intended to preclude the use of these tanks at vapor pressure slightly above or below atmospheric within the range normally required to operate vent valves. If these pressures or vacuums exceed 0.03 psig (0.2 kPa gage), especially in combination with large diameter tanks, the forces involved may require special consideration in the design.

NC-3821.2 Design Temperature. The Design Temperature shall not be greater than 200°F (95°C).

NC-3821.3 Loadings. The requirements of NC-3111 shall be met.

NC-3821.4 Welded Joint Restrictions. The restrictions given in (a) through (c) below on type and size of joints or welds shall apply.

(a) Tack welds shall not be considered as having any strength value in the finished structure.

(b) The minimum size of fillet welds shall be in accordance with NC-4246.6.

(c) All nozzle welds shall be in accordance with NC-4246.5.

NC-3821.5 Limits of Calculated Stresses for Design and Service Loadings. Stress limits for Design and Service Loadings are specified in Table NC-3821.5-1. The symbols used in Table NC-3821.5-1 are defined as follows:

$S = $ allowable stress value given in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3, psi (MPa). The allowable stress shall correspond to the highest metal temperature at the section under consideration during the loading under consideration.
NC-3900  ZERO psi TO 15 psi (0 kPa TO 100 kPa) STORAGE TANK DESIGN

NC-3910  GENERAL REQUIREMENTS

NC-3911  Acceptability

NC-3911.1  Scope. The design rules for 0 psi to 15 psi (0 kPa to 100 kPa) storage tanks shall cover above ground welded storage tanks. These tanks may contain liquids or gases such as refueling water, condensate, borated reactor coolant, or radioactive waste. Such tanks are normally located within building structures.

NOTE: These rules do not limit storage tanks from being installed below grade or below ground, provided the tanks are not subject to external pressure resulting from earth or fill.

NC-3912  Design Report

The Certificate Holder of a storage tank conforming to the design requirements of this subarticle is required to provide a Design Report as part of his responsibility for achieving structural integrity of the tank. The Design Report shall be certified when required by NCA-3550.

NC-3920  DESIGN CONSIDERATIONS

NC-3921  Design and Service Loadings

(a) Conditions shall be identified as Design or Service, and if Service, they shall have Service Limits designated Level A, B, C, or D (NCA-2142).

(b) The provisions of NC-3110 shall apply.

(c) The stress limits of NC-3921.8 shall be met.

NC-3921.1  Design Pressure.

(a) At or Above Maximum Liquid Level. The walls of the gas or vapor space and other components shall be designed for a pressure not less than that at which the pressure relief valves are to be set. The relief valve set points shall allow a suitable margin from the pressure normally existing in this space so as to allow for the increases in pressure caused by variations in the temperature or gravity of the liquid contents of the tank and other factors affecting the pressure in the space. Walls and components in this space shall also be designed for the maximum partial vacuum that can be developed in the space when the inflow of air, gas, or vapor through the vacuum relief

![Proposal 19-2786](image)

**Table NC-3865-3**

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ASME BPVC.III.1.NC-2019

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176

23 of 56
(d) The restriction of valve capacity is permitted only by the use of a lift restraining device, which shall limit valve lift and shall not otherwise interfere with flow through the valve.

(e) The lift restraining device is designed so that, if adjustable, the adjustable feature shall be sealed. Seals shall be installed in accordance with NC-7515.

(f) For main steam service for Class 2 construction, the safety or safety relief valve is not used in combination with a rupture disk and shall not have their lift restricted to a value less than 70%.

(g) For air and gas service and for Classes 2 and 3 steam service other than main steam service, if a valve design has been tested in combination with a rupture disk in accordance with the requirements of Article NC-7000, restricted lift valves of this design may be used in combination without further testing. Valves shall not have their lift restricted to a value less than 30% of the full rated lift, nor less than 0.080 in. (2.0 mm).

(h) During production testing, the manufacturer shall assure that the set pressure, blowdown, and valve performance meet the applicable requirements of this Article and the valve Design Specification.

Valves beyond the capability of the production test facility, because of size or flow rate, may be adjusted for blowdown and performance based on test or experience data, or other adequate technical justification, to meet the requirements of this Article and the valve Design Specification. The basis for the manufacturer’s adjusting ring settings shall be documented in the Overpressure Protection Report (NC-7200).

(i) When sizing and selecting valves, the restricted lift capacity shall be determined by multiplying the capacity at full rated lift, as defined in NC-7734, by the ratio of the restricted lift to the full rated lift.

(j) Valves shall be marked in accordance with the relevant nameplate stamping provisions of NC-7800 modified as follows:

(1) Replace “capacity” with “restricted lift capacity.”
(2) Add “restricted lift ___ in. (mm)”

NC-7512 Safety Valve Operating Requirements

NC-7512.1 Antichattering and Lift Requirements.

(a) Safety valves shall be constructed to operate without chattering and to attain rated lift at a pressure which does not exceed the set pressure by more than 3% or 2 psi (15 kPa), whichever is greater.

(b) For valves used for main steam service, conformance with (a) above shall be established for each production valve by testing on steam at the stamped set pressure. The test shall take into account valve discharge piping back pressure as specified in the valve Design Specification.

NC-7512.2 Set Pressure Tolerance.

(a) The set pressure tolerance plus or minus shall not exceed the following: 2 psi (15 kPa) for pressures up to and including 70 psi (480 kPa), 3% for pressures over 70 psi (480 kPa) up to and including 300 psi (2 MPa), 10 psi (70 kPa) for pressures over 300 psi (2 MPa) up to and including 1,000 psi (7 MPa), and 1% for pressures over 1,000 psi (7 MPa). The set pressure tolerance shall apply unless a greater tolerance is established as permissible in the Overpressure Protection Report (NC-7200) and in the safety valve Design Specification (NCA-3250).

(b) Conformance with the requirements of (a) shall be established for each production valve by test. Steam valves shall be tested on steam. Alternative fluids may be used as the test media if the requirements of NC-7560 have been met.

NC-7512.3 Blowdown.

(a) Safety valves shall be adjusted to close after blowdown to a pressure not lower than that specified in the valve Design Specification (NCA-3250) and the basis for the setting is covered in the Overpressure Protection Report (NC-7200).

(b) For valves used for main steam service, conformance with (a) shall be established for each production valve by testing on steam at the stamped set pressure. The test shall take into account valve discharge piping back pressure as specified in the valve Design Specification (NCA-3250).

(c) For valves used for other than main steam service, the adjustment shall be determined by test or proration from the Certificate Holder’s blowdown test data. Alternative fluids may be used as the test media if the requirements of NC-7560 have been met.

NC-7513 Safety Relief and Relief Valve Operating Requirements

Safety relief and relief valves shall be constructed to attain rated lift at a pressure which does not exceed the set pressure by more than 10% or 3 psi (20 kPa), whichever is greater.

NC-7513.1 Set Pressure Tolerance.

(a) The set pressure tolerance plus or minus from the set pressure of safety relief and relief valves shall not exceed 2 psi (15 kPa) for pressures up to and including 70 psi (480 kPa) and 3% for pressures above 70 psi (480 kPa).

The set pressure tolerance shall apply unless a greater tolerance is established as permissible in the Overpressure Protection Report (NC-7200) and in the valve Design Specification (NCA-3250).

(b) Conformance with the requirements of (a) shall be established for each production valve by test. Steam valves shall be tested on steam, air or gas valves on air or gas, and liquid valves on liquid. Alternative fluids may be used as the test media if the requirements of NC-7560 have been met.
NC-7513.2 Blowdown. Safety relief and relief valves shall be adjusted to close after blowing down to a pressure not lower than that specified in the valve Design Specification (NCA-3250) and the basis for the setting shall be covered in the Overpressure Protection Report (NC-7200). The adjustment shall be determined by test or by proration from the Certificate Holder's blowdown test data. Alternative fluids may be used as the test media if the requirements of NC-7560 have been met.

NC-7514 Credited Relieving Capacity

The credited relieving capacity of safety, safety relief, and relief valves shall be based on the certified relieving capacity. In addition, the capacity can be prorated as permitted by NC-7700.

NC-7515 Sealing of Adjustments

Means shall be provided in the design of all valves for sealing all adjustments or access to adjustments which can be made without disassembly of the valve. For a pilot-operated pressure relief valve, an additional seal shall be provided to seal the pilot and main valve together. Seals shall be installed by the Certificate Holder at the time of initial adjustment. Seals shall be installed in a manner to prevent changing the adjustment or disassembly of the valve without breaking the seal. The seal shall serve as a means of identifying the Certificate Holder making the initial adjustment.

NC-7520 PILOT-OPERATED PRESSURE RELIEF VALVES

NC-7521 General Requirements

Pilot-operated pressure relief valves shall operate independently of any external energy source.

NC-7522 Operating Requirements

NC-7522.1 Actuation. The pilot control device shall be actuated directly by the fluid pressure of the protected system.

NC-7522.2 Response Time. The Overpressure Protection Report (NC-7200) shall include the effects of divergence between opening (set) and closing (blowdown) pressures of the pilot valve and the pressures at which the main valve attains rated lift and closes. These divergences are caused by the inherent time delay (e.g., response time) between the operation of the pilot and the main valve, and the rate of the system pressure change. The limits for response time shall be specified in the valve Design Specification (NCA-3250).

NC-7522.3 Main Valve Operation. The main valve shall operate in direct response to the pilot control device. The valve shall be constructed to attain rated lift under stable conditions at pressures which do not exceed the set pressure by more than 3% or 2 psi (15 kPa), whichever is greater, for steam, and 10% or 3 psi (20 kPa), whichever is greater, for air, gas, or liquid service.

NC-7522.4 Sensing Mechanism Integrity. For other than spring loaded direct acting pilot control devices, means shall be provided to detect failure of the pressure-sensing element, such as bellows, when operation of the pilot control device is dependent upon the integrity of a pressure-sensing element.

NC-7522.5 Set Pressure Tolerance.

(a) The set pressure tolerance shall apply only to the pilot valve.

(b) The set pressure tolerance plus or minus shall not exceed the following:

1. 2 psi (15 kPa) for pressures up to and including 70 psi (480 kPa);
2. 3% for pressures over 70 psi (480 kPa) up to and including 300 psi (2 MPa);
3. 10 psi (70 kPa) for pressures over 300 psi (2 MPa) up to and including 1,000 psi (7 MPa); and
4. 1% for pressures over 1,000 psi (7 MPa) for steam, air, and gas valves.

The set pressure tolerance as stated shall apply unless a greater tolerance is established as permissible in the Overpressure Protection Report (NC-7200) and the valve Design Specification (NCA-3250).

(c) Conformance with the requirements of (b) above shall be established for each production valve by test. Steam valves shall be tested on steam, air or gas valves on air or gas, and liquid valves on liquid. Alternative fluids may be used as the test media if the requirements of NC-7560 have been met.

NC-7522.6 Blowdown.

(a) The blowdown requirements shall only apply to the pilot valve.

(b) Pilot valves shall be adjusted to close after blowing down to a pressure not lower than that specified in the valve Design Specification (NCA-3250) and the basis for the setting is covered in the Overpressure Protection Report (NC-7200).

(c) The adjustment shall be determined by test or by proration from the Certificate Holder's blowdown test data. Alternative fluids may be used as the test media if the requirements of NC-7560 have been met.

NC-7523 Credited Relieving Capacity

Except as required in NC-7523.1 and NC-7523.2, the credited relieving capacity of pilot-operated pressure relief valves shall be based on the certified relieving capacity. In addition, the capacity may be prorated as permitted in NC-7700.

NC-7523.1 System Upset Conditions. For system upset conditions in main steam service, the relieving capacity with which these values are credited shall be not more than...
(a) the stamped relieving capacity of the smaller one when two valves are installed;
(b) the stamped relieving capacity of the smaller two where three valves are installed;
(c) three-fourths of the total stamped relieving capacity where more than three valves are installed.

NC-7523.2 System Emergency Conditions. For system emergency conditions in main steam service, the relieving capacity with which these valves are credited shall be not more than
(a) the relieving capacity of the valve with smaller stamped capacity where two valves are installed;
(b) the relieving capacity of all except the valve with the largest stamped capacity where more than two valves are installed.

NC-7524 Sealing of Adjustments
The sealing requirements of NC-7515 shall apply.

NC-7530 POWER-ACTUATED PRESSURE RELIEF VALVES

NC-7531 General Requirements
Power-actuated pressure relief valves, which depend upon an external energy source such as electrical, pneumatic, or hydraulic systems and which respond to signals from pressure or temperature sensing devices, may be used, provided the requirements of this subsubarticle are met.

NC-7532 Operating Requirements
NC-7532.1 Response Time. In systems protected by power operated pressure relief valves, consideration shall be given to the time lapse between the signal to open and achieving the fully opened position, and the time lapse between the signal to close and achieving the fully closed position.

NC-7532.2 Sensors, Controls, and External Energy Sources.
(a) The sensors, controls, and external energy sources for valve operation shall have redundancy and independence at least equal to that required for the control and safety protection systems associated with the system.
(b) The relief valve and its auxiliary devices treated as a combination shall comply with the following requirements:
(1) The valve opening pressure shall be controlled within a tolerance as specified in NC-7512.2 of the set pressure when the automatic control is in use.
(2) The valve blowdown shall be controlled to a pressure not lower than that specified in the valve Design Specification (NCA-3250).

NC-7533 Certified Relieving Capacity
The power-actuated pressure relief valve certified relieving capacity and the proration of capacity shall be as determined by NC-7700.

NC-7534 Credited Relieving Capacity
NC-7534.1 Expected System Pressure Transient Conditions. For expected system pressure transient conditions, the relieving capacity with which these valves are credited shall be not more than
(a) the certified relieving capacity of the smaller one when two valves are installed;
(b) one-half of the total certified relieving capacity when three or more valves are installed.

NC-7534.2 Unexpected System Excess Pressure Transient Conditions. For unexpected system excess pressure transient conditions, the relieving capacity with which these valves are credited shall not be more than
(a) the relieving capacity of the valve with the smaller stamped capacity where two valves are installed;
(b) the relieving capacity of all except the valve with the largest stamped capacity for valves where three through ten valves are installed;
(c) the relieving capacity of all except two valves of the largest certified capacity where more than ten valves are installed.

NC-7540 SAFETY VALVES WITH AUXILIARY ACTUATING DEVICES

NC-7541 General Requirements
Safety valves with auxiliary actuating devices that operate independently of the spring loading of the valve may be used, provided the requirements of NC-7510 are met except as modified by this subsubarticle.

NC-7542 Construction
(a) The construction shall be such that the valve opens automatically by direct action of the fluid at a pressure not higher than the safety valve set pressure and relieves at the certified relieving capacity in the event of failure of any essential part of the valve’s auxiliary devices.
(b) The construction of the auxiliary actuating device shall be such that the safety valve will not be prevented from operating as defined in NC-7510 when the auxiliary actuating device is deenergized.

