NC-3500 VALVE DESIGN

NC-3510 GENERAL REQUIREMENTS

NC-3511 Design Specification

Design and Service Conditions (NCA‐2142) 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.

Please replace "NC" with "NCD" everywhere throughout NC-3500. Previously Board approved record 16-2225 must be incorporated as well. Record 16-2225 addresses both NC and ND, but since edits are consistent, only the NC portion need be considered.
Figure NC-3451(a)-1
Horizontal Single-Acting Power Pump Liquid Ends

(a)

(b)
NC-3512 Standard Design Rules

NC-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:

\[ t_m = 0.4t_o + 0.2 \text{ for } d \leq 50 \text{ in.} \{1,250 \text{ mm} \} \]

or

\[ t_m = 0.008d + 0.2 \text{ for } d > 50 \text{ in.} \{1,250 \text{ mm} \} \]

where

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

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

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

(b) 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.

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

(2) 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.

NC-3512.2 Socket Welding End and Nonwelding End Valves. The design of valves with socket welding end connections and nonwelding end connections other than ASME B16.5 flanges shall conform to the applicable requirements for Standard Class category butt welding end valves of ASME B16.34, except that the end connections shall conform to the applicable requirements of NC-3661 or NC-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 NC-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 NC-3661, NC-3671.3, or NC-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 NC-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.

(f) The valve’s design shall be qualified and a maximum pressure–temperature rating shall be determined in accordance with the requirements of MSS SP-105, Section 5. A lesser pressure–temperature rating may be applied to the valve.

(g) Valves shall be hydrostatic tested per the requirements of NC-3531 at pressures appropriate for the valve’s applied pressure rating.

NC-3512.3 Wafer or Flangeless Valves. The design of valves that can be bolted between flanges (i.e., butterfly valves) shall conform to the applicable requirements of Standard Class category valves of ASME B16.34 and the requirements of (a) through (e) below.

(a) The design shall provide for bolt-up using all of the bolt holes and the bolt circle of the specified flange.

(b) Bolt holes parallel to the body run may be either threaded or unthreaded. threaded holes may be blind holes suitable for use with bolt studs.

(c) The required minimum valve body wall thickness shall be measured from the valve inside circumference to either the valve outside circumference or the circumference of a circle inscribed about the inner tangents to the bolt holes, whichever is smaller.
(d) The inner ligament of either a through hole or a blind threaded hole in the vicinity of a stem penetration shall not be less than 25% of the required body neck thickness.

(e) The inner ligament for singular holes parallel to the body run shall not be less than 25% of the required valve body wall thickness. Such holes shall not be larger than \( \frac{3}{6} \) in. (10 mm) diameter.

NC-3512.4 Design and Service Loadings. The design requirements of NC-3512.1 and NC-3512.2 include pressure-temperature ratings for Design Loadings and Service Loadings for which Level A Limits are designated. When any Service Loadings are stipulated for which Level B, Level C, or Level D Limits are designated in the Design Specification, the requirements of NC-3520 shall be met.

NC-3512.5 Openings for Auxiliary Connections. Openings for auxiliary connections, such as for drains, bypasses, and vents, shall meet the requirements of ASME B16.34 and the applicable requirements of NC-3330.

NC-3513 Alternative Design Rules

For butt welding end valves and for socket welding end valves whose end connections conform to the requirements of NC-3661, the design requirements for Special Class category valves of ASME B16.34 may be used in place of NC-3512 when permitted by the Design Specification, provided that the following requirements are met.

(a) The nondestructive examination requirements of ASME B16.34, Special Class, shall be met for all sizes of butt welding and socket welding end valves in accordance with the examination methods and acceptance standards of NC-2500.

(b) When any Service Loadings are stipulated for which Level B, Level C, or Level D Limits are designated in the Design Specification, the requirements of NC-3520 shall be met.

(c) Openings for auxiliary connections, such as for drains, bypasses, and vents, shall meet the requirements of ASME B16.34 and the applicable reinforcement requirements of NC-3330.

NC-3515 Acceptability of Metal Bellows and Metal Diaphragm Stem Sealed Valves

Valves using metal bellows or metal diaphragm stem seals shall be constructed in accordance with the rules of this subarticle, based on the assumption that the bellows or diaphragms do not retain pressure and Design Pressure is imposed on a required backup stem seal such as packing. The bellows or diaphragms need not be constructed in accordance with the requirements of this Section.

