area provided multiplied by the ratio of the nozzle or reinforcement material design stress value to the vessel material design stress value. No reduction in the reinforcing required shall be taken for the increased strength of reinforcing material and weld metal having higher design stress values than that of the material of the vessel wall. Deposited weld metal outside of either the vessel wall or any reinforcing pad used as reinforcement shall be credited with an allowable stress value equivalent to the weaker of the materials connected by the weld. Vessel-to-nozzle or pad-to-nozzle attachment weld metal within the vessel wall or within the pad may be credited with a stress value equal to that of the vessel wall or pad, respectively.

NC-3336.1 Strength of Weld. On each side of the plane defined in NC-3334, the strength of the attachment joining the vessel wall and reinforcement or any two parts of the attached reinforcement shall be at least equal to the lesser of (a) or (b) below:

(a) the strength in tension of the cross section of the element of reinforcement being considered;
(b) the strength in tension of the area defined in NC-3332 less the strength in tension of the reinforcing area which is integral in the vessel wall.

NC-3336.2 Strength of Attachment. The strength of the attachment joint shall be considered for its entire length on each side of the plane of the area of reinforcement defined in NC-3334. For outward openings, consideration shall also be given to the strength of the attachment joint on one side of the plane transverse to the parallel sides of the opening which passes through the center of the semicircular end of the opening.

NC-3350 DESIGN OF WELDED CONSTRUCTION
NC-3351 Welded Joint Categories

The term category defines the location of a joint in a vessel but not the type of joint. The categories are for use in specifying special requirements regarding joint type and method of examination for certain welded joints. Since these special requirements, which are based on service, material, and thickness, do not apply to every welded joint, only those joints to which special requirements apply are included in the categories. The special requirements apply to joints of a given category only when specifically stated. The joints included in each category are designated as joints of Categories A, B, C, and D. Figure NC-3351-1 illustrates typical joint locations included in each category.

NC-3351.1 Category A. Category A comprises longitudinal welds joining the main shell, communicating chambers, transitions in diameter, or nozzles; any welded joint within a sphere, within a formed or flat head, or within the side plates of a flat-sided vessel; circumferential welded joints connecting hemispherical heads to main shells, to transitions in diameter, to nozzles, or to communicating chambers.

NC-3351.2 Category B. Category B comprises circumferential welded joints within the main shell, communicating chambers, nozzles, or transitions in diameter including joints between the transition and a cylinder at either the large or small end; circumferential welded joints connecting formed heads other than hemispherical to main shells, to transitions in diameter, to nozzles, or to communicating chambers.

NC-3351.3 Category C. Category C comprises welded joints connecting flanges, Van Stone laps, tubeshells, or flat heads to main shell, to formed heads, to transitions in diameter, to nozzles, or to communicating chambers and any welded joint connecting one side plate to another side plate of a flat-sided vessel.

NC-3351.4 Category D. Category D comprises welded joints connecting communicating chambers or nozzles to main shells, to spheres, to transitions in diameter, to heads, or to flat-sided vessels and those joints connecting nozzles to communicating chambers. For nozzles at the small end of a transition in diameter, see Category B.

NC-3352 Permissible Types of Welded Joints

The design of the vessel shall meet the requirements for each category of joint. Butt joints are full penetration joints between plates or other elements that lie approximately in the same plane. Category B angle joints between plates or other elements that have an offset angle α not exceeding 30 deg are considered as meeting the requirements for butt joints. Figure NC-3352-1 shows typical butt welds for each category joint.

NC-3352.1 Joints of Category A. All welded joints of Category A shall meet the fabrication requirements of NC-4241 and shall be capable of being examined in accordance with NC-5210.

NC-3352.2 Joints of Category B. All welded joints of Category B shall meet the fabrication requirements of NC-4242 and shall be capable of being examined in accordance with NC-5220.
(2) Self-supporting roofs having the roof plates stiffened by sections welded to the plates need not conform to the minimum thickness requirements but shall be not less than $1/4$ in. (5 mm).

(c) Top Angle to Roof-to-Shell Joint. The cross-sectional area of the top angle, in.$^2$ (mm$^2$), plus the cross-sectional areas of the shell and roof plates within a distance of 16 times their thicknesses, measured from their most remote point of attachment to the top angle, shall equal or exceed:

(U.S. Customary Units)

\[
\frac{DR}{1,500}
\]

(SI Units)

\[
\frac{DR}{0.216}
\]

NC-3856.3 Top Angle Attachment for Self-Supporting Roofs.

(a) The top angle sections for self-supporting roofs shall meet the requirements of NC-4246.4.

(b) For self-supporting roofs, the edges of the roof plates may be flanged horizontally to rest flat against the top angle to improve welding conditions.