NC-7543 Expected System Pressure Transient Conditions
For expected system pressure transient conditions, credit for capacity (NC-7546) can be taken for valves opening at the setpoint of the auxiliary actuating device in accordance with (a) and (b) below.
III
RULES FOR CONSTRUCTION OF NUCLEAR FACILITY COMPONENTS

Division 1 - Subsection ND

Class 3 Components

ASME Boiler and Pressure Vessel Committee on Construction of Nuclear Facility Components
specifications for tubes listed in Section II, Part D, Subpart 1, Table 1A, and to all of the special requirements of this Article that apply to that product form. Heat transfer fins shall be of the same P-Number as the tube and shall be attached by a machine welding process, such as the electric resistance welding or the high frequency resistance welding process. In addition, the following requirements shall apply:

(a) The heat transfer fins need not be certified material. The material for the heat transfer fins shall be identified and suitable for welding, however, Certified Material Test Reports are not required.

(b) The machine welding process used to weld the heat transfer fins to the tubular material shall be performed in accordance with a Welding Procedure Specification.

(c) The procedure qualification shall require that a minimum of 12 cross sections through the weld zone shall be examined at 5X minimum magnification. There shall be no cracks in the base material or weld; and the weld penetration shall be limited to 20% of the nominal tube wall thickness.

(d) For P-No. 1 material, the weld that attaches the fins to the tubing shall be heat treated after welding to a minimum temperature of 1,000°F (540°C).

(e) The fin is not considered to provide any support to the tube under pressure loading.

**ND-2128 Bolting Material**

(a) Material for bolts and studs shall conform to the requirements of one of the specifications listed in Section II, Part D, Subpart 1, Table 3. Material for nuts shall conform to SA-194 or to the requirements of one of the specifications for nuts or bolting listed in Section II, Part D, Subpart 1, Table 3.

(b) The use of washers is optional. When used, they shall be made of wrought material, with mechanical properties compatible with the nuts with which they are to be employed.

**ND-2130 Certification of Material**

All materials used in construction of components shall be certified as required in NCA-3862 and NCA-3861. Certified Material Test Reports are required for pressure-retaining material, except as provided by NCA-3861, and for small products as defined in ND-2610(c). A Certificate of Compliance may be provided in lieu of a Certified Material Test Report for all other material. Copies of all Certified Material Test Reports and Certificates of Compliance applicable to material used in a component shall be furnished with the material.

**ND-2140 Welding Material**

For the requirements governing the material to be used for welding, see **ND-2400**.

**ND-2150 Material Identification**

All material shall be marked in accordance with the marking requirements of the material specification. Material for small items shall be controlled during manufacture and installation of the component so that they are identifiable as acceptable material at all times. Welding and brazing material shall be controlled during the repair of material and the manufacture and installation so that they are identifiable as acceptable until the material is actually consumed in the process (ND-4122).

**ND-2160 Deterioration of Material in Service**

Consideration of deterioration of material caused by service is generally outside the scope of this Subsection. It is the responsibility of the Owner to select material suitable for the conditions stated in the Design Specifications (NCA-3250), with specific attention being given to the effects of service conditions upon the properties of the material.

**ND-2170 Heat Treatment to Enhance Impact Properties**

Carbon steels, low alloy steels, and high alloy chromium (Series 4XX) steels may be heat treated by quenching and tempering to enhance their impact properties. Postweld heat treatment of the component at a temperature of not less than 1,100°F (595°C) may be considered to be the tempering phase of the heat treatment.

**ND-2180 Procedures for Heat Treatment of Material**

When heat treating temperature or time is required by the material specification and the rules of this Subsection, the heat treating shall be performed in temperature-surveyed and -calibrated furnaces or the heat treating shall be controlled by measurement of material temperature by thermocouples in contact with the material or attached to blocks in contact with the material or by calibrated pyrometric instruments. Heat treating shall be performed under furnace loading conditions such that the heat treatment is in accordance with the material specification and the rules of this Subsection.

**ND-2190 Non-pressure-retaining Material**

(a) Material in the component support load path and not performing a pressure-retaining function (see ND-1130) welded to pressure-retaining material shall meet the requirements of Article NF-2000.

(b) Material not performing a pressure-retaining function and not in the component support load path (non-structural attachments) welded at or within 2t of the pressure-retaining portion of the component need not comply with Article ND-2000 or Article NF-2000 provided the requirements of ND-4430 are met.
ND-3113 Service Conditions

(a) Each condition to which the components may be subjected shall be classified in accordance with NCA-2142(b) designated in the Design Specifications in such detail as will provide a complete basis for design in accordance with this Article.

(b) When any Level B, Level C, or Level D Conditions are specified in the Design Specifications, they shall be evaluated in accordance with NCA-2140 and in compliance with the applicable design rules and stress limits of this Article.

ND-3115 Casting Quality Factors

A casting quality factor shall be applied to the allowable stress values for cast material given in Section II, Part D, Subpart 1, Tables 1A, 1B, 2B, and 3.

ND-3120 SPECIAL CONSIDERATIONS

ND-3121 Corrosion

(a) Materials subject to thinning by corrosion, erosion, mechanical, or other environmental effects shall have provision made for these effects in the Design Specifications by indicating the increase in the thickness of the material over that determined by the design equations. Other suitable methods of protection may be used. Material added for these purposes need not be of the same thickness for all areas of the component if different rates of attack are expected for the various areas.

(b) Except as required in (c) below, no additional thickness need be provided when previous experience in like service has shown that corrosion does not occur or is of only a superficial nature.

(c) Vessels constructed of materials listed in Section II, Part D, Subpart 1, Tables 1A and 2B with a required minimum thickness of less than \(\frac{3}{4}\) in. (6 mm) that are to be used in compressed air service, steam service, or water service shall be provided with a corrosion allowance on the metal surface in contact with such substance of not less than one-sixth of the calculated plate thickness.

(d) Telltale holes may be used to indicate when the thickness has been reduced to a minimum. When telltale holes are provided, they shall be at least \(\frac{1}{16}\) in. (5 mm) in diameter and have a depth not less than 80% of the thickness required for a section of like dimensions. These holes shall be provided in the surface opposite to that where deterioration is expected.

ND-3122 Cladding

The rules of this paragraph apply to the design of clad components constructed of material permitted in Section II, Part D, Subpart 1, Tables 1A and 2B.

ND-3122.1 Stresses. No structural strength shall be attributed to the cladding.

ND-3122.2 Design Dimensions. The dimensions given in (a) and (b) below shall be used in the design of the component.

(a) For components subjected to internal pressure, the inside diameter shall be taken at the nominal inner face of the cladding.

(b) For components subjected to external pressure, the outside diameter shall be taken at the outer face of the base metal.

ND-3123 Welds Between Dissimilar Metals

In satisfying the requirements of this Article, caution shall be exercised in construction involving dissimilar metals having different chemical compositions, mechanical properties, and coefficients of thermal expansion in order to avoid difficulties in service.

ND-3125 Configuration

Accessibility to permit the examinations required by the Edition and Addenda of Section XI as specified in the Design Specification for the component shall be provided in the design of the component.

ND-3130 GENERAL DESIGN RULES

ND-3131 General Requirements

The design shall be such that the design rules of this Article are satisfied for all configurations and loadings using the maximum allowable stress values \(S\) of Section II, Part D, Subpart 1, Tables 1A, 1B, and 3 in the various equations and including the use of the standard products listed in Table NCA-7100-1.

ND-3131.1 Design Reports. The N Certificate Holder is required to provide a Design Report as part of the responsibility for achieving structural integrity of the component. The Design Report shall be certified when required by NCA-3550.

ND-3131.2 Proof Tests to Establish Maximum Allowable Pressure. When the configuration of a component is such that the stresses resulting from internal or external pressure cannot be determined with adequate accuracy by the rules of this Article, the maximum allowable pressure shall be determined by proof testing in accordance with the rules of ND-6900, except for piping as otherwise provided in this Article.

ND-3132 Dimensional Standards for Standard Products

Dimensions of standard products shall comply with the standards and specifications listed in Table NCA-7100-1 when the standard or specification is referenced in the specific design subarticle. However, compliance with these standards does not replace or eliminate the requirements for stress analysis when called for by the design subarticle for a specific component.

Proposal 19-2786
Step 2. Using the value of A calculated in Step 1, enter the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration. Move vertically to an intersection with the material/temperature line for the Design Temperature. Interpolation may be made between lines for intermediate temperatures. In cases where the value at A falls to the right of the end of the material/temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. For values of A falling to the left of the material/temperature line, see Step 4.

Step 3. From the intersection obtained in Step 2, move horizontally to the right and read the value of factor B. This is the maximum allowable compressive stress for the values of T and R used in Step 1.

Step 4. For values of A falling to the left of the applicable material/temperature line, the value of B shall be calculated using the following equation:

\[ B = \frac{AE}{2} \]

Step 5. Compare the value of B determined in Steps 3 or 4 with the computed longitudinal compressive stress in the cylindrical shell or tube, using the selected values of T and R. If the value of B is smaller than the computed compressive stress, a greater value of T must be selected and the design procedure repeated until a value of B is obtained that is greater than the compressive stress computed for the loading on the cylindrical shell or tube. The joint efficiency for butt-welded joints may be taken as unity.

**ND-3133.7** Tubes and Pipes When Used as Tubes.

The required wall thickness for tubes and pipe under external pressure shall be determined in accordance with Figure ND-3133.7-1.

**ND-3135** Attachments

(a) Except as in (c) and (d) below, attachments and connecting welds within the jurisdictional boundary of the component as defined in **ND-1130** shall meet the stress limits of the component.

(b) The design of the component shall include consideration of the interaction effects and loads transmitted through the attachment to and from the pressure-retaining portion of the component.

(c) Beyond 2t from the pressure-retaining portion of the component, where t is the nominal thickness of the pressure-retaining material, the appropriate design rules of Article NF-3000 may be used as a substitute for the design rules of Article ND-3000 for portions of attachments that are in the component support load path.

(d) Nonstructural attachments shall meet the requirements of **ND-4435**.

**ND-3300** VESSEL DESIGN

**ND-3310** GENERAL REQUIREMENTS

Class 3 vessel requirements as stipulated in the Design Specifications (NCA-3250) shall conform to the design requirements of this Article.

**ND-3320** DESIGN CONSIDERATIONS

**ND-3321** Stress Limits for Design and Service Loadings

Stress limits for Design and Service Loadings are specified in Table ND-3321-1. The symbols used in Table ND-3321-1 are defined as follows:

- \( S \) = allowable stress value given in Section II, Part D, Subpart 1, Tables 1A and 1B. The allowable stress shall correspond to the highest metal temperature at the section under consideration during the condition under consideration.
- \( \sigma_b \) = bending stress. This stress is equal to the linear varying portion of the stress across the solid section under consideration. It excludes discontinuities and concentrations, and is produced only by pressure and other mechanical loads.
- \( \sigma_L \) = local membrane stress. This stress is the same as \( \sigma_m \), except that it includes the effect of discontinuities.
- \( \sigma_m \) = general membrane stress. This stress is equal to the average stress across the solid section under consideration. It excludes discontinuities and concentrations, and is produced only by pressure and other mechanical loads.

Typical examples of locations for which \( \sigma_b, \sigma_L, \) and \( \sigma_m \) are applicable are shown in Table ND-3321-2.

**ND-3322** Special Considerations

The provisions of **ND-3120** apply.

**ND-3323** General Design Rules

The provisions of **ND-3310** apply except as modified by the rules of this subarticle. In case of conflict, this subarticle governs the design of vessels.

**ND-3324** Vessels Under Internal Pressure

**ND-3324.1** General Requirements. Equations are given for determining the minimum thicknesses under internal pressure loading in cylindrical and spherical shells and ellipsoidal, torispherical, conical, toriconical, and hemispherical heads. Provision shall be made for any of the other loadings listed in **ND-3111** when such loadings are specified.
ND-3411.2 Exemptions. The rules of ND-3400 do not apply to (a) through (c) below:
(a) pump shafts and impellers (shafts may be designed in accordance with Section III Appendices, Nonmandatory Appendix S)
(b) nonstructural internals
(c) seal packages

ND-3412 Acceptability
The requirements for the design of pumps are given in (a) and (b) below.
(a) The design shall be such that the requirements of ND-3100 are satisfied.
(b) The rules of this subarticle shall be met.

ND-3413 Design Specifications
Design and Service Loadings (NCA-2142) shall be stipulated in the Design Specification (NCA-3250). Loads from thermal expansion, deadweight, and applicable seismic forces from the connected piping shall be included in the Design Specification.

ND-3414 Design and Service Loadings
The general design considerations, including definitions, of ND-3100 plus the requirements of ND-3320, ND-3330, ND-3361, and ND-3362, are applicable to pumps. The pump shall conform to the requirements of ND-3400. The stress limits listed in ND-3416 shall be used for the specified Design and Service Loadings. Classical bending and direct stress equations, where free body diagrams determine a simple stress distribution that is in equilibrium with the applied loads, or any design equations, which have been demonstrated to be satisfactory may be used.

ND-3415 Loads From Connected Piping
Loads imposed on pump inlets and outlets by connected piping shall be considered in the pump casing design.

ND-3416 Stress and Pressure Limits for Design and Service Loadings
Stress limits for maximum normal stress for Design and Service Loadings are specified in Table ND-3416-1. The symbols used in Table ND-3416-1 are defined as follows:
\[ S = \text{allowable stress, given in Section II, Part D, Subpart 1, Tables 1A and 1B. The allowable stress shall correspond to the highest metal temperature of the section under consideration during the condition under consideration.} \]
\[ \sigma_b = \text{bending stress. This stress is equal to the linear varying portion of the stress across the solid section under consideration. It excludes discontinuities and concentrations, and is produced only by pressure and other mechanical loads.} \]
\[ \sigma_L = \text{local membrane stress. This stress is the same as } \sigma_m, \text{ except that it includes the effect of discontinuities.} \]
\[ \sigma_m = \text{general membrane stress. This stress is equal to the average stress across the solid section under consideration. It excludes discontinuities and concentrations, and is produced only by pressure and other mechanical loads.} \]

ND-3417 Earthquake Loadings
(a) The effects of earthquake shall be considered in the design of pumps, pump supports, and restraints. The stresses resulting from these earthquake effects shall be included with the stresses resulting from pressure or other applied loads.
(b) Where pumps are provided with drivers on extended supporting structures and these structures are essential to maintaining pressure integrity, an analysis shall be performed when required by the Design Specifications.

ND-3418 Corrosion
The requirements of ND-3121 apply.