NC-3516 Acceptability of Elastomer Diaphragm Valves

Valves using elastomer diaphragms, wherein the diaphragm performs the function of a disc or plug, shall be constructed in accordance with NC-3500. This is based on the assumptions that the diaphragms do not retain pressure, Design Pressure is imposed on the backup stem seal, and the additional requirements below.

(a) Design temperature shall not exceed 350°F (175°C).

(b) Valve size and Pressure Class shall not exceed NPS 12 (DN 300) for Class 150 and NPS 4 (DN 100) for Class 300.

(c) A backup stem seal shall be provided.

(d) Diaphragms shall meet the requirements of MSS SP-100.

NC-3520 SERVICE LOADING LIMITS

NC-3521 General Requirements

(a) When the piping system in which the valve is located is designed to the requirements of NC-3600, the valve body is considered adequate to withstand piping end loads, provided that conditions (1) and (2) below are satisfied. In lieu of (1) and (2), the design procedure of NB-3545.2 is acceptable.

(1) The section modulus and metal area at a plane normal to the flow passage through the region at the valve body crotch, that is, in the plane A–A of Figure NC-3521-1, shall be not less than 110% of the section modulus and metal area of the piping connected to the valve body inlet and outlet nozzles.

(2) The allowable stress for valve body material is equal to or greater than the allowable stress of the connected piping material. If the valve body material allowable stress is less than that of the connected piping material, the valve section modulus and metal area shall be not less than 110% of the section modulus and metal area of the connected piping multiplied by the ratio \( \frac{S_{pipe}}{S_{valve}} \).

(b) The maximum internal pressure resulting from Service Loadings for which Level A, Level B, Level C, or Level D limits are designated shall not exceed the tabulated factors in Table NC-3521-1 times the Design Pressure or the rated pressure at the applicable service temperature. If these pressure limits are met, loadings for the stress limits in Table NC-3521-1 are considered to be satisfied. Conversely, if the stress limits in Table NC-3521-1 are met, the factored pressure limit, \( P_{max} \), need not be met.

(c) Where valves are provided with operators having extended structures and these structures are essential to maintaining pressure integrity, an analysis, when required by the Design Specification, shall be performed based on static forces resulting from equivalent earthquake accelerations acting at the center of gravity of the extended masses. The valve bodies shall conform to the stress limits listed in NC-3522. Classical bending
Figure NC-3521-1
Typical Sections of Valve Bodies

(a)  
(b)  
(c)  
(d)  
(e)
and direct stress equations, where free body diagrams determine a simple stress distribution that is in equilibrium with the applied loads, may be used.

### (19) NC-3522 Stress and Pressure Limits

Stress and pressure limits for service loadings are specified in Table NC-3521-1. The symbols used in Table NC-3521-1 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.
- $\sigma_b$: 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.
- $\sigma_L$: local membrane stress, psi (MPa). This stress is the same as $\sigma_m$ except that it includes the effect of discontinuities.
- $\sigma_m$: 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.

### NC-3530 GENERAL RULES

#### NC-3531 Hydrostatic Tests

The following requirements apply to valves designated to either NC-3512 or NC-3513.

**NC-3531.1 Shell Hydrostatic Test.** A shell hydrostatic test shall be made using either water or air in accordance with the requirements of ASME B16.34. Stem seal leakage during this test is permissible. Hydrostatic tests for metal bellows of metal diaphragm stem sealed valves shall include hydrostatic testing of the valve body, bonnet, body-to-bonnet joint, and either the bellows or diaphragm or the required backup stem seal. End closure seals for retaining fluid at test pressure in welding end valves may be positioned in the welding end transitions as defined in ASME B16.34 in reasonable proximity to the end plane of the valve so as to ensure safe application of the test pressure.

**NC-3531.2 Valve Closure Test.** After the shell hydrostatic test, a valve closure test shall be performed in accordance with ASME B16.34, except that all valve sizes shall be subjected to a test differential pressure across the valve disk not less than 110% of the 100°F (38°C) pressure rating. During this test, seat leakage value is defined by the Design Specification.

**NC-3531.3 Time at Pressure.** The duration of the shell hydrostatic test shall meet the requirements of NC-6223. The duration of the valve closure test shall be the greater of either 1 min/in. (2.5 sec/mm) of minimum wall thickness $t_m$ or the testing time requirement of ASME B16.34, but not less than 1 min.