NC-3860 TANK CONNECTIONS AND APPURTENANCES

NC-3861 Roof Manholes

Roof manholes shall conform to Figure NC-3861-1 and Table NC-3861-1, except that alternative designs which provide equivalent strength are permissible if agreed to by the Owner or his designee.

NC-3862 Roof Nozzles

(a) Flanged roof nozzles shall conform to Figure NC-3862(a)-1 and Table NC-3862(a)-1. Threaded nozzles shall conform to Figure NC-3862(a)-2 and Table NC-3862(a)-2. Alternative designs for flanged roof nozzles and threaded nozzles can be used, provided they are of equivalent strength and agreed to by the Owner or his designee.

(b) Roof nozzles are not intended to take loads from pipe reactions. Earthquake loadings need not be considered.

NC-3863 Bottom Outlet Elbows

Bottom outlet elbows shall conform to Figure NC-3863-1 and Table NC-3863-1.

NC-3864 Threaded Connections

Threaded piping connections shall be female and shall be tapered. The threads shall conform to the requirements for taper pipe threads included in ANSI/ASME B1.20.1.

NC-3865 Platforms, Walkways, and Stairways

Platforms, walkways, and stairways shall be in accordance with Tables NC-3865-1 through NC-3865-3.

NC-3866 Nozzle Piping Transitions

The stress limits of Table NC-3821.5-1 shall apply to all portions of nozzles which lie within the limits of reinforcement given in NC-3334, except as provided in NC-3867. Stresses in the extension of any nozzle beyond the limits of reinforcement shall be subject to the stress limits of NC-3600.

NC-3867 Consideration of Standard Reinforcement

(a) Where a nozzle-to-shell junction is reinforced in accordance with the rules of NC-3334, the stresses in this region due to internal pressure may be considered to satisfy the limits of Table NC-3821.5-1. Under these conditions, no analysis is required to demonstrate compliance for pressure induced stresses in the nozzle region.

(b) Where external piping loads are to be designed for, membrane plus bending stresses due to these loads shall be calculated in the nozzle, and membrane stresses shall be calculated in the local nozzle shell region. These stresses, in conjunction with pressure induced stresses, shall meet the limits of Table NC-3821.5-1 for $(\sigma_m + \sigma_b)$. In this case, the pressure induced stresses in the $(\sigma_m + \sigma_b)$ category may be assumed to be no greater than the limits specified for $\sigma_m$ in Table NC-3821.5-1 for a given loading.

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 or 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.

NC-3911.2 Design Requirements.

(a) The design requirements for 0 psig to 15 psig (0 kPa to 100 kPa) storage tanks shall conform to the design rules of NC-3100 and NC-3300, except where they may be modified by the requirements of this Subarticle. The specific design requirements shall be stipulated in 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...
(b) For through-thickness temperature differences, adjacent points are defined as any two points on a line normal to any surface.

13 Normal service is defined as any set of service conditions other than startup and shutdown that are specified for the vessel to perform its intended function.

14 Adjacent points are defined as points that are spaced less than the distance $2\sqrt{RT}$ from each other, where $R$ and $t$ are the mean radius and thickness, respectively, of the vessel, nozzle, flange, or other part in which the points are located.

15 The head design curves have been developed considering membrane stress requirements, plastic collapse, cyclic load conditions, and the effects of maximum allowable tolerances in accordance with NC-4222. See Section III Appendices, Nonmandatory Appendix A, Article A-4000 for the design equations for the curves of Figure NC-3224.6-1.

16 Heads having $D/2h = 2$ have equivalent torispherical properties of a torisphere of $L/D = 0.90$ and $r/D = 0.17$.

17 The minimum thickness for all pipe materials is the nominal thickness listed in Table 2 of ASME B36.10M less $12\frac{1}{2}\%$. For diameters other than those listed in the table, the minimum thickness shall be that of the next larger pipe size.

18 The equations provide safe construction as far as stress is concerned. Greater thicknesses may be necessary if deflection would cause leakage at threaded or gasketed joints.

19 When axial compressive loadings occur in addition to the external pressure, the combined axial loading shall meet the requirements of NC-3245.

20 Stress means the maximum normal stress.

21 Since $H$, $h$, in some cases will subtract from the total moment, the moment in the flange ring when the internal pressure is zero may be the determining loading for the flange design.

22 The rules in NC-3329(f) apply to ligaments between tube holes and not to single openings. They may give lower efficiencies in some cases than those for symmetrical groups that extend a distance greater than the inside diameter of the shell as covered in NC-3329(c). When this occurs, the efficiencies computed by the rules under NC-3329(b) shall govern.