ND-3419 Cladding
Cladding design dimensions used in the design of pumps shall be as required in ND-3122.

ND-3420 Definitions

ND-3421 Radially Split Casing
A radially split casing shall be interpreted as one in which the primary sealing joint is radially disposed around the shaft.

<table>
<thead>
<tr>
<th>Table ND-3416-1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stress and Pressure Limits for Design and Service Loadings</strong></td>
</tr>
<tr>
<td>Service Limits</td>
</tr>
<tr>
<td>Design and Level A</td>
</tr>
<tr>
<td>Level B</td>
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<td>Level C</td>
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<td>Level D</td>
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</tbody>
</table>

NOTES:
(1) These requirements for acceptability of pump design are not intended to assure the operability of the pump.
(2) The maximum pressure shall not exceed the tabulated factors listed under \( P_{max} \) times the Design Pressure.
ND-3438 Supports

Pump supports shall be designed in accordance with the requirements of Subsection NF, unless included under the rules of ND-3411.1(j).

ND-3440 DESIGN OF SPECIFIC PUMP TYPES

ND-3441 Standard Pump Types

19 ND-3441.1 Design of Type A Pumps. Type A pumps are those having single volutes and radially split casings with a single suction as illustrated in Figures ND-3441.1-1 and ND-3441.1-2. Pumps with nozzle sizes NPS 4 (DN 100) discharge and smaller shall be constructed in accordance with (a) through (e). Larger pumps are permitted as stipulated in (f).

(a) Casing Wall Thickness. Except where specifically indicated in these rules, no portion of the casing wall shall be thinner than the value of $t$, which is determined as follows:

$$ t = \frac{PA}{S} $$

or 0.25 in. (6 mm), whichever is greater, where

$A =$ scroll dimension, in. (mm), inside casing as shown in Figure ND-3441.1(a)-1. If the value of dimension $A$ exceeds 20 in. (500 mm), the equation shall not be used and (f) below applies.

$P =$ Design Pressure, psig (MPa gage)

$S =$ allowable stress, including casting factor, psi (MPa)

(ND-2571 and Section II, Part D, Subpart 1, Tables 1A and 1B)

$t =$ minimum allowable wall thickness, in. (mm)

(b) Cutwater Tip. The cutwater tip radius shall not be less than 0.05 $t$.

(c) Cutwater Fillets. All cutwater fillets, including the tips, where they meet the casing wall, shall have a minimum radius of 0.1$t$ or 0.25 in. (6 mm), whichever is greater.

(d) Crotch Radius [Figure ND-3441.1(a)-1]. The crotch radius shall not be less than 0.3$t$.

(e) Bottom of Casing. That section of the pump casing within the diameter defined by dimension $A$ in Figure ND-3441.1(a)-1 on the inlet side of the casing, normally referred to as the bottom of the casing, shall have a wall thickness the greater of $t$ from (a) or $t_b$. The value of $t_b$ shall be determined by methods of ND-3300 or Section III Appendices, Nonmandatory Appendix A using the appropriate equations for the casing shape.

(f) Pumps with an "A" dimension greater than 20 in. (500 mm) or nozzles larger than NPS 4 (DN 100) discharge are permitted. Design of these larger pumps must be performed in accordance with Section III Appendices, Mandatory Appendix II, Experimental Stress Analysis, or ND-3414. If the design is qualified by analysis, the analysis shall be certified in accordance with NCA-3551.1.

ND-3441.2 Design of Type B Pumps. Type B pumps are those having single volutes and radially split casings with a single suction as illustrated in Figure ND-3441.2-1. Any design method that has been demonstrated to be satisfactory for the specified design conditions may be used.

ND-3441.3 Design of Type C Pumps. Type C pumps are those having double volutes and radially split casings with a single suction as illustrated in Figures ND-3441.3-1 and ND-3441.3-2. The splitter is considered a structural part of the casing. Casing design shall be in accordance with the requirements of this subarticle and with those given in (a) through (e) below.

(a) Casing Wall Thickness. Except where specifically indicated in these rules, no portion of the casing wall shall be thinner than the value of $t$ determined as follows:

$$ t = \frac{(0.5PA)}{S} $$

where

$A =$ scroll dimension, inside casing as shown in Figure ND-3441.3-2, in. (mm)

$P =$ Design Pressure, psig (MPa gage)
\[ \sigma_{\text{bending}} = \frac{M_{Gd}}{2l_f} \]

(-k) Determine the shear and bending flange stresses \(\sigma_s'\), psi (MPa), and \(\sigma_b'\), psi (MPa), respectively

\[ \sigma_s' = \frac{H_o}{wt_f} \]

\[ \sigma_b' = \frac{M_{bt}}{2l_f} \]

(-l) Determine the tensile and bending case stresses \(\sigma_s''\), psi (MPa), and \(\sigma_b''\), psi (MPa), respectively

\[ \sigma_s'' = \frac{H_D}{wt_C} \]

\[ \sigma_b'' = \frac{M_{btC}}{2l_C} \]

(-m) Use the following method for combining stresses in combined sections:

\[ F_X = \text{load on section } X, \text{lb (N)} \]
\[ F_Y = \text{load on section } Y, \text{etc., lb (N)} \]
\[ S_X = \text{stress in section } X, \text{psi (MPa)} \]
\[ S_Y = \text{stress in section } Y, \text{etc., psi (MPa)} \]

The combined stress \(S_{\text{COMB}}\) is as follows:

\[ S_{\text{COMB}} = \left( \frac{F_X}{S_X} \right) + \left( \frac{F_Y}{S_Y} \right) \]

(-n) Determine the maximum stresses using (-1) through (-4) below.

(-1) To determine the preliminary bolt stress, establish the load \(W\) and stress \(\sigma_{\text{PRE}}\) for Section \(X\) and Section \((Y + Z)\)

\[ \sigma_{\text{PRE}}^{\text{COMB}} = \frac{W_X + W_Y}{\sigma_{\text{PRE}}^X} \]

The allowable limit for this stress is \(S_b\).

(-2) To determine the resultant bolt stress, establish the load \(F_R\) and the stresses \(\sigma_i\) and \(\sigma_b\) for Section \(X\) and Section \((Y + Z)\)

\[ \sigma_{\text{COMB}} = \frac{F_R^X + F_{R(Y + Z)}}{\sigma_i^X} + \frac{F_R^Y}{\sigma_b^Y} \]

The allowable limit for \(\sigma_{\text{COMB}}\) is \(2S_b\).

(-3) To determine the flange stresses, establish the load \(H_o\), the shear stress \(\sigma_s'\), and the bending stress \(\sigma_b'\) for Section \(X\) and Section \((Y + Z)\)

\[ \sigma_s'_{\text{COMB}} = \frac{H_{oX} + H_{o(Y + Z)}}{\sigma_s^X} \]

\[ \sigma_b'_{\text{COMB}} = \frac{H_{oY} + H_{o(Y + Z)}}{\sigma_b^Y} \]

\[ \sigma_s''_{\text{COMB}} = \left( \frac{\sigma_s'^2}{\sigma_s'^{\text{COMB}}} + \frac{\sigma_b'^2}{\sigma_b'^{\text{COMB}}} \right)^{1/2} \]

\[ \sigma_b''_{\text{COMB}} = \left( \frac{\sigma_b'^2}{\sigma_b'^{\text{COMB}}} + \frac{\sigma_b''^2}{\sigma_b''^{\text{COMB}}} \right)^{1/2} \]

where \(\sigma_s''_{\text{max}}\) is the maximum normal stress. The allowable limit for \(\sigma_s''_{\text{max}}\) is \(S_c\) and the allowable limit for \(\sigma_b''_{\text{max}}\) is \(1.5S_c\).

(-4) To determine the case stresses, establish the load \(H_D\), the tensile stress \(\sigma_t'\), and the bending stress \(\sigma_b''\) for Section \(X\) and for Section \((Y + Z)\)

\[ \sigma_t''_{\text{COMB}} = \frac{H_{DX} + H_{D(Y + Z)}}{\sigma_t^X} \]

\[ \sigma_b''_{\text{COMB}} = \frac{H_{DY} + H_{D(Y + Z)}}{\sigma_b^Y} \]

The allowable limit for \(\sigma_t''_{\text{COMB}}\) is \(S_c\). The total stress is \(\sigma_t''_{\text{COMB}} + \sigma_b''_{\text{COMB}}\). The allowable limit for total stress is \(1.5S_c\).

(-a) The above procedure will generally show some bolt stresses in excess of the indicated allowable values. Under these circumstances it is permissible to average bolt stresses between adjacent bolts. Such averaged stresses shall not exceed the specified allowables.

**ND-3441.8 Design of Type H Pumps.** Type H pumps are those having axially split, barrel-type casings (Figures ND-3441.8-1 and ND-3441.8-2) and radially split covers. The axially split casing shall be designed in accordance with the rules of ND-3441.7 for Type G pumps. The radially split cover shall be designed in accordance with the rules of ND-3437.

**ND-3441.9 Design of Type K Pumps.** Type K pumps are vertical pumps of one or more stages having a radially split casing, as illustrated in Figures ND-3441.9-1 and ND-3441.9-2. The basic configuration is a casing consisting of a barrel and a head joined by bolted flanges. There
is an inner assembly consisting of internal chambers of the head, one or more bowls, column sections, and a suction bell, all joined by bolted flanges and arranged so that the external surfaces of these parts are subjected to inlet pressure. These pumps may be furnished with or without column(s) and with or without lateral restraints between the inner assembly and outer casing.

(a) Flanged Joints. Except for flanged joints conforming to (5), flanged joints may be analyzed and the stresses evaluated by using methods given in Section III Appendices, Mandatory Appendix XI if of the "RF" type and in accordance with Section III Appendices, Nonmandatory Appendix L if of the "FF" type, as modified by (1) through (4) below or by (5) below.

(1) The Design Pressure to be used for the calculation of \( H \) in Section III Appendices, Mandatory Appendix XI or Section III Appendices, Nonmandatory Appendix L shall be replaced by the flange design pressure

\[
P_{TD} = P + P_{eq}
\]  

(1)

where

\( P \) = design or Service Condition Pressure as defined in NCA-2140, psi (MPa)

\( P_{eq} \) = equivalent pressure to account for the axial force and moments applied to the flange joint, psi (MPa)

The equivalent pressure, \( P_{eq} \), shall be determined from the seismic and external loads acting on the flanged joint using the equation

\[
P_{eq} = \frac{KM_f}{\pi G^2} + \frac{4F}{\pi G^2}
\]  

(2)

where

\( F \) = the axial load at the flange, lbf (N)

\( G \) = the diameter at the location of the gasket load reaction, in. (mm)

\( K \) = If the loads include dynamic loads the value of this coefficient shall be 8. If the loads are static the value shall be 16.

\( M_f \) = the resultant bending moment on the flange as taken from paragraph ND-3658, in.-lbf (N·mm)

(2) Section III Appendices, Mandatory Appendix XI, XI-3223, eqs. (3) and (4) or Section III Appendices, Nonmandatory Appendix L, L-3221 shall be used to establish minimum bolt area required using allowable stress values given in Section II, Part D, Subpart 1, Tables 1A and 1B.

(3) Section III Appendices, Mandatory Appendix XI, XI-3240, eq. (6) for longitudinal hub stress shall be revised to include primary axial membrane stress as follows:

\[
S_H = \frac{FM_g}{I_{S_1}B^2} + \frac{PB}{4g_0}
\]  

(3)

where \( P \) is the Design or Service Pressure as defined in NCA-2140, psi (MPa). Other terms are defined in Section III Appendices, Mandatory Appendix XI, XI-3130.

(4) The allowable stress limits \( S_H, S_R, \) and \( S_T \) shall not be greater than 1.5\( S \).

(5) If the flanged joint conforms to one of the standards listed in Table NCA-7100-1 and if each \( P_{TD} \) as calculated by eq. (1)(1) is less than the rated pressure at the Design or Service Temperature utilized, the requirements of this subparagraph are satisfied.

(b) Casing. The barrel and head of the casing shall be designed in accordance with the requirements of ND-3400 and with those given in (1) and (2) below.

(1) Barrel. The Design Pressure for the barrel shall be the pump inlet pressure or as otherwise stated in the Design Specification (NCA-3258), but in no case shall it be
ND-3500 VALVE DESIGN

ND-3510 GENERAL REQUIREMENTS

ND-3511 Design Specification

Design and Service Conditions (NCA-2142) shall be stipulated in the Design Specification (NCA-2258). The requirements of NCA-3254(c) for specifying the location of valve boundary jurisdiction may be considered to have been met by employing the minimum limits of ND-1131, unless the Design Specification extends the boundary of jurisdiction beyond these minimum limits. The requirements of NCA-3254(b) for specifying the boundary conditions are not applicable to valve end connections.

CAUTION: Certain types of double-seated valves have the capability of trapping liquid in the closed position. If such a cavity accumulates liquid and is in the closed position at a time when adjacent system piping is increasing in temperature, a substantial and uncontrolled increase in pressure in the body or bonnet cavity may result. Where such a condition is possible, it is the responsibility of the Owner or his designee to provide, or require to be provided, protection against harmful overpressure in such valves.

ND-3512 Standard Design Rules

ND-3512.1 Flanged and Butt-Welding End Valves.

The design of valves with flanged and butt-welding ends shall conform to the applicable requirements for Standard Class category valves of ASME B16.34 except as provided in (a) and (b) below.

(a) Valves with flanged and butt welding ends may be designated as Class 75 in sizes larger than NPS 24 (DN 600), provided that the following additional requirements are met.

(1) The maximum rated pressure shall be 75 psi (520 kPa) for fluid temperatures from −20°F to 350°F (−30°C to 175°C).

(2) The minimum valve body wall thickness, exclusive of corrosion allowance, shall be in accordance with the following:

\[ t_m = 0.4t_o + 0.2 \text{ for } d \leq 50 \text{ in. (1250 mm)} \]

or

\[ t_m = 0.008d + 0.2 \text{ for } d > 50 \text{ in. (1250 mm)} \]

where

\[ d = \text{inside diameter, in. (mm)} \]

\[ t_m = \text{minimum body wall thickness, in. (mm)} \]

\[ t_o = \text{minimum body wall thickness as tabulated in ASME B16.34 for Class 150, in. (mm)} \]

(3) Flanges shall be designed in accordance with the requirements of Section III Appendices, Mandatory Appendix XI, ANSI/AWWA C207 Class E, or ASME B16.47.

(4) The minimum hydrostatic shell test pressure shall be 125 psi (860 kPa) and shall be maintained for a minimum of 10 min.

(5) The minimum valve closure test pressure shall be 85 psi (590 kPa) and shall be maintained for a minimum of 10 min.

(b) Valves with flanged ends in sizes larger than NPS 24 (DN 600) may be used, provided that the following additional requirements are met.