**NC-3531.4 Exemptions to the Valve Closure Test.**

(a) For valves that are designed for Service Conditions that have the pressure differential across the closure member limited to values less than the 100°F (38°C) pressure rating, or that have closure members or actuating...
devices (direct, mechanical, fluid, or electrical) that would be subject to damage at high differential pressures, the test pressure may be reduced to 110% of the maximum specified differential pressure in the closed position. This exception shall be identified in the Design Specification, and this maximum specified differential pressure shall be noted on the valve nameplate and the N Certificate Holder’s Data Report Form.

(b) For valves designed for nonisolation service, the primary function of which is to modulate flow, and which by their design are prevented from providing full closure, the valve closure test defined in NC-3531.2 is not required. This exception shall be identified in the Design Specification and noted on the valve nameplate and the N Certificate Holder’s Data Report Form.

NC-3590 PRESSURE RELIEF VALVE DESIGN

NC-3591 Acceptability

NC-3591.1 General Requirements. The rules of this subsubarticle constitute the requirements for the design acceptability of spring loaded pressure relief valves. The design rules for pilot-operated and power-actuated pressure relief valves are covered by NC-3500. The rules of this subsubarticle cover the pressure-retaining integrity of the valve inlet and outlet connections, nozzle, disk, body structure, bonnet (yoke), and body-to-bonnet (yoke) bolting. The rules of this subsubarticle also cover other items such as the spring, spindle (stem), spring washers, and set pressure adjusting screw. The rules of this subsubarticle do not apply to guides, control rings, bearings, set screws, and other non-pressure-retaining items. Figures NC-3591.1-1 and NC-3591.1-2 are illustrations of typical pressure relief valves.

NC-3591.2 Definitions. The definitions for pressure relief valve terms used in this subsubarticle are given in ASME Section II, Part D, Subpart 1, Tables 1A, 1B, and 3.

NC-3592 Design Considerations

NC-3592.1 Design Conditions. The general design requirements of NC-3100 are applicable, with consideration for the design conditions of the primary and secondary pressure zones. In case of conflict between NC-3100 and NC-3590, the requirements of NC-3590 shall apply. Mechanical loads for both the closed and open (full discharge) positions shall be considered in conjunction with the service conditions. In addition, the requirements of Article NC-7000 shall be met.

NC-3592.2 Stress Limits for Specified Service Loadings.

(a) Level A Service Loadings. Stress limits for Level A service loadings for the valve shall be as follows.

1. The general membrane stress shall not exceed $S$.
2. The general membrane stress plus bending stress shall not exceed $1.5S$.
3. Substantiation by analysis of localized stresses associated with contact loading of bearing or seating surfaces is not required.
4. The values of $S$ shall be in accordance with Section II, Part D, Subpart 1, Tables 1A, 1B, and 3.

(b) Levels B, C, and D Service Loadings. Stress limits for Levels B, C, and D service loadings are specified in Table NC-3592.2(b)-1.

NC-3593 Special Rules

NC-3593.1 Hydrostatic Test. Pressure relief valve shell hydrostatic tests shall be made in accordance with NC-3531.1 and NC-3531.3 except that the inlet (primary pressure-containing) portion of the pressure relief valve shall be shell tested at a pressure at least equal to 1.5 times the set pressure marked on the valve. For closed system application, the outlet portion of the pressure relief valve shall be shell tested to 1.5 times the design secondary pressure (NC-7111).

NC-3593.2 Marking. In addition to marking required by NCA-8220 and Article NC-7000, the secondary Design Pressure shall be marked on the valve or valve nameplate.

NC-3594 Service Loading Limits

(a) When the piping system in which the valve is located is designed to the requirements of NC-3600, the valve body may be considered adequate to withstand piping end loads, provided that conditions (1) and (2) below are satisfied.

1. The section modulus and metal area at a plane normal to the flow passage through the region at the valve inlet and outlet (Figures NC-3591.1-1 and NC-3591.1-2) shall be not less than 110% of the section modulus and metal area of the piping connected (or joined) to the valve inlet and outlet.
Figure NC-3591.1-1
Typical Pressure Relief Devices

Open Bonnet

Closed Bonnet

Yoke

Adjusting screw

Bonnet (closed)

Spring washers

Spindle (stem)

Balancing piston (if required)

Bellows (if required)

Guide

Secondary pressure zone

Control rings

Body

Primary pressure zone

Nozzle

Cap

Disk

Record 19-1995
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Figure NC-3591.1-2
Typical Pressure Relief Devices

- Cap
- Adjusting screw
- Bonnet (closed)
- Spring
- Spring washers
- Spindle (stem)
- Guide
- Secondary pressure zone
- Control rings
- Body
- Primary pressure zone
- Nozzle
- Safety Relief Valve
- Relief Valve
- Nozzle
### Table NC-3592.2(b)-1
Pressure Relief Devices Service Loading Limits

<table>
<thead>
<tr>
<th>Service Loading</th>
<th>Stress Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level B</td>
<td>$\sigma_m \leq 1.1S$</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 NOTES:**
(a) A casting quality factor is not required to satisfy these limits.
(b) The above limits are not intended to ensure the functional adequacy of the valve. However, the designer is cautioned that the requirements of Article NC-7000 relative to set pressure, lift, blowdown, and closure shall be met.
(c) The above limits are applicable to those portions of the valves that are pressure retaining or affect pressure-retaining items of these valves.