23 Communicating chambers are defined as appurtenances to the vessel that intersect the shell or heads of a vessel and form an integral part of the pressure retaining enclosure, such as sumps.

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

25 Written for fittings with internal threads but also applicable to externally threaded and socket- or butt-welded fittings.

26 All dimensions given are nominal.

27 It is recognized that other acceptable procedures may exist which also constitute adequate design methods, and it is not the intention to rule out these alternative methods, provided they can be shown to have been satisfactory by actual service experience.

28 The minimum thickness of straight pipe shown in Table NC-3642.1(c)-1 should be sufficient to allow the pipe to meet the minimum wall thickness requirements of NC-3641 after having been bent on the radii shown.

29 Expansion Joint Manufacturers Association, 25 North Broadway, Tarrytown, NY 10591.

30 See Section III Appendices, Mandatory Appendix II, II-1520(g).

31 The pressure term in eqs. NC-3652(8), NC-3653.1(a)(9a), NC-3653.1(b)(9b) and NC-3653.2(c)(11) may not apply for bellows and expansion joints.

32 Design Pressure may be used if the Design Specification states that peak pressure and earthquake need not be taken as acting concurrently.

33 Socket welds should not be used where the existence of crevices could accelerate corrosion.

34 Fillet and partial penetration welds should not be used where severe vibration is expected.
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.

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 psi (0.2 kPa), especially in combination with large diameter tanks, the forces involved may require special consideration in the design.

Any specified corrosion allowance for the shell plates shall be added to the calculated thickness.

The nominal thickness of shell plates refers to the tank shell as constructed. The thicknesses specified are based on erection requirements.


The decrease in yield stress at Design Temperature shall be taken into account.

The equations applying to self-supporting roofs provided for a uniform live load of 25 lb/ft² (1.2 kPa).

Whenever a tank is to be operated with liquid levels that at no time reach the top of the roof but is to be filled to the top of the roof during the hydrostatic test, it shall be designed for both of these maximum liquid level conditions, using in each case the density of the liquid employed. If a tank is not designed to be filled to the top of the roof, overfill protection is required.

A suitable margin shall be allowed between the pressure normally existing in the gas or vapor space and the pressure at which the relief valves are set 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 gas or vapor space.

This partial vacuum shall be greater than that at which the vacuum relief valves are set to open.


These rules do not apply when the circumferential stress on a cylindrical wall is compressive as in a cylinder acted upon by external pressure.

In these expressions if the unit force is latitudinal, \( R \) shall be considered to be \( R_1 \) and, if meridional, \( R \) shall be considered as equal to \( R_2 \).

(a) Equation NC-3932.2(a)(2) has been derived from a summation of the components, normal to the surface, of the \( T_1 \) and \( T_2 \) forces acting on a unit area of the tank wall subjected only to a pressure \( P \). To be technically correct, the normal to the surface components of other loads, such as metal, snow, or insulation, should be added to or subtracted from the term \( P \). For the usual internal Design Pressure, these added loads are small compared to the pressure \( P \), and can be omitted without significant error. When the pressure \( P \) is relatively small, including the case of a partial vacuum loading, the other load components can have a substantial effect on the calculated \( T_2 \) force and the resultant thickness.

(b) Example F.3.01 in Appendix F of API 620 Feb. 1970 Edition calculates the required roof thicknesses under a small vacuum by considering the metal, insulation, and snow loads in eqs. NC-3932.2(a)(1), NC-3932.2(a)(2), NC-3932.2(c)(1)(3), and NC-3932.2(c)(1)(4). The designer should note that if these loads had been omitted the calculated thicknesses would have been much less than the correct values.

(c) In eqs. NC-3932.2(a)(1), NC-3932.2(a)(1)(3), NC-3932.2(c)(2)(6), and NC-3932.2(c)(3)(8), the term \( W \) is intended to include loads, such as metal weight, of significant value. At points away from the vertical center line of the roof, the value of \( T_2 \) is required for the thickness calculations of eqs. NC-3932.3(d), Step 1(16), NC-3932.3(d), Step 3(18), and NC-3932.3(d), Step 5(20), and the value of \( P \) in eqs. NC-3932.2(a)(2), NC-3932.2(c)(1)(4), and NC-3932.2(c)(2)(7) must be modified by the normal components of the added loads for the correct determination of \( T_2 \).

These rules do not contain provisions in respect to the design of cylindrical sidewalls subject to partial internal vacuum in tanks constructed for storage of gases or vapors alone.

The vacuum relief valve or valves shall be set to open at a smaller partial vacuum so that the 1 oz/in.² (0.43 kPa) partial vacuum will not be exceeded when the inflow of air or gas through the valves is at its maximum specified rate.