(1) For ASME B16.47, the Pressure Class shall be limited to Class 150 and Class 300.

(2) The operating temperatures shall be limited to the range of −20°F to 650°F (−30°C to 345°C).

(3) Flanges are designed in accordance with the requirements of Section III Appendices, Mandatory Appendix XI or ASME B16.47.

ND-3512.2 Socket Welding End and Nonwelding End Valves. The design of valves with socket welding end connections and nonwelding piping end connections other than ASME B16.5 flanges shall conform to the applicable requirements for Standard Class category butt welding valves of ASME B16.34 except that the end connections shall conform to the applicable requirements of ND-3661 or ND-3671.

Instrument, control, and sampling line valves, NPS 1 (DN 25) and smaller, with welding or nonwelding piping or tubing end connections other than flanges, and with body wall thickness not meeting Standard Class category valves of ASME B16.34, are acceptable, provided that the following additional requirements of (a) through (g) are met:

(a) The valve design shall meet one or more of the following:

(1) the pressure design rules of ND-3324

(2) an experimental stress analysis (Section III Appendices, Mandatory Appendix II)

(3) design based on stress analysis (Section III Appendices, Mandatory Appendix XIII) and meeting the limits of Section III Appendices, Mandatory Appendix XIII

(b) The end connections shall meet the requirements of ND-3661, ND-3671.3, or ND-3671.4 for welded, threaded, flared, flareless, and compression-type fitting tube ends.

(c) Valve loadings, including but not limited to operation, closure, and assembly, shall be accounted for by one of the following methods:

(1) experimental stress analysis (Section III Appendices, Mandatory Appendix II), or

(2) design based on stress analysis (Section III Appendices, Mandatory Appendix XIII).

(d) All valves shall meet the requirements of ND-3521.

(e) Valve bonnets threaded directly into valve bodies shall have a lock weld or locking device to ensure that the assembly does not disengage through either stem operation or vibration.
ND-3595.8 Adjusting Screw. The adjusting screw shall be analyzed for thread stress in accordance with the method of ASME B1.1 and this stress shall not exceed 0.6S. The general membrane stress of the adjusting screw shall not exceed the stress limits of ND-3592.2, based on the root diameter of the thread.

ND-3595.9 Spring. The valve spring shall be designed so that the full lift spring compression shall be no greater than 80% of the nominal solid deflection. The permanent set of the spring (defined as the difference between the free height and the height measured a minimum of 10 min after the spring has been compressed solid three additional times after presetting at room temperature) shall not exceed 1.0% of the free height.

ND-3596 Design Reports

ND-3596.1 General Requirements. The manufacturer shall certify compliance with the requirements of this subsubarticle in accordance with the provisions of NCA-3211.10.

ND-3600 PIPING DESIGN

ND-3610 GENERAL REQUIREMENTS

ND-3611 Acceptability

The requirements for acceptability of a piping system are given in the following subparagraphs.

ND-3611.1 Allowable Stress Values. Allowable stress values to be used for the design of piping systems are given in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3.

ND-3611.2 Stress Limits. (a) Design and Service. Loadings shall be specified in the Design Specification.

(b) Design Loadings. The sum of stresses due to design internal pressure, weight, and other sustained loads shall meet the requirements of eq. ND-3652(8).

(c) Service Loadings. The following Service Limits shall apply to Service Loadings as designated in the Design Specification.

(1) Level A and B Service Limits. For Service Loadings for which Level A and B Service Limits are designated in the Design Specification, the requirements of ND-3653 shall be met. When Level B Limits apply, the peak pressure \( P_{\text{max}} \) alone shall not exceed 1.1 times the pressure \( P_a \) calculated in accordance with eq. ND-3641.1(5). The calculation of \( P_a \) shall be based on the maximum allowable stress for the material at the coincident temperature.

(2) Level C Service Limits. For Service Loadings for which Level C Service Limits are designated in the Design Specification, the sum of stresses shall meet the requirements of ND-3654.

(3) Level D Service Limits. For Service Loadings for which Level D Service Limits are designated in the Design Specification, the sum of stresses shall meet the requirements of ND-3655.

(4) Test Conditions. Testing shall be in accordance with Article ND-6000. Occasional loads shall not be considered as acting at time of test.

(d) External Pressure Stress. Piping subject to external pressure shall meet the requirements of ND-3641.2.

(e) Allowable Stress Range for Expansion Stresses. The allowable stress range \( S_A \) is given by eq. (1)

\[
S_A = f(1.25S_c + 0.25S_h)
\]

where

\( f = \) stress range reduction factor for cyclic conditions for total number \( N \) of full temperature cycles over total number of years during which system is expected to be in service, from Table ND-3611.2(e)-1

\( S_c = \) basic material allowable stress at minimum (cold) temperature, psi (MPa)

\( S_h = \) basic material allowable stress at maximum (hot) temperature, psi (MPa)
local strain. Calculations for the expansion stress \( S_e \) shall be based on the modulus of elasticity at room temperature \( E_c \).

(a) Stress Range. Stresses caused by thermal expansion, when of sufficient initial magnitude, relax in the hot condition as a result of local yielding or creep. A stress reduction takes place and usually appears as a stress of reversed sign when the component returns to the cold condition. This phenomenon is designated as self-springing of the line and is similar in effect to cold springing. The extent of self-springing depends on the material, the magnitude of the initial expansion and fabrication stress, the hot service temperature, and the elapsed time. While the expansion stress in the hot condition tends to diminish with time, the sum of the expansion strains for the hot and cold conditions during any one cycle remains substantially constant. This sum is referred to as the strain range; however, to permit convenient association with allowable stress, stress range is selected as the criterion for the thermal design of piping.

(b) Local Overstrain. All the commonly used methods of piping flexibility analysis assume elastic behavior of the entire piping system. This assumption is sufficiently accurate for systems in which plastic straining occurs at many points or over relatively wide regions but fails to reflect the actual strain distribution in unbalanced systems in which only a small portion of the piping undergoes plastic strain or in which, for piping operating in the creep range, the strain distribution is very uneven. In these cases, the weaker or higher stressed portions will be subjected to strain concentrations due to elastic follow-up of the stiffer or lower stressed portions. Unbalance can be produced

(1) by use of small pipe runs in series with larger or stiffer pipe, with the small lines relatively highly stressed;
(2) by local reduction in size or cross section, or local use of a weaker material;
(3) in a system of uniform size, by use of a line configuration for which the neutral axis or thrust line is situated close to the major portion of the line itself, with only a very small offset portion of the line absorbing most of the expansion strain.

(c) Conditions of this type shall be avoided, particularly where materials of relatively low ductility are used; if unavoidable, they shall be mitigated by the judicious application of cold spring.

(d) It is recommended that the design of piping systems of austenitic steel materials be approached with greater overall care as to general elimination of local stress raisers, examination, material selection, fabrication quality, and erection.

ND-3672.7 Flexibility. Piping systems shall be designed to have sufficient flexibility to prevent pipe movements from causing failure from overstress of the pipe material or anchors, leakage at joints, or detrimental distortion of connected equipment resulting from excessive thrusts and moments. Flexibility shall be provided by changes of direction in the piping through the use of bends, loops, or offsets; or provisions shall be made to absorb thermal movements by utilizing expansion, swivel, or ball joints or corrugated pipe.

ND-3672.8 Expansion, Swivel, or Ball Joints. Expansion, swivel, or ball joints, if used, shall conform to the requirements and limitations of ND-3649.

ND-3673 Analysis

ND-3673.1 Method of Analysis. All systems shall be analyzed for adequate flexibility by a structural analysis unless one of the following conditions is met:

(a) The system can be judged technically adequate by an engineering comparison with previously analyzed systems.

(b) The operating temperature of the piping system is at or below 150°F (65°C) and the piping is laid out with inherent flexibility, as provided in ND-3672.7.

(c) The operating temperature of the piping system is at or below 250°F (120°C) and the piping is analyzed for flexibility using simplified methods of calculation such as handbooks or charts.

ND-3673.2 Basic Assumptions and Requirements.

(a) When calculating the flexibility of a piping system between anchor points, the system between anchor points shall be treated as a whole. The significance of all parts of the line and of all restraints, such as supports or guides, including intermediate restraints introduced for the purpose of reducing moments and forces on equipment or small branch lines, shall be considered.

(b) Comprehensive calculations shall take into account the flexibility factors found to exist in piping products or joints other than straight pipe. Credit may be taken where extra flexibility exists in such products or joints. Flexibility factors and stress intensification factors for commonly used piping products and joints are shown in Table ND-3673.2(b)-1 [see also Figure ND-3673.2(b)-2]. The stress intensification factors and flexibility factors in Table ND-3673.2(b)-1 shall be used unless specific experimental or analytical data exist that would warrant lower stress intensification factors or higher flexibility factors.

(c) Flexibility factors are identified herein by \( k \) with appropriate subscripts. The general definition of a flexibility factor is

\[
    k = \frac{\theta_{ab}}{\theta_{nom}}
\]

where

\[
    \theta_{ab} = \text{rotation of end } a, \text{ with respect to end } b, \text{ due to a moment load } M \text{ and in the direction of the moment } M
\]

\[
    \theta_{nom} = \text{nominal rotation assuming the component acts as a beam with the properties of the nominal pipe. For an elbow, } \theta_{nom} \text{ is the nominal rotation assuming the elbow acts as a curved beam}
\]
The flexibility factor \( k \) is defined in detail for specific components in Table ND-3673.2(b)-1.

(d) Stress intensification factors are identified herein by \( i \). The definition of a stress intensification factor is based on fatigue bend testing of mild carbon steel fittings and is

(US Customary Units)

\[ iS = 245,000 N^{-0.2} \]

(SI Units)

\[ iS = 1700 N^{-0.2} \]

where

\[ i = \text{stress intensification factor} \]
\[ S = \text{amplitude of the applied bending stress at the point of failure, psi (MPa)} \]

\[ N = \text{number of cycles to failure} \]

(e) For piping products or joints not listed in Table ND-3673.2(b)-1, flexibility or stress intensification factors shall be established by experimental or analytical means.

(f) Experimental determination of flexibility factors shall be in accordance with Section III Appendices, Mandatory Appendix II, II-1900. Experimental determination of stress intensification factors shall be in accordance with Section III Appendices, Mandatory Appendix II, Article II-2000.

(g) Analytical determination of flexibility factors shall be consistent with the definition above.

(h) Analytical determination of stress intensification factors may be based on the empirical relationship

\[ i = \frac{C_2 K_2}{2}, \text{ but not less than 1.0} \]

where \( C_2 \) and \( K_2 \) are stress indices for Class 1 piping products or joints from NB-3681(a)-1, or are determined as explained below.

Analytical determination of stress intensification factors shall be correlated with experimental fatigue results. Experimental correlation may be with new test data or with test data from similar products or joints reported in literature. Finite element analyses or other stress analysis methods may be used to determine \( C_2 \); however, test or established stress concentration factor data should then be used to determine \( K_2 \).

(i) For certain piping products or joints the stress intensification factor may vary depending on the direction of the applied moment, such as in an elbow or branch connection. For these cases, the stress intensification factor used in eqs. ND-3653.2(a)(10a), ND-3653.2(b)(10b) and ND-3653.2(c)(11) shall be the maximum stress intensification factor for all loading directions as determined in accordance with (f) or (h) above.

(j) Stress intensification factors determined in accordance with (f) above shall be documented in accordance with Section III Appendices, Mandatory Appendix II, II-2050. The test report may be included and certified with the Design Report (NCA-3551.1 and NCA-3555) for the individual piping system or a separate report furnished (Section III Appendices, Mandatory Appendix II, II-2050).

(k) Stress intensification factors determined in accordance with (h) above shall be documented in a report with sufficient detail to permit independent review. The report shall be included and certified as part of the design report for the piping system (NCA-3551.1 and NCA-3555).

(l) The total expansion range as determined from ND-3672.3 shall be used in all calculations, whether or not the piping is cold sprung. Expansion of the line, linear and angular movements of the equipment, supports, restraints, and anchors shall be considered in the determination of the total expansion range.

(m) Where simplifying assumptions are used in calculations or model tests, the likelihood of underestimates of forces, moments, and stresses, including the effects of stress intensification, shall be evaluated.

(n) Dimensional properties of pipe and fittings used in flexibility calculations shall be based on nominal dimensions.

(o) When determining stress intensification factors by experimental methods, ND-3653.3(d) shall not apply. The nominal stress at the point under consideration (crack site, point of maximum stress, etc.) shall be used.

**ND-3673.3 Cold Sprunging.** The beneficial effect of judicious cold springing in assisting a system to attain its most favorable position is recognized. Inasmuch as the life of a system under cyclic conditions depends on the stress range rather than the stress level at any one time, no credit for cold spring is allowed with regard to stresses. In calculating end thrusts and moments acting on equipment, the actual reactions at any one time, rather than their range, shall be used. Credit for cold springing is allowed in the calculations of thrusts and moments, provided the method of obtaining the designed cold spring is specified and used.

**ND-3673.4 Movements.** Movement caused by thermal expansion and loadings shall be determined for consideration of obstructions and design of proper supports.

**ND-3673.5 Computing Hot and Cold Reactions.**

(a) In a piping system with no cold spring or an equal percentage of cold springing in all directions, the reactions of \( R_h \) and \( R_c \), in the hot and cold conditions,
Proposal 19-2786

ND-3700  ELECTRICAL AND MECHANICAL PENETRATION ASSEMBLIES

ND-3720  DESIGN RULES

(a) The design of the pressure-retaining portion of electrical and mechanical penetration assemblies shall be the same as for vessels (ND-3300).

(b) For closing seams in electrical and mechanical penetration assemblies meeting the requirements of ND-4730(c), the closure head shall meet the requirements of ND-3325 using a factor C = 0.20. The fillet weld shall be designed using an allowable stress of 0.55.

ND-3800  DESIGN OF ATMOSPHERIC STORAGE TANKS

ND-3810  GENERAL REQUIREMENTS

ND-3811  Acceptability

The requirements for acceptability of atmospheric storage tanks are given in the following subparagraphs.

ND-3811.1  Scope. The design rules for atmospheric storage tanks cover vertical cylindrical flat bottom above ground welded tanks at atmospheric pressure. The tanks may contain liquids such as refueling water, condensate, borated reactor coolant, or liquid radioactive waste. Such tanks may be within building structures, depending upon external pressure resulting from earth or fill.

NOTE: These rules do not limit storage tanks from being installed below grade or below ground, provided the tanks are not subject to external pressure.

ND-3811.2  Design Requirements. The design rules for atmospheric storage tanks shall conform to the design requirements of ND-3100 and ND-3300, except as they may be modified by the requirements of this subarticle. The joint efficiency E shall be based on the requirements of ND-3352. The specific design requirements shall be stipulated in the Design Specifications.

