\[
F_D = \frac{2(2 - \mu) P_{lD}^2}{(16 P_{lD} + t_{vD}(\sigma_{lD})^2)}
\]

(7)

where

- \( A_D \) = the mean diameter of the vaned portion of the bowl as defined in Figure NCD-3441.10-2, in. (mm).
- \( F_D \) = vane load/unit length, lbf/in. (N·mm)
- \( l_{D} \) = the radial mean vane length as defined in Figure NCD-3441.10-2, in. (mm)
- \( n_v \) = the number of vanes in the bowl waterway
- \( P_b \) = the maximum internal bowl differential pressure, psi (MPa)
- \( t_{D} \) = the shell thickness at the vane-shell intersection as defined in Figure NCD-3441.10-2, in. (mm)
- \( t_{v} \) = the mean vane thickness, in. (mm)
- \( \mu \) = Poisson’s ratio

The local shell bending stress \( \sigma_v \) shall be less than 1.5SE. Its value is determined by the equation

\[
\sigma_v = \frac{F_D}{t_v}
\]

(8)

(3) Bowl Flanges. Flanged joints in the bowls shall be designed in accordance with (a) except that the design pressure shall be \( P_b \). The equivalent pressure shall be determined using eq. (a)(1)(1), as applied to the bowl geometry and shall be not less than the maximum differential pressure that can be developed across the wall of that bowl under any Service Condition. Unpacked flange joints are permitted. The flange joint between the individual bowl discharge flange and the next stage bowl inlet flange is usually such that the outlet flange rotational restraint is insufficient to restrict outlet flange rotation. Therefore, the prying action between flat faced flanges can be ignored and the outlet flange shall be analyzed in accordance with Section III Appendices, Mandatory Appendix XI. This may not be true for ribbed flanges or the last stage bowl that attaches to the column assembly. The definition of the outlet flange geometry for the analysis is shown in Figure NCD-3441.10-2.

The minimum radial distance between the bolt circle and the outside of the bowl or the inside rabbet fit shall be equal to or greater than one bolt nominal diameter.

(c) Suction Bell. The Design Pressure for the suction bell \( P_{sb} \) shall be determined as the sum of the differential pressure developed at the first stage of the pump under any service condition plus an equivalent pressure to account for moments on the suction bell. The equivalent pressure shall be calculated using eq. (a)(1)(1), with \( F = 0 \) in eq. (a)(1)(2), except using the geometry of the suction bell. The suction bell pressure, \( P_{sb} \) is applied only to the suction bell flange. Below the suction bell flange (Section A–A of Figure NCD-3441.10-1), the remaining portion of the bell and any strainer basket that may be attached thereto are not considered subject to a differential pressure load.

NCD-3441.11 For Class 2 Only — Type N Pumps.

(a) Type N pumps have radially split, multistage barrel type casings with single nozzles each for suction and discharge, radially disposed with respect to the shaft axis [Figure NCD-3441.11-1, sketch (a)].

The design shall be in accordance with the applicable requirements of NCD-3400.

(b) Minimum transition radii at critical sections of the barrel shall be limited to 0.2 in.

(c) The circumferential pitch between drilled and tapped holes shall be a minimum of 2d where d is the nominal diameter of the bolt or stud [Figure NCD-3441.11-1, sketch (b)].

(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 NCD-3441.11-1, sketch (c)].

NCD-3442 Special Pump Types

NCD-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.

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

NCD-3450 DESIGN OF CLASS 2 RECIPROCATING PUMPS

NCD-3451 Scope

(a) These rules cover the strength and pressure integrity of the structural parts of the liquid end [Figure NCD-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
Figure NCD-3441.11-1
Type N Pump

(a)

(b) (c)
Figure NCD-3451(a)-1
Horizontal Single-Acting Power Pump Liquid Ends

(a)

(b)
(b) These rules do not apply to the plunger or piston, nonstructural internals, including valves, valve seats, gaskets, packing, and cylinder mounting bolt. Hydrostatic testing of packing glands is not required.

NCD-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 NCD-3100 are satisfied in addition to these rules.

NCD-3453 Material and Stresses

Material and allowable stresses shall conform to the requirements of Article NCD-2000.

NCD-3454 Design Requirements

NCD-3454.1 Design of Welded Construction.

(a) Design of welded construction shall be in accordance with NCD-3350.

(b) Partial penetration welds, as shown in Figure NCD-4244.1-5 sketch (c-3) and Figure NCD-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.

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

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

NCD-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.

NCD-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.

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

NCD-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.

NCD-3500 VALVE DESIGN

NCD-3510 GENERAL REQUIREMENTS

NCD-3511 Design Specification

Design and Service Conditions (NCA-2142) shall be stipulated in the Design Specification (NCA-3211.19(b)). The requirements of NCA-3211.19(c)(1)(-a) for specifying the location of valve boundary jurisdiction may be considered to have been met by employing the minimum limits of NCD-1131, unless the Design Specification extends the boundary of jurisdiction beyond these minimum limits. The requirements of NCA-3211.19(c)(1)(-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.

NCD-3512 Standard Design Rules

NCD-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:

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

or

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

where

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

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

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