(2) The allowable stress for valve body material shall be equal to or greater than the allowable stress of the connected piping material. If the valve body material allowable stress is less than that of the connected piping material, the valve section modulus and metal area shall be not less than 110% of the section modulus and metal area of the connecting pipe multiplied by the ratio $\frac{\delta_{pipe}}{S_{valve}}$.

(b) The pressure-retaining portions of pressure relief valves shall conform to the stress limits listed in Table NC-3592.2(b)-1 for those Service Loadings stipulated as Level B, C, or D.

(c) Pressure relief valves have extended structures, and these structures are essential to maintaining pressure integrity. An analysis, when required by the Design Specification, shall be performed based on static forces resulting from equivalent earthquake accelerations acting at the centers of gravity of the extended masses. Classical bending and direct stress equations, where free body diagrams determine a simple stress distribution that is in equilibrium with the applied loads, may be used.

**NC-3595 Design of Pressure Relief Valve Parts**

**NC-3595.1 Body.** Minimum wall thicknesses of valve bodies shall conform to the applicable requirements for Standard Class category valves of ASME B16.34, taking into account the dimensional and pressure conditions of the primary and secondary zones. Minimum wall thickness adjacent to the inlet nozzle and for a distance equal to that minimum wall thickness from the plane of the back face of the inlet flange shall be that required for Standard Class category valves of ASME B16.34 for the inlet flange size and pressure class. Minimum wall thicknesses elsewhere in the secondary zone shall be determined by the requirements for Standard Class category valves of ASME B16.34 for the outlet flange size and pressure class, including such other rules and considerations of ASME B16.34 as may be applicable. In valve design where the outlet flange is an extension of the bonnet, the bonnet design shall conform to these rules. Where the inlet flange geometry involves inside contours encroaching on the metal section boundary represented by dimension B in Tables 9, 12, 15, 18, 21, 24, or 27 in ASME B16.5, adequacy of the design shall be proven by stress calculation in accordance with NC-3658. Additional metal thickness needed for operating stresses, shapes other than circular, stress concentrations, and adequate structural strength of valve body crotch areas for bending stresses and installation stress that may be imposed on the valve must be determined by the manufacturer.

**NC-3595.2 Bonnet (Yoke).** The bonnet (yoke) may be analyzed using classic bending and direct stress equations, with appropriate free body diagrams. The general membrane stress and the general membrane stress plus bending stress shall not exceed the stress limits of NC-3592.2.

**NC-3595.3 Nozzle.** The minimum wall thickness of the nozzle shall be determined from the limit on general membrane stress. Alternatively, the rules of NB-3594.3 may be used. These requirements are not applicable to the transition region to the seat contacting area of the nozzle defined by $L$ in Figure NC-3595.3-1, provided the dimension $L$ is less than the nominal wall thickness $t$.

**NC-3595.4 Body-to-Bonnet Joint.** For valves having inlet piping connections NPS 2 (DN 50) and less, body-to-bonnet connections may be threaded. The thread shear stress, considering all loadings, shall not exceed 0.6 times the allowable stress $S$. The body-to-bonnet bolting shall be designed to resist the hydrostatic end force of the rated maximum secondary Design Pressure combined with the total spring load to full lift, and to maintain sufficient compression for a tight joint on the gasket or joint contact surface. The bolt stresses for these loadings shall not exceed the allowable stress values of Section II, Part D, Subpart 1, Table 3.

**NC-3595.5 Disk.** The stress evaluation shall be made for the condition that results in the maximum stress in the disk. The bending stress shall not exceed the stress limits of NC-3592.2.

**NC-3595.6 Spring Washer.** The shear stress shall not exceed 0.6.S. The bending stress shall not exceed the stress limits of NC-3592.2.

**NC-3595.7 Spindle (Stem).** The general membrane stress shall not exceed the stress limits of NC-3592.2.
**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 $0.6S$. 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.