ND-3812  Design Report

The manufacturer of a storage tank conforming to the design requirements of this subarticle is required to provide a Design Report as part of his responsibility of achieving structural integrity of the tank. The Design Report shall be certified when required by NCA-3550.

ND-3820  DESIGN CONSIDERATIONS

ND-3821  Design and Service Conditions

(a) Conditions shall be identified as Design or Service, and if Service they shall have Level A, B, C, or D Service Limits designated.

(b) The provisions of ND-3110 shall apply.

(c) The stress limits given in ND-3821.5 shall be met.

ND-3821.1  Design Pressure. The Design Pressure shall be atmospheric.

The limitation of the Design Pressure to atmospheric is not intended to preclude the use of these tanks at vapor pressure slightly above or below atmospheric within the range normally required to operate vent valves. If these pressures or vacuums exceed 0.03 psig (0.2 kPa gage), especially in combination with large diameter tanks, the forces involved may require special consideration in the design.

ND-3821.2  Design Temperature. The Design Temperature shall be not greater than 200°F (90°C).

ND-3821.3  Loadings. The requirements of ND-3111 shall be met.

ND-3821.4  Welded Joint Restrictions. The restrictions given in (a) through (c) below on type and size of joints or welds shall apply.

(a) Tack welds shall not be considered as having any strength value in the finished structure.

(b) The minimum size of fillet welds shall be in accordance with ND-4246.6.

(c) All nozzle welds shall be in accordance with ND-4246.5.

ND-3821.5  Limits of Calculated Stresses for Design and Service Loadings. Stress limits for Design and Service Loadings are specified in Table ND-3821.5-1. The symbols used in Table ND-3821.5-1 are defined as follows:

\[ S = \text{allowable stress value given in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3, psi (MPa). The allowable stress shall correspond to the highest metal temperature at the section under consideration during the loading under consideration.} \]

\[ \sigma_b = \text{bending stress, psi (MPa). This stress is equal to the linear varying portion of the stress across the solid section under consideration. It excludes discontinuities and concentrations, and is produced only by pressure and other mechanical loads.} \]

\[ \sigma_L = \text{local membrane stress, psi (MPa). This stress is the same as } \sigma_m, \text{ except that it includes the effect of discontinuities.} \]

\[ \sigma_m = \text{general membrane stress, psi (MPa). This stress is equal to the average stress across the solid section under consideration. It excludes discontinuities and concentrations, and is produced only by pressure and other mechanical loads.} \]

NOTE: Typical examples of locations and loadings for which \( \sigma_m, \sigma_L, \text{ and } \sigma_b \) are applicable are shown in Section III Appendices, Mandatory Appendix XIII, Table XIII-2600-1, with \( \sigma \) considered as equivalent to \( P \) in Section III Appendices, Mandatory Appendix XIII, Table XIII-2600-1.
ND-3900  DESIGN OF 0 psi TO 15 psi (0 kPa TO 100 kPa) STORAGE TANKS

ND-3910  GENERAL REQUIREMENTS

ND-3911  Acceptability

ND-3911.1  Scope. The design rules for 0 psi to 15 psi (0 kPa to 100 kPa) storage tanks shall cover above ground welded storage tanks. These tanks may contain liquids or gases such as refueling water, condensate, borated reactor coolant, or radioactive waste. Such tanks are normally located within building structures.

NOTE: These rules do not limit storage tanks from being installed below grade or below ground, provided the tanks are not subject to external pressure resulting from earth or fill.

ND-3911.2  Design Requirements.

(a) The design requirements for 0 psi to 15 psi (0 kPa to 100 kPa) storage tanks shall conform to the design rules of ND-3100 and ND-3300 except where they are modified by the requirements of this subarticle. The joint efficiency $E$ shall be based on the requirements of ND-3352. The specific design requirements shall be stipulated by the Design Specifications.

(b) The total liquid capacity of a tank shall be defined as the total volumetric liquid capacity below the high liquid design level. The nominal liquid capacity of a tank shall be defined as the total volumetric liquid capacity between the plane of the high liquid design level and the elevation of the tank grade immediately adjacent to the wall of the tank or such other low liquid design level as the Certificate Holder shall stipulate.

ND-3920  DESIGN CONSIDERATIONS

ND-3921  Design and Service Loadings

(a) Loadings shall be identified as Design or Service, and, if Service, they shall have Level A, B, C, or D Service Limits designated (NCA-2142).

(b) The provisions of ND-3110 shall apply.

(c) The stress limits of ND-3921.8 shall be met.

ND-3921.1  Design Pressure.

(a) At or Above Maximum Liquid Level. The walls of the gas or vapor space and other components shall be designed for a pressure not less than that at which the pressure relief valves are to be set. The relief valve set points shall allow a suitable margin from the pressure normally existing in this space so as to allow for the increases in pressure caused by variations in the temperature or gravity of the liquid contents of the tank and other factors affecting the pressure in the space. Walls and components in this space shall also be designed for the maximum

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Table ND-3865-3

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<th>Height of Rise, $R$, in. (mm)</th>
<th>Width of Run, $r$, in. (mm)</th>
<th>Angle</th>
<th>Height of Rise, $R$, in. (mm)</th>
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<td>$9$ (225)</td>
<td>$8$ (200)</td>
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</tr>
</tbody>
</table>

ASME BPVC.III.1.ND-2019  Proposal 19-2786 40 of 56
(c) Systems designed to withstand the maximum differential pressure do not require vacuum relief valves.

ND-7330 SYSTEM FAULTED CONDITIONS
This Article does not provide rules for overpressure protection of system faulted conditions.

ND-7400 SET PRESSURES OF PRESSURE RELIEF DEVICES

ND-7410 SET PRESSURE LIMITATIONS FOR EXPECTED SYSTEM PRESSURE TRANSIENT CONDITIONS

The stamped set pressure of at least one of the pressure relief devices connected to the system shall not exceed the Design Pressure of any component within the pressure-retaining boundary of the protected system. Additional pressure relief devices may have higher stamped pressures, but in no case shall all the set pressures be such that the total system pressure exceeds the system limitations specified in ND-7310.

ND-7420 SET PRESSURE LIMITATIONS FOR UNEXPECTED SYSTEM EXCESS PRESSURE TRANSIENT CONDITIONS

The establishment of the stamped set pressure shall take into account the requirements of ND-7320.

ND-7500 OPERATING AND DESIGN REQUIREMENTS FOR PRESSURE AND VACUUM RELIEF VALVES

ND-7510 SAFETY, SAFETY RELIEF, AND RELIEF VALVES

ND-7511 General Requirements

ND-7511.1 Spring-Loaded Valves. Valves shall open automatically by direct action of the fluid pressure as a result of forces acting against a spring.

ND-7511.2 Balanced Valves. Balanced valves, whose operation is independent of back pressure, may be used if means are provided to verify the integrity of the balancing devices.

(19) ND-7511.3 Restricted Lift Valves. The capacity of a Certification Mark with NV Designator-stamped valve may be reduced by the valve manufacturer provided the following limitations have been met:
(a) The valve size shall be NPS 3/4 (DN 20) or larger.
(b) The valve design shall be tested and the capacity shall be certified in accordance with the rules specified in ND-7731 and ND-7734.
(c) No changes shall be made in the design of the valve except to change the valve lift by use of the lift restraining device.

(d) The restriction of valve capacity is permitted only by the use of a lift restraining device, which shall limit valve lift and shall not otherwise interfere with flow through the valve.
(e) The lift restraining device is designed so that, if adjustable, the adjustable feature shall be sealed. Seals shall be installed in accordance with ND-7515.
(f) For air and gas service and for Classes 2 and 3 steam service other than main steam service, if a valve design has been tested in combination with a rupture disk in accordance with the requirements of Article ND-7000, restricted lift valves of this design may be used in combination with rupture disks without further testing. Valves shall not have their lift restricted to a value less than 30% of the full rated lift, nor less than 0.080 in. (2.0 mm).
(g) During production testing, the manufacturer shall assure that the set pressure, blowdown, and valve performance meet the applicable requirements of this Article and the valve Design Specification.

Valves beyond the capability of the production test facility, because of size or flow rate, may be adjusted for blowdown and performance based on test or experience data, or other adequate technical justification, to meet the requirements of this Article and the valve Design Specification. The basis for the manufacturer’s adjusting ring settings shall be documented in the Overpressure Protection Report (ND-7200).

(h) When sizing and selecting valves, the restricted lift capacity shall be determined by multiplying the capacity at full rated lift, as defined in ND-7734, by the ratio of the restricted lift to the full rated lift.

(i) Valves shall be marked in accordance with the relevant nameplate stamping provisions of ND-7800 modified as follows:
(1) Replace “capacity” with “restricted lift capacity.”
(2) Add “restricted lift ________ in. (mm).”

ND-7512 Safety Valve Operating Requirements

ND-7512.1 Antichattering and Lift Requirements.
Safety valves shall be constructed to operate without chattering and to attain rated lift at a pressure that does not exceed the set pressure by more than 3% or 2 psi (15 kPa), whichever is greater.

ND-7512.2 Set Pressure Tolerance.
(a) The set pressure tolerance plus or minus shall not exceed the following: 2 psi (15 kPa) for pressures up to and including 70 psi (480 kPa); 3% for pressures over 70 psi (480 kPa) up to and including 300 psi (2 MPa); 10 psi (70 kPa) for pressures over 300 psi (2 MPa) up to and including 1,000 psi (7 MPa); and 1% for pressures over 1,000 psi (7 MPa).

The set pressure tolerance shall apply unless a greater tolerance is established as permissible in the Overpressure Protection Report (ND-7200) and in the safety valve Design Specification (NCA-2350).
(b) Conformance with the requirements of (a) shall be established for each production valve by test. Steam valves shall be tested on steam. Alternative fluids may be used as the test media if the requirements of ND-7560 have been met.

ND-7512.3 Blowdown. Safety valves shall be adjusted to close after blowing down to a pressure not lower than that specified in the valve Design Specification (NCA-3250) and the basis for the setting is covered in the Overpressure Protection Report (ND-7200). The adjustment shall be determined by test or by proration from the Certificate Holder’s blowdown test data. Alternative fluids may be used as the test media if the requirements of ND-7560 have been met.

ND-7513 Safety Relief and Relief Valve Operating Requirements

Safety relief and relief valves shall be constructed to attain rated lift at a pressure that does not exceed the set pressure by more than 10% or 3 psi (20 kPa), whichever is greater.

(19) ND-7513.1 Set Pressure Tolerance.

(a) The set pressure tolerance plus or minus from the set pressure of safety relief and relief valves shall exceed 2 psi (15 kPa) for pressures up to and including 70 psi (480 kPa) and 3% for pressures above 70 psi (480 kPa).

The set pressure tolerance shall apply unless a greater tolerance is established as permissible in the Overpressure Protection Report (ND-7200) and in the valve Design Specification (NCA-3250).

(b) Conformance with the requirements of (a) shall be established for each production valve by test. Steam valves shall be tested on steam, air or gas valves on air or gas, and liquid valves on liquid. Alternative fluids may be used as the test media if the requirements of ND-7560 have been met.

ND-7513.2 Blowdown. Safety relief and relief valves shall be adjusted to close after blowing down to a pressure not lower than that specified in the valve Design Specification (NCA-3250) and the basis for the setting shall be covered in the Overpressure Protection Report (ND-7200). The adjustment shall be determined by test or by proration from the Certificate Holder’s blowdown test data. Alternative fluids may be used as the test media if the requirements of ND-7560 have been met.

ND-7514 Credited Relieving Capacity

The credited relieving capacity of safety, safety relief, and relief valves shall be based on the certified relieving capacity. In addition, the capacity can be prorated as permitted by ND-7700.

ND-7515 Sealing of Adjustments

Means shall be provided in the design of all valves for sealing all adjustments or access to adjustments that can be made without disassembly of the valve. For a pilot-operated pressure relief valve, an additional seal shall be provided to seal the pilot and main valve together. Seals shall be installed by the Certificate Holder at the time of initial adjustment. Seals shall be installed in a manner to prevent changing the adjustment or disassembly of the valve without breaking the seal. The seal shall serve as a means of identifying the Certificate Holder making the initial adjustment.

ND-7520 PILOT-OPERATED PRESSURE RELIEF VALVES

ND-7521 General Requirements

Pilot-operated pressure relief valves shall operate independently of any external energy source.

ND-7522 Operating Requirements

ND-7522.1 Actuation. The pilot control device shall be actuated directly by the fluid pressure of the protected system.

2 Response Time. The Overpressure Protection Report (ND-7200) shall include the effects of divergence between opening (set) and closing (blowdown) pressures of the pilot valve and the pressures at which the main valve attains rated lift and closes. These divergences are caused by the inherent time delay (i.e., response time) between the operation of the pilot and the main valve, and the rate of the system pressure change. The limits for response time shall be specified in the valve Design Specification (NCA-3250).

ND-7522.3 Main Valve Operation. The main valve shall operate in direct response to the pilot control device. The valve shall be constructed to attain rated lift under stable conditions at pressures that do not exceed the set pressure by more than 3% or 2 psi (15 kPa), whichever is greater, for steam, and 10% or 3 psi (20 kPa), whichever is greater, for air, gas, or liquid service.

ND-7522.4 Sensing Mechanism Integrity. For other than spring loaded direct acting pilot control devices, means shall be provided to detect failure of the pressure-sensing element, such as bellows, when operation of the pilot control device is dependent upon the integrity of a pressure-sensing element.

ND-7522.5 Set Pressure Tolerance. (19)

(a) The set pressure tolerance shall apply only to the pilot valve.

(b) The set pressure tolerance plus or minus shall not exceed the following:

(1) 2 psi (15 kPa) for pressures up to and including 70 psi (480 kPa)
(2) 3% for pressures over 70 psi (480 kPa) for liquid valves, and 3% for pressures over 70 psi (480 kPa) up to and including 300 psi (2 MPa).

(3) 10 psi (70 kPa) for pressures over 300 psi (2 MPa) up to and including 1,000 psi (7 MPa).

(4) 1% for pressures over 1,000 psi (7 MPa) for steam, air, and gas valves.

The set pressure tolerance as stated shall apply unless a greater tolerance is established as permissible in the Overpressure Protection Report (ND-7200) and the valve Design Specification (NCA-3250).

(c) Conformance with the requirements of (b) above shall be established for each production valve by test. Steam valves shall be tested on steam, air, or gas valves or air or gas, and liquid valves on liquid. Alternative fluids may be used as the test media if the requirements of ND-7560 have been met.

ND-7522.6 Blowdown.

(a) The blowdown requirements shall only apply to the pilot valve.

(b) Pilot-operated valves shall be adjusted to close after blowing down to a pressure not lower than that specified in the valve Design Specification (NCA-3250) and the basis for the setting is covered in the Overpressure Protection Report (ND-7200).

(c) The adjustment shall be determined by test or by proration from the Certificate Holder's blowdown test data. Alternative fluids may be used as the test media if the requirements of ND-7560 have been met.

ND-7523 Credited Relieving Capacity

The credited relieving capacity of pilot-operated pressure relief valves shall be based on the certified relieving capacity. In addition, the capacity may be prorated as permitted in ND-7700.

ND-7524 Sealing of Adjustments

The sealing requirements of ND-7515 shall apply.

ND-7530 POWER-ACTUATED PRESSURE RELIEF VALVES

ND-7531 General Requirements

Power-actuated pressure relief valves, which depend upon an external energy source such as electrical, pneumatic, or hydraulic systems and that respond to signals from pressure or temperature sensing devices, may be used, provided the requirements of this sub-subarticle are met.

ND-7532 Operating Requirements

ND-7532.1 Response Time. In systems protected by power operated pressure relief valves, consideration shall be given to the time lapse between the signal to open and achieving the fully opened position and to the time lapse between the signal to close and achieving the fully closed position.

ND-7532.2 Sensors, Controls, and External Energy Sources.

(a) The sensors, controls, and external energy sources for valve operation shall have redundancy and independence at least equal to that required for the control and safety protection systems associated with the system.

(b) The relief valve and its auxiliary devices treated as a combination shall comply with the following requirements:

(1) The valve opening pressure shall be controlled within a tolerance as specified in ND-7512.2 of the set pressure when the automatic control is in use.

(2) The valve blowdown shall be controlled to a pressure not lower than that specified in the valve Design Specification (NCA-3250).

ND-7533 Certified Relieving Capacity

The power-actuated pressure relief valve certified relieving capacity and the proration of capacity shall be as determined by ND-7700.

ND-7534 Credited Relieving Capacity

ND-7534.1 Expected System Pressure Transient Conditions. For expected system pressure transient conditions, the relieving capacity with which these valves are credited shall be not more than

(a) the certified relieving capacity of the smaller one when two valves are installed;

(b) one-half of the total certified relieving capacity when three or more valves are installed.

ND-7534.2 Unexpected System Excess Pressure Transient Conditions. For unexpected system excess pressure transient conditions, the relieving capacity with which these valves are credited shall not be more than

(a) the relieving capacity of the valve with the smaller stamped capacity where two valves are installed;

(b) the relieving capacity of all except the valve with the largest certified capacity for valves where three through ten valves are installed;

(c) the relieving capacity of all except two valves of the largest certified capacity where more than ten valves are installed.

ND-7540 SAFETY VALVES WITH AUXILIARY ACTUATING DEVICES

ND-7541 General Requirements

Safety valves with auxiliary actuating devices that operate independently of the spring loading of the valve may be used, provided the requirements of ND-7510 are met except as modified by this sub-subarticle.
III
RULES FOR CONSTRUCTION
OF NUCLEAR FACILITY
COMPONENTS

Division 1 - Subsection NF

Supports

ASME Boiler and Pressure Vessel Committee
on Construction of Nuclear Facility Components
ARTICLE NF-1000
INTRODUCTION

NF-1100 SCOPE AND GENERAL REQUIREMENTS

NF-1110 ASPECTS OF CONSTRUCTION COVERED BY THESE RULES

(a) Subsection NF contains rules for the material, design, fabrication, examination, installation, and preparation of certification documents (Certificate of Compliance and NS-1 Certificate of Conformance) for supports for components and piping which are intended to conform to the requirements for Class 1, 2, 3, and MC construction as set forth in Subsections NB, NC, ND, and NE, respectively, of this Section.

(b) They do not cover deterioration that may occur in service as a result of corrosion, erosion, radiation effects, or metallurgical instability of the materials (NCA-1130).

(c) Nuclear power plant supports (NCA-9200 provides the definitions of “support” and other terms) for which the rules are specified in this Subsection are those metal elements which transmit loads between components (NCA-1210), including piping systems, and intervening elements and the building structure. However, the term support does not encompass a structural element the function of which is to carry dynamic loads caused by a postulated loss of pressure-retaining integrity.

(d) The Owner shall be responsible for assuring the adequacy of the building structure and all intervening elements in the support load path in accordance with the requirements of NCA-3240 and NCA-2250. To the extent necessary, the support designer shall consider the structural interaction with intervening elements and the building structure.

(e) Except for the requirements listed in (1) through (11), the requirements of Subsection NF do not apply to bearings, bushings, gaskets, hydraulic fluids, seals, shims, slide plates, retaining rings, wear shoes, springs, washers, wire rope, compression spring end plates, thread locking devices, cotter pins, sight glass assemblies, spring hanger travel and hydro stops, nameplates, nameplate attachment devices, padding between piping and supports, or for compression dynamic stops used as stops (stops do not include snubbers and dampers; see NF-3412.4 and NF-3412.5) for seismic and other dynamic loads that are designed primarily for compressive loading and are not connected to the support or pressure boundary.

(1) The material of the exempt items shall be selected to tolerate the environmental conditions to which they will be exposed, such as temperature, fluids, humidity, and irradiation.

(2) The exempt item shall be designed for the loading conditions and other requirements identified in the Design Specification.

(3) Design Output Documents (NCA-3550) shall indicate items that are exempt.

(4) Materials, fabrication, and installation of the exempt items shall comply with Design Output.

(5) Class 1 springs shall be inspected in accordance with NF-2520.

(6) Washers shall comply with the requirements of NF-2128(b) and NF-4700.

(7) Wire rope shall comply with the requirements of NF-2530 and Article NF-3000.

(8) Compression spring end plates shall comply with the requirements of Articles NF-3000, NF-4000, NF-5000, and NF-8000.

(9) Compression dynamic stops shall comply with the requirements of Articles NF-3000, NF-4000, NF-5000, and NF-8000.

(10) Thread locking devices shall comply with the requirements of NF-4725.1.

(11) The means by which exempt items are attached to supports shall comply with the applicable requirements of this Subsection.

NF-1120 RULES FOR SUPPORTS AND THEIR CLASSIFICATION

NF-1121 Rules for Supports

The rules of Subsection NF provide requirements for new construction and include consideration of mechanical loads which result from the constraint of free end displacements and anchor point motions defined in NF-3121.12 and NF-3121.13, but not thermal or peak stresses.

NF-1122 Classification of Supports

Supports shall be constructed to the requirements of this Subsection that are applicable to the class of the component, including piping system, they are intended to support. Supports may be optionally classified as permitted in NCA-2134. When the components are optionally classified to a higher class as permitted in NCA-2134(d), the support need not be classified to the higher class.
NF-2150 MATERIAL IDENTIFICATION

The identification of material requiring Certified Material Test Reports shall meet the requirements of NCA-4256. Material furnished by a Material Organization with Certificates of Compliance shall be identified by a controlled system meeting the requirements of the applicable material specification, grade, and class. Identification of the material to the Material Organization’s Certificate of Compliance is not required after the support manufacturer has verified that the material meets the requirements of this Section. Material for small items shall be controlled during the manufacture of the supports so that they are identifiable as acceptable material at all times. Welding material shall be controlled during the repair of material and the manufacture and installation of supports so that it is identifiable as acceptable material until the material is actually consumed in the process (NF-4122).

NF-2160 DETERIORATION OF MATERIAL IN SERVICE

Consideration of deterioration of material caused by service is generally outside the scope of this Subsection. It is the responsibility of the Owner to select material suitable for the conditions stated in the Design Specifications (NCA-3250), with specific attention being given to the effect of Service Conditions upon the properties of the material.

NF-2170 HEAT TREATMENT TO ENHANCE IMPACT PROPERTIES

Carbon steel, low alloy steels, and high alloy chromium (Series 4XX) steels may be heat treated by quenching and tempering to enhance their impact properties. Postweld heat treatment of the support at a temperature of not less than 1,100°F (595°C) may be considered to be the tempering phase of the heat treatment.

NF-2180 PROCEDURES FOR HEAT TREATMENT OF MATERIAL

When heat treating temperature or time is required by the material specification and the rules of this Subsection, the heat treating shall be performed in temperature-surveyed and temperature-calibrated furnaces or the heat treating shall be controlled by measurement of material temperature thermocouples in contact with the material or attached to blocks in contact with the material or by calibrated pyrometric instruments. Heat treating shall be performed under furnace loading conditions such that the heat treatment is in accordance with the material specification and the rules of this Subsection.

NF-2200 MATERIAL TEST COUPONS AND SPECIMENS FOR FERRITIC STEEL MATERIAL

NF-2210 HEAT TREATMENT REQUIREMENTS

NF-2211 Test Coupon Heat Treatment for Ferritic Material

If ferritic steel material is subjected to heat treatment during construction of a support, the material used for the impact test specimens shall be heat treated in the same manner as the support, except that test coupons and specimens for P-No. 1 Group Nos. 1 and 2 material with a nominal thickness of 2 in. (50 mm) or less are not required to be so heat treated. The support manufacturer shall provide the Material Organization with the temperature and heating and cooling rate to be used. In the case of postweld heat treatment, the total time at temperature or temperatures for the test material shall be at least 80% of the total time at temperature or temperatures during actual postweld heat treatment of the material, and the total time at temperature or temperatures for the test material, coupon, or specimen may be performed in a single cycle.

NF-2212 Test Coupon Heat Treatment for Quenched and Tempered Material

NF-2212.1 Cooling Rates. When ferritic steel material is subjected to quenching from the austenitizing temperature, the test coupons representing those materials shall be cooled at a rate similar to and no faster than the main body of the material except in the case of certain forgings and castings (NF-2223.3 and NF-2226.4). This rule shall apply for coupons taken directly from the material as well as for separate test coupons representing the material, and one of the general procedures described in NF-2212.2 or one of the specific procedures described in NF-2220 shall be used for each product form.

NF-2212.2 General Procedures. One of the general procedures in (a), (b), and (c) may be applied to quenched and tempered material or test coupons representing the material, provided the specimens are taken relative to the surface of the product in accordance with NF-2220. Further specific details of the methods to be used shall be the obligation of the Material Organization and the Certificate Holder.

(a) Any procedure may be used which can be demonstrated to produce a cooling rate in the test material that matches the cooling rate of the main body of the product within 25°F (14°C) and 20 sec at all temperatures after cooling begins.

(b) If cooling rate data for the material and cooling rate control devices for the test specimens are available, the test specimens may be heat treated in the device to represent the material, provided that the provisions of (a) are met.
NF-2224 Bars and Bolting Material

NF-2224.1 Location of Coupons. Coupons shall be taken so that specimens shall have their longitudinal axes at least \( \frac{1}{4} t \) from the outside or rolled surface and with the midlength of the specimen at least \( t \) from a heat-treated end, where \( t \) is either the bar diameter or thickness.

NF-2224.2 Bolting Material. For bolting material, the coupons shall be taken in conformance with the applicable material specification and with the midlength of the specimen at least one diameter or thickness from a heat-treated end. When the studs, nuts, or bolts are not of sufficient length, the midlength of the specimen shall be at the midlength of the studs, nuts, or bolts. The studs, nuts, or bolts selected to provide test coupon material shall be identical with respect to the quenched contour and size, except for length, which shall equal or exceed the length of the represented studs, nuts, or bolts.

NF-2225 Tubular Products and Fittings

NF-2225.1 Location of Coupons. Coupons shall be taken so that specimens shall have their longitudinal axes at least \( \frac{1}{4} t \) from the inside or outside surface and with the midlength of the specimen at least \( t \) from a heat-treated end, where \( t \) is the nominal wall thickness of the tubular product.

NF-2225.2 Separately Produced Coupons Representing Fittings. Separately produced test coupons representing fittings may be used. When separately produced coupons are used, the requirements of NF-2223.3 shall be met.

NF-2226 Castings

NF-2226.1 Castings With 2 in. (50 mm) Maximum Thickness and Less. For castings with a maximum thickness of 2 in. (50 mm) and less, the specimens shall be taken from either the standard separately cast coupons or the casting, in accordance with the material specification.

NF-2226.2 Castings With Thicknesses Exceeding 2 in. (50 mm) Maximum Thickness. For castings exceeding a thickness of 2 in. (50 mm), the coupons shall be taken from the casting (or an extension of it) so that specimens shall have their longitudinal axes at least \( \frac{1}{4} t \) of the maximum heat-treated thickness from any surface and with the midlength of the specimens at least \( t \) from any second surface. A thermal buffer may be used [NF-2212.2(c)(3)].

NF-2226.3 Separately Cast Test Coupons for Castings With Thicknesses Exceeding 2 in. (50 mm). In lieu of the requirements of NF-2226.2, separately cast test coupons may be used under the conditions of (a) through (c).

(a) The separate test coupon representing castings from one heat and one heat-treated lot shall be of the same heat of material and shall be subjected to substantially the same foundry practices as the production casting it represents.

(b) The separate test coupon shall be heat treated in the same furnace charge and under the same conditions as the production casting, unless cooling rates applicable to the bulk castings are simulated in accordance with NF-2212.2.

(c) The separate test coupon shall not be less than \( 3t \times 3t \times t \), where \( t \) equals the nominal thickness of the casting. Test specimens shall be taken with their longitudinal axes at the region midway between midthickness and the surface and with the midlength of the specimens no nearer any heat-treated edge than a distance equal to the casting thickness.

NF-2226.4 Castings Machined or Cast to Finished Configuration Before Heat Treatment. In lieu of the requirements of NF-2226.1, NF-2226.2, or NF-2226.3, test coupons may be removed from prolongations or other stock provided on the product. The coupons shall be taken so that specimens shall have their longitudinal axes at a distance below the nearest heat-treated surface equivalent at least to the greatest distance that the indicated high tensile stress surface will be from the nearest surface during heat treatment and with the midlength of the specimens a minimum of twice this distance from a second heat-treated surface. In any case, the longitudinal axes of the specimens shall be at least \( \frac{3}{4} \) in. (19 mm) from any heat-treated surface and the midlength of the specimens shall be at least 1\( \frac{1}{2} \) in. (38 mm) from any second heat-treated surface. The Certificate Holder shall specify the surfaces of the finished product subjected to high tensile stresses in service.

NF-2227 Rolled Shapes

For rolled shapes, the coupons shall be taken so that specimens shall have their longitudinal axes on a line representing the center of the thickest element of the shape and with the midlength of the specimen at least \( t \) from a heat-treated end.

NF-2300 Fracture Toughness Requirements for Material

NF-2310 Material to Be Impact Tested

NF-2311 Supports for Which Impact Testing of Material Is Required

When impact testing is required, the methods of Section III Appendices, Nonmandatory Appendix G may be used as an alternative design procedure for assuring protection against nonductile failure.

(a) Support materials shall be impact tested in accordance with the requirements listed below.

(1) Attachments to the component or piping shall meet the requirements for impact testing stipulated in the applicable Subsection.

(2) Class 1, 2, 3, and MC component supports shall meet the requirements of NF-2300.
(3) For Class 1, 2, and 3 piping supports, Class 1, 2, and 3 Standard Supports, and all other types and Classes of supports, the Design Specification (NCA-3250) shall state whether or not impact testing is required for the material of which the support is constructed. When impact testing is required, the tests shall meet the requirements of NF-2300 for Class 1, 2, 3, or MC, respectively, and shall become a requirement of this Subsection.

(b) The requirements for supports shall be as specified in NF-2300, except that the materials described in (1) through (13) are not to be impact tested as a requirement in NF-2300, except that the materials described in (1) and shall become a requirement of this Subsection.

1 Material with a nominal section thickness of \( \frac{5}{8} \) in. (16 mm) and less.

2 Bolting, including studs, nuts, and bolts, with a nominal size of 1 in. (25 mm) and less.

3 Bars with a nominal cross-sectional area of 1 in.\(^2\) (650 mm\(^2\)) and less.

4 Material for fittings with all pipe connections of \( \frac{5}{8} \) in. (16 mm) nominal wall thickness and less.

5 Austenitic stainless steels, including precipitation-hardened austenitic Grade 660 (UNS S66286).

6 Nonferrous materials.

7 Material for supports when the maximum stress does not exceed 6,000 psi (40 MPa) tension or is compressive.

8 Rolled structural shapes, when the thickness of a flange is \( \frac{5}{8} \) in. (16 mm) or less.

9 Materials for Class 1, 2, or MC supports, listed in Table NF-2311(b)-1, for thicknesses \( \frac{21}{2} \) in. (64 mm) and less when the Lowest Service Temperature\(^2\) is at least 30°F (15°C) above the tabulated temperature. This exemption from impact testing does not apply to either the weld metal (NF-2430) or the weld procedure qualification (NF-4335).

10 Materials for Class 3 supports, listed in Table NF-2311(b)-1, for thicknesses \( \frac{21}{2} \) in. (64 mm) and less, when the Lowest Service Temperature is equal to or greater than the tabulated temperature. This exemption from impact testing does not apply to either the weld metal (NF-2430) or the weld procedure qualification (NF-4335).

11 Materials for Class 2 and MC supports for which the Lowest Service Temperature exceeds 150°F (65°C).

12 Materials for Class 3 supports for which the Lowest Service Temperature exceeds 100°F (38°C).

13 Materials for Class 2, 3, and MC supports for which the Lowest Service Temperature (LST) is equal to or above the Minimum Design Metal Temperature of Figure NF-2311(b)-1 for the materials listed and the applicable material thicknesses.

(c) The Design Specification (NCA-3250) shall state the Lowest Service Temperature (LST) for the support and the designated impact test temperature, when required.

### Table NF-2311(b)-1

<table>
<thead>
<tr>
<th>Material Condition</th>
<th>Material Condition</th>
<th>( T_{NDT} ), °F (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Note (1)]</td>
<td>[Note (1)]</td>
<td>[Note (2)], [Note (3)]</td>
</tr>
<tr>
<td>SA-537, Class 1</td>
<td>N</td>
<td>-30 (−35)</td>
</tr>
<tr>
<td>SA-516, Grade 70</td>
<td>Q &amp; T</td>
<td>-10 (−25)</td>
</tr>
<tr>
<td>SA-516, Grade 70</td>
<td>N</td>
<td>0 (−18)</td>
</tr>
<tr>
<td>SA-508, Class 1</td>
<td>Q &amp; T</td>
<td>+10 (10)</td>
</tr>
<tr>
<td>SA-533, Grade B</td>
<td>Q &amp; T</td>
<td>+10 (10)</td>
</tr>
<tr>
<td>SA-299 [Note (4)]</td>
<td>N</td>
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<tr>
<td>SA-216, Grades WCB, WCC</td>
<td>Q &amp; T</td>
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</tr>
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<td>SA-36 (Plate)</td>
<td>HR</td>
<td>+40 (5)</td>
</tr>
<tr>
<td>SA-508, Class 2</td>
<td>Q &amp; T</td>
<td>+40 (5)</td>
</tr>
</tbody>
</table>

**NOTES:**

1 Material Condition letters refer to:

| N | Normalize |
| Q & T | Quench and Temper |
| HR | Hot Rolled |

2 These values for \( T_{NDT} \) were established from data on heavy section steel [thickness greater than \( \frac{21}{2} \) in. (64 mm)]. Values for sections less than \( \frac{21}{2} \) in. (64 mm) thick are held constant until additional data are obtained.

3 \( T_{NDT} \) is temperature at or above nil-ductility transition temperature (ASTM E208); \( T_{NDT} \) is 10°F (5.6°C) below the temperature at which at least two specimens show no-break performance.

4 Materials made to a fine grain melting practice.

### NF-2320 IMPACT TEST PROCEDURES

#### NF-2321 Charpy V-Notch Tests

The Charpy V-notch test (C\(_v\)), when required, shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Figure 11, Type A. A test shall consist of a set of three full-size 10 mm × 10 mm specimens. The lateral expansion and absorbed energy, as applicable, and the test temperature, as well as the orientation and location of all tests performed to meet the requirements of NF-2330 shall be reported in the Certified Material Test Report.

#### NF-2322 Location and Orientation of Test Specimens

Impact test specimens for quenched and tempered material shall be removed from the locations and orientation specified for tensile test specimens in each product form in NF-2220 except that for plates the orientation of the impact test specimens shall be longitudinal. For material in other heat-treated conditions, impact test specimens shall be removed from the locations and orientations specified for tensile test specimens in the material specification except that for plates the orientation of the impact specimens shall be longitudinal, and for structural shapes
ARTICLE NF-3000
DESIGN

NF-3100 GENERAL DESIGN REQUIREMENTS

NF-3110 LOADING CRITERIA

NF-3111 Loading Conditions

The loadings that shall be taken into account in designing a support include, but are not limited to, those in the following:

(a) weight of the piping or component and normal contents under plant and system operating and test conditions, including loads due to static and dynamic head and fluid flow effects
(b) weight of the support
(c) superimposed static and thermal loads and reactions induced by the supported system components
(d) dynamic loads, including loads caused by earthquake and vibration
(e) effects from piping thermal expansion
(f) anchor and support movement effects
(g) environmental loads such as wind and snow loads
(h) expansion or contraction of a component produced by internal or external pressure

Guidelines for classification of these loadings into primary, secondary, or peak are listed in NF-3120 and NF-3220.

NF-3112 Design Loadings

The Design Loadings shall be established in accordance with NCA-2142.1 and NF-3112.1 through NF-3112.3.

NF-3112.1 Design Temperature. The specified Design Temperature shall be established in accordance with NCA-2142.1(b). The metal temperature shall be determined by computation using accepted heat transfer procedures or by measurement from equipment in service under plant and system equivalent operating conditions. In lieu of heat transfer analysis or measurements, the component or piping Design Temperature may be used. In no case shall the temperature at the surface of the metal exceed the maximum temperature listed in Section II, Part D, Subpart 1, Tables 1A, 1B, 2A, 2B, 3, 4, and Y-1, or exceed the maximum temperature limitations specified elsewhere in this Subsection.

NF-3112.2 Design Mechanical Loads. The specified Design Mechanical Loads shall be established in accordance with NCA-2142.1(c), and shall include all loads from the component or piping acting on the support.

NF-3112.3 Design Stress Intensity and Allowable Stress Values. When the procedures of design by analysis (NF-3220) are employed, the applicable design stress intensity values \( S_m \) listed in Section II, Part D, Subpart 1, Table 2A, 2B, and 4 shall be used. When the procedures of linear elastic analysis (NF-3320) are employed, the allowable stress values shall be the applicable yield strength values \( S_y \) listed in Section II, Part D, Subpart 1, Table Y-1 as modified by the design factors given in NF-3322. The material shall not be used at metal and design temperatures that exceed the temperature limit in the applicability column for which stress or stress intensity values are listed. The values in the tables may be interpolated for intermediate temperatures.

NF-3113 Service Conditions

Each Service Condition to which the piping or component may be subjected shall be categorized in accordance with NCA-2142.2, and Service Limits [NCA-2142.4(b)] shall be designated in the Design Specification in such detail as will provide a complete basis for design in accordance with this Article.

NF-3114 Test Conditions

The component and piping support loadings resulting from test conditions shall be identified (NCA-2142).

NF-3115 Design Interface

The design interface between the support and the component shall be established in the Design Specifications (NCA-3254). In order to establish the interface loads, a system analysis is performed (Section III Appendices, Mandatory Appendix XXVII, XXVII-1410). In some cases, the design procedures or service limits permitted for supports in this Article could result in support behavior different from that utilized in the system analysis. If necessary, the support Design Specification shall restrict the design procedure or establish more restrictive limits to reflect those utilized in the system analysis.

NF-3120 DESIGN CONSIDERATIONS

NF-3121 Terms Relating to Design by Analysis

NF-3121.1 General Considerations.

(a) Terms that are common to the design by stress analysis of Plate- and Shell-Type, Linear-Type, and Standard Supports are defined in NF-3121.2 through NF-3121.17.
**NF-3133 Stress Analysis**

A detailed stress analysis or Design Report, as required by NCA-3550 for all supports, shall be prepared in sufficient detail to show that each of the stress limits of NF-3200 or NF-3300 is satisfied when the support is subjected to the loadings of NF-3110.

**NF-3134 Support Tolerances**

(a) Tolerances shall be specified by the designer in the design output documents. Fabrication tolerances and local installation tolerances as contained in Nonmandatory Appendix NF-D are only mandatory when invoked by the designer.

(b) When specifying the support tolerances, the support designer shall consider the piping support location/orientation tolerances specified by the piping designer (Section III Appendices, Nonmandatory Appendix T, T-1230).

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**Table NF-3131(a)-1**

Reference Paragraphs for Procedures for Design of Component Supports, Piping Supports, and Standard Supports

<table>
<thead>
<tr>
<th>Type and Class of Support</th>
<th>Plate and Shell</th>
<th>Linear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design by Analysis</td>
<td>Bolting</td>
</tr>
<tr>
<td>Component</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 1</td>
<td>NF-3220, NF-3225, NF-3226, NF-3270, NF-3280</td>
<td></td>
</tr>
<tr>
<td>Class 2 and MC [Note (1)]</td>
<td>NF-3250, NF-3255, NF-3256, NF-3270, NF-3280</td>
<td></td>
</tr>
</tbody>
</table>

Piping

| Class 1                   | NF-3220, NF-3225, NF-3226, NF-3270, NF-3280 |          | NF-3220, NF-3225, NF-3226, NF-3270, NF-3280 |          | NF-3200, NF-3224, NF-3324, NF-3370, NF-3380 |
| Class 2                   | NF-3250, NF-3255, NF-3256, NF-3270, NF-3280 |          | NF-3250, NF-3255, NF-3256, NF-3270, NF-3280 |          | NF-3200, NF-3224, NF-3324, NF-3370, NF-3380 |

Standard

| Class 1 [Note (1)]        | NF-3220, NF-3225, NF-3226, NF-3270, NF-3280 |          | NF-3220, NF-3225, NF-3226, NF-3270, NF-3280 |          | NF-3200, NF-3224, NF-3324, NF-3370, NF-3380 |
| Class 2 [Note (1)]        | NF-3250, NF-3255, NF-3256, NF-3270, NF-3280 |          | NF-3250, NF-3255, NF-3256, NF-3270, NF-3280 |          | NF-3200, NF-3224, NF-3324, NF-3370, NF-3380 |

**NOTE:**

(1) Supports for Class 2 vessels designed to NC-3200 shall be designed in accordance with Class 1 requirements.

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**NF-3140 GENERAL DESIGN PROCEDURES**

**NF-3141 Types of Procedures**

(a) The design procedure which may be used is dependent on the type of support being designed and the Class of construction involved. Three design procedures are recognized, namely

1. design by analysis
   - (a) maximum shear stress theory
   - (b) maximum stress theory

2. experimental stress analysis (Section III Appendices, Mandatory Appendix II)

3. load rating

(b) Unless either the experimental stress analysis procedure or the load rating procedure is used, the requirements of the following paragraphs apply.
NF-3282.4 Alternative Load Rating Method Using $TL_u$ or $TL_y$ Test Results Only. Either $TL_u$ or $TL_y$ test results may be used to establish a support load rating, provided the load rating as determined by the method of NF-3282.2 or NF-3282.3 is modified as follows:

(a) For load rating based on $TL_y$ test results only

(1) for supports constructed of materials having definitely determinable yield points and specified minimum $S_T/S_T$ ratios not greater than 0.625, the load rating shall be multiplied by 0.83. If $S_{(act)}$ of the material is not known, 0.67 shall be used in place of multiplier 0.83

(2) for supports constructed of carbon steel with specified minimum tensile strengths of not over 70,000 psi (485 MPa), $S_{(act)}$ shall be increased by 5,000 psi (34 MPa) prior to determining the load rating

(3) for all other materials the determined load rating shall be multiplied by 0.67

For supports loaded in compression, a $TL_u$ test shall be performed with the compressive load rating determined in accordance with NF-3282.3.

(b) For load rating based on $TL_u$ test results, the determined load rating shall be multiplied by 0.50.

NF-3300 DESIGN RULES FOR LINEAR-TYPE SUPPORTS

NF-3310 GENERAL REQUIREMENTS

This subarticle provides rules for the design of Linear-Type Supports by either linear elastic analysis (NF-3320) or plastic (limit) analysis (NF-3340). Linear elastic analytical procedures are also provided (NF-3330) for the design of members and connections which will be subjected to high cycle fatigue conditions in service.

NF-3311 Design Considerations

NF-3311.1 Linear Elastic Analysis. The rules for linear elastic analysis are based on the yield strength values at temperature of the materials used in constructing linear-type supports that are set forth in Section II, Part D, Subpart 1, Table Y-1. The allowable stresses are determined in NF-3320 by applying factors of safety dependent on the structural member involved to these yield strength values.

NF-3311.2 High Cycle Fatigue Analysis. The rules for designing Linear-Type Supports given in NF-3330 are essentially the same as those given in NF-3320 for linear elastic analysis, except that the maximum range of stress, namely, the difference between the minimum and maximum value of the stress throughout each cycle and the frequency with which the support will be subjected to this range of stress, shall be taken into consideration when so stipulated by the Design Specification (NCA-3250).

NF-3311.3 Limit Analysis. The rules for limit (plastic) analysis given in NF-3340 may be used as an alternative to the linear elastic analysis method. These rules permit proportioning Linear-Type Supports on the basis of limit design by determining their lower bound collapse loads. The requirements set forth in NF-3320 governing allowable stresses to be used in designing Linear-Type Supports are waived when the limit design procedure is employed, but all other pertinent provisions of NF-3320 shall apply.

NF-3311.4 Basis for Determining Stress in Design by Analysis. The theory of failure used in the rules for the design of Linear-Type Supports is the maximum stress theory. In the maximum stress theory, the controlling stress is the maximum principal stress.

NF-3311.5 Terms Relating to Design by Analysis. Terms used in the design of Linear-Type Supports by stress analysis are defined in NF-3313.

NF-3312 Analysis Methods

Linear-Type Supports may be designed by either elastic or limit analysis, limits for which are given in NF-3312.1.

NF-3312.1 Elastic Analysis. In elastic analysis it is assumed that all component and support stiffnesses remain constant.

(a) Design Limits. The rules and stress limits that must be satisfied in an elastic analysis for any Design Loading shall be stated in the Design Specification.

(b) Service Limits, Level A Through D. The rules and stress limits which must be satisfied in an elastic analysis for any Level A through D Service Loading stated in the Design Specification are those given in NF-3321 multiplied by the appropriate stress limit factor from Table NF-3312.1(b)-1.

(c) Test Limits. The rules and stress limits that must be satisfied for any Test Loadings stated in the Design Specification are those given in NF-3321 multiplied by the appropriate stress limit factor in Table NF-3312.1(b)-1 under Test Loadings.

NF-3313 Nomenclature and Numbering of Equations

NF-3313.1 Nomenclature. Except where symbols are used in the text of the paragraphs that follow to represent the value of complex algebraic expressions, the nomenclature adopted in NF-3300 is defined as follows:

\[
A = \text{gross area of an axially loaded compression member, in.}^2 (\text{mm}^2) \\
a = \text{clear distance between transverse stiffeners; dimension parallel to the direction of stress, Table NF-3332.3-1, in. (mm)}
\]
(9) Fillet Welds in Holes and Slots. Fillet welds in holes or slots may be used to transmit shear in lap joints or to prevent the buckling or separation of lapped parts and to join elements of built-up members. Such fillet welds may overlap, subject to the provisions of (6). Fillet welds in holes or slots are not to be considered plug or slot welds.

(e) Plug and Slot Welds

(1) Use of Plug and Slot Welds. Plug and slot welds may be used to transmit shear in a lap joint or to prevent buckling of lapped parts and to join component parts of built-up members.

(2) Diameter of Holes for Plug Welds. The diameter of the holes for a plug weld shall be not less than the thickness of the part containing it plus \( \frac{7}{16} \) in. (8 mm), rounded to the next greater odd \( \frac{1}{16} \) in. (1.5 mm), nor greater than the minimum diameter plus \( \frac{7}{8} \) in. (3 mm) or \( \frac{2}{14} \) times the thickness of the weld metal.

(3) Spacing of Plug Welds. The minimum center-to-center spacing of plug welds shall be four times the diameter of the hole.

(4) Length of Slot Welds. The length of slot for a slot weld shall not exceed 10 times the thickness of the weld. The width of the slot shall be not less than the thickness of the part containing it plus \( \frac{3}{16} \) in. (8 mm), rounded to the next greater odd \( \frac{1}{16} \) in. (1.5 mm), nor greater than the minimum diameter plus \( \frac{3}{8} \) in. (3 mm) or \( \frac{2}{14} \) times the thickness of the weld metal.

(5) Spacing of Slot Welds. The minimum spacing of lines of slot welds in a direction transverse to their length shall be four times the width of the slot. The minimum center to center spacing in a longitudinal direction on any line shall be two times the length of the slot.

(6) Thickness of Plug and Slot Welds. The thickness of plug and slot welds in material \( \frac{7}{8} \) in. (16 mm) or less in thickness shall be equal to the thickness of the material. In material over \( \frac{7}{8} \) in. (16 mm) in thickness, it shall be at least one-half the thickness of the material but not less than \( \frac{3}{8} \) in. (16 mm).

(7) Effective Shearing Area of Plug and Slot Welds. The effective shearing area of plug and slot welds shall be considered as the nominal cross-sectional area of the hole or slot in the plane of the faying surface.

(f) Full Penetration and Partial Penetration Joints. The effective area shall be the effective weld length multiplied by the effective throat thickness.

(1) The effective weld length for any groove weld, square or skewed, shall be the length of weld throughout which the correct proportioned cross section exists. In a curved weld it shall be its true length measured along its curvature.

(2) The effective throat thickness of a full penetration groove weld which shall conform to the requirements of Article NF-4000 shall be the thickness of the thinner part joined. No increase is permitted for weld reinforcement.

(3) The effective throat of partial penetration groove welds is dependent upon the type of groove.

(a) For square, U, and J groove welds, the effective throat is equal to the depth of preparations.

(b) For V and bevel groove welds with an included angle at the root equal to or greater than 60 deg, the effective throat shall be the minimum distance from the root to the face of the weld.

(c) For V and bevel groove welds with an included angle at the root less than 60 deg but equal to or greater than 45 deg, the effective throat shall be the minimum distance from the root to the face of the weld less \( \frac{7}{8} \) in. (3 mm).

(d) For V and bevel groove welds, with an included angle at the root less than 45 deg but equal to or greater than 30 deg, the effective throat shall be the minimum distance from the root to the face of the weld less \( \frac{1}{16} \) in. (3 mm) and multiplied by 0.75. The required effective throat must be specified on the drawing.

(e) For V and bevel groove welds, angles less than 30 deg at the root are not allowed.

(f) For flare bevel groove welds, when filled flush to the surface, the effective throat shall be 0.31 times the outside radius of the curved section forming the groove. For formed rectangular tubing, the outside radius may be considered as two times the wall thickness.

(g) For flare V groove welds, when filled flush to the surface, the effective throat shall be 0.5 [except use 0.375 for GMAW when \( R \geq \frac{1}{2} \) in. (13 mm)] times the outside radius.

(g) Consideration of Lamellar Tearing. Welded joint configurations causing significant through-thickness tensile stress [as defined in NF-1215(b)] during fabrication and/or service on rolled product forms should be avoided. However, if this type of construction is used, the designer should consider one or several of the following factors that may reduce the susceptibility of the joint to experience lamellar tearing and provide documentation, including fabrication requirements, in the Design Output Documents:

(1) Reduce volume of weld metal to the extent practical.

(2) Select materials that are resistant to lamellar tearing.

(3) Invoke any of the special fabrication requirements of NF-4441.

NF-3324.6 Design Requirements for Bolted Joints. The rules and stress limits for bolting shall be as given in this paragraph. The stress limits which must be satisfied for any Design, Levels A through D, and Test Loadings, shall be those given in this paragraph, multiplied by the appropriate stress limit factors given in Table NF-3225.2-1 for the particular loading specified in the Design Specification (NCA-3250). This product shall not exceed the yield strength of the material at temperature.
ARTICLE NF-4000
FABRICATION AND INSTALLATION

NF-4100  GENERAL REQUIREMENTS

NF-4110  INTRODUCTION

NF-4111  Fabrication and Installation

Supports shall be fabricated and installed in accordance with the requirements of this Article and shall be manufactured from material which meets the requirements of Article NF-2000.

NF-4112  Reassembly of Subsection NF Supports

The Certificate Holder may reassemble supports from completed supports that have not been in operating service or from parts and material of disassembled supports that have not been in operating service, provided all required documentation is available and the applicable Code requirements are met.

The program for maintaining identification of material and parts, including material documentation and certification documents (Certificate of Compliance and NS-1 Certificate of Conformance) shall be described in a written procedure.

NF-4120  CERTIFICATION OF MATERIALS AND FABRICATION BY SUPPORT CERTIFICATE HOLDER

NF-4121  Means of Certification

The NS Certificate Holder for a support shall certify Code compliance by the furnishing of an NS-1 Certificate of Conformance (NCA-3686) for welded supports or a Certificate of Compliance (NCA-3689) for nonwelded supports.

NF-4121.1  Certification of Treatments, Tests, and Examinations. If the Certificate Holder performs treatments, tests, repairs, or examinations required by Articles of this Section, he shall certify that he has fulfilled that requirement (NCA-3861[c]). Reports of all required treatments and the results of all required tests, repairs, and examinations performed by the NS Certificate Holder shall be maintained as quality assurance records in accordance with NCA-4134.17.

NF-4121.2  Repetition of Tensile or Impact Tests. If during the fabrication or installation of the support the material is subjected to heat treatment that has not been covered by treatment of the test coupons (NF-2200) and that may reduce either the tensile or impact properties below the required values, the tensile and impact tests shall be repeated by the Certificate Holder on test specimens taken from test coupons which have been taken and treated in accordance with the requirements of Article NF-2000.

NF-4122  Material Identification

Material for supports shall carry identification markings which will remain distinguishable until the support is fabricated or installed. If the original identification markings are cut off or the material is divided, the marks shall be accurately transferred to the parts or a coded marking shall be used to assure identification of each piece of material during subsequent fabrication or installation, unless otherwise provided by NF-2150. Material supplied with a Certificate of Compliance and welding and brazing material shall be identified and controlled so that they can be traced to each support, or else a control procedure shall be employed which ensures that the specified material is used.

NF-4123  Visual Examinations

Visual examination activities that are not referenced for examination by other specific Code paragraphs, and are performed solely to verify compliance with requirements of NF-2000, may be performed by the persons who perform or supervise the work. These visual examinations are not required to be performed by personnel and procedures qualified to NF-5500 and NF-5100, respectively, unless so specified.

NF-4125  Testing of Welding and Brazing Materials

All welding and brazing materials shall meet the requirements of NF-2400.

NF-4130  REPAIR OF MATERIAL

NF-4131  Elimination and Repair of Defects

Material originally accepted on delivery in which defects exceeding the limits of NF-2500 are known or discovered during the process of fabrication or installation is unacceptable. The material may be used provided the condition is corrected in accordance with the requirements of NF-2500 for the applicable product form, except (a) weld repair is not required if the defect is removed by mechanical means and does not reduce the section below the minimum thickness required by Article NF-3000 (b) when weld repair is performed
III
RULES FOR CONSTRUCTION
OF NUCLEAR FACILITY
COMPONENTS

Appendices

ASME Boiler and Pressure Vessel Committee
on Construction of Nuclear Facility Components
NONMANDATORY APPENDIX T
RECOMMENDED TOLERANCES FOR RECONCILIATION OF PIPING SYSTEMS

ARTICLE T-1000
INTRODUCTION AND SCOPE

T-1100 INTRODUCTION

The building structure and major components of a power plant are constructed according to rules that permit varied tolerances. Since piping system installation follows construction of the building and installation of the major components, the piping systems must be permitted to vary within the space allotted to them. In addition, a large number of systems are often installed in a limited space. Interferences often occur and changes within Installation Tolerances may be used to eliminate the interference. The tolerances provided in this Appendix bridge the gap between the exactness associated with a design by analysis, and a practical and acceptable installation.

The basis for the tolerances and guidance in this Appendix was developed by the PVRC Technical Committee on Piping Systems. Additional guidance on implementation of these tolerances has been published by EPRI.

T-1110 SCOPE

This Appendix provides recommended tolerances and methods for satisfying the requirements of NCA-3554, "Modification of Documents and Reconciliation With Design Report" for piping systems designed to the rules of NB-, NC-, or ND-3600. The use of this Appendix is limited to piping systems designed to the rules of Section III Division 1, Subsections NB, NC, and ND; and Section III Division 5, Subsection HB, Subpart A and Subsection HC, Subpart A. This Appendix may be used by other Section III Divisions if a justification for its use consistent with that developed by the PVRC Technical Committee on Piping is provided and the justification is included in the Design Report. This Appendix provides:

(a) identification of dimensions and weights significant to the piping stress analysis; and

(b) acceptable tolerances for these dimensions and weights such that if piping is installed within these tolerances, the reconciliation is accomplished.

These tolerances have been established such that their effect on the accuracy of analysis results is minimal and is consistent with accepted practices and the use of tolerances in the Code. These tolerances are applicable to most situations; however, specific situations where more restrictive tolerances may be needed are identified.

The tolerances in this Appendix are applicable to piping systems where conventional seismic analysis methods were used for the original design, i.e., modal response spectrum analysis methods. For piping systems where seismic analysis methods that are significantly more sensitive to the tolerances were used in the original design (i.e., seismic time history analysis methods), the Designer shall review the applicability of these tolerances and establish more stringent guidelines if necessary. Further, this Appendix shall be restricted to piping systems analyzed using linear elastic methods.

This Appendix does not relieve the Designer of responsibility for consideration of other unique situations where more restrictive tolerances may be required to satisfy the intent of the design bases or the Code.

Installation Tolerances more restrictive than the Total Tolerances recommended in this Appendix may be specified. Less restrictive tolerances may be specified when engineering justification is provided to demonstrate that the design requirements have been satisfied.

Tolerances for complete, installed piping systems are addressed. Tolerances provided for manufacturing or fabricating the individual items or subassemblies that make up piping systems are not addressed, but the effect of these tolerances on the as-installed condition shall be within the Total Tolerance. Other design and construction areas which may be included in reconciliation such as design or operating conditions, support details, and gaps are not addressed.

Tolerances for support erection, including length and orientation of individual members and pipe location on the support, are specified in Subsection NF, Appendix NF-D, Tolerances.
NONMANDATORY APPENDIX CC
ALTERNATIVE RULES FOR LINEAR PIPING SUPPORTS

ARTICLE CC-1000
INTRODUCTION

CC-1100 INTRODUCTION

CC-1110 SCOPE AND GENERAL REQUIREMENTS

CC-1111 Scope of This Appendix

This Appendix provides alternative rules to the requirements of Division 1, Subsections NCA and NF, and Division 5, Subsection HA and Subsection HF, Subpart A for Linear Piping Supports that are constructed to ANSI/AISC N690-1994, “Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities,” including Supplement 2, ANSI/AISC N690–1994 (R2004) S2, and the requirements of this Appendix.

CC-1112 General Requirements

(a) When this Appendix is used, the Owner or his designee shall provide a Design Specification (NCA-3252, NCA-3255) that permits the use of this Appendix and identifies the loadings and combinations of loadings for which the supports are to be designed. The Design Specification shall contain sufficient detail to provide a complete basis for construction of the supports.

(b) The Owner or his designee shall perform a documented review of the calculations for each support to determine that all the specified loadings have been evaluated and that the acceptance criteria provided in this Appendix and in ANSI/AISC N690 have been considered. The responsibility for the method of analysis and the accuracy of the calculations remains with the designer.

(c) The supports shall be constructed under a Quality Assurance Program that meets the requirements specified by the Owner.