11.5.4 *Radiographs for multiple tanks.* When two or more tanks are erected, either concurrently or continuously, in the same location, the number of radiographs to be taken (Sec. 11.5.1 and Sec. 11.5.2) may be based on the aggregate footage of welds of the same type and thickness in such group of tanks, rather than on the footage in each individual tank.

11.5.5 *Multiple welders on single joint.* It is to be recognized that the same welder or welding operator may or may not weld both sides of the same butt joint. Therefore, it is permissible to test two welders' or welding operators' work with one radiograph. When an inspection of this type is rejected, it must be determined whether one or both welders or welding operators were at fault through examination of the radiograph or by subsequent tests of each welder's or welding operator's work. Insofar as possible, an equal number of locations shall be examined from the work of each welder or welding operator on the tank, except that this requirement shall not apply where the length of seams welded by a welder or welding operator is much less than the average.

11.5.6 *Single-pedestal columns and large-diameter dry risers.* Single-pedestal columns and large-diameter dry risers more than 36 in. in diameter not in contact with the water shall have one radiograph taken in the first 10 ft (3 m) of completed circumferential butt weld joint without regard to the number of welders or welding operators. Thereafter, without regard to the number of welders or welding operators, one spot radiograph shall be examined in each additional 200 ft (60 m) and any remaining major fraction thereof. No spot radiograph need be taken at junctures of circumferential and longitudinal joints.

Sec. 11.6 Procedures for Inspection of Welded-Shell Butt Joints—Radiographic Testing

The inspection of welded-shell butt joints for which complete joint penetration is specified shall be made by x-ray or gamma-ray methods. No credit on the value for joint efficiency shall be allowed for such radiographic inspection.

11.6.1 *Application.* The procedure outlined shall apply only to complete penetration welded-shell butt joints.

11.6.2 *Radiographic examination method.* Except as modified in this section, the radiographic examination method shall be in accordance with ASME BPVC Sec. V, Article 2.

11.6.3 *Level II radiographers.* Level II radiographers shall perform the final acceptance of the radiographs. Level II radiographers shall be qualified in accordance with the current edition of ASNT SNT-TC-1A and all supplements,
N

Table 19 Maximum height of weld reinforcement of weld for butt joints above plate surface

Plate Thickness					
Minimum		Maximum		Maximum Height of Crown	
in.	*(mm)*	*in.*	*(mm)*	*in.*	*(mm)*
		½	(13)	1⁄16	(1.6)
>½	(>13)	1	(25)	3⁄32	(2.4)
>1	(>25)			⅛	(3.2)

11.6.4 *Final acceptance of radiographs.* The requirements of Sec. T-274 and Sec. T-285 of ASME BPVC Sec. V are to be used only as a guide. Final acceptance of radiographs shall be based on the ability to see the prescribed penetrometer image and the specified essential hole or the essential wire.

11.6.5 *Finished reinforcement surface.* The finished surface of reinforcement at the location of the radiograph may be flush with the plate or may have a reasonably uniform crown not to exceed the values in Table 19.

11.6.6 *Radiographic film.* Each radiograph shall clearly show a minimum of 6 in. (152 mm) of weld length except for a junction of vertical and horizontal welds, which shall clearly show not less than 2 in. (50 mm) of horizontal weld length on each side of the vertical intersection and a minimum of 3 in. (75 mm) of weld length on the vertical seam. The film shall be centered on the weld and shall be of sufficient width to permit adequate space for the location of identification markers and a thickness gauge or penetrometer.

11.6.7 *Radiographic procedure.* The weld shall be radiographed by a technique that will determine quantitatively the size of defects in accordance with the sensitivity required by Table T-276 of ASME BPVC Sec. V, based on the average thickness of the two plates joined plus weld reinforcement.

11.6.8 *Penetrometer placement.* One penetrometer shall be used for each film, to be placed adjacent to or across the weld seam at the approximate center of the location to be examined. For vertical welds, the penetrometer shall be placed parallel to the seam; for horizontal welds, the penetrometer shall be placed parallel to the weld seam. Wire penetrometers shall be placed across the weld. See Sec. T-277 of ASME BPVC Sec. V for more details.

11.6.9 *Review of radiographs.* Radiographs shall be reviewed before any repairs of welds.

11.6.10 *Radiographic standards.* Except as permitted in Sec. 11.4.4, sections of welds shown by radiography, in addition to visual inspection, to have any of the following imperfections shall be judged unacceptable:

1. Any crack, incomplete fusion, or inadequate penetration.
2. Any individual elongated inclusion having a length greater than two-thirds the thickness of the thinner plate of the joint except that, regardless of the plate thickness, no such inclusion shall be longer than ¾ in. (19 mm), and no such inclusion shorter than ¼ in. (6 mm) shall be cause for rejection.
3. Any group of inclusions in line, in which the sum of the longest dimensions of all such imperfections is greater than *T* (where *T* is the thickness of the thinner plate joined) in a length of 6*T*, except when the space between every pair of adjacent imperfections is greater than three times the length of the longer of the imperfections; when the length of the radiograph is less than 6*T*, the permissible sum of the lengths of all inclusions shall be proportionately less than *T*, provided that the limits of the deficient welding are clearly defined.
4. Rounded indications in excess of those shown as acceptable in ASME BPVC Sec. VIII, Div. 1, Appendix 4.

11.6.11 *Defective welds.* When a section of weld is shown by a radiograph to be unacceptable or the limits of the deficient welding are not defined by such radiograph, two adjacent radiographs shall be taken. However, if the original radiograph shows at least 3 in. (76 mm) of acceptable weld between the defect and any one edge of the film, an additional radiograph need not be taken on that side of the defect. If the weld at the first adjacent radiograph fails to comply with the requirements of Sec. 11.6.10, additional adjacent radiographs shall be made until the limits of unacceptable welding are determined. Alternatively, if the defect extends beyond the first adjacent radiographs, the complete defect may be determined by air carbon arc gouging. A final radiograph shall be taken at the end of the air carbon arc gouge to ensure that the entire defect has been removed. Welding performed by the welder or welding operator on that joint may be replaced, in which case one radiograph shall be taken at any selected location on any other joint on which the same welder or welding operator has welded. If any of the additional radiographs fail to comply with the requirements of Sec. 11.6.10, the limits of unacceptable welding shall be determined as previously described.

11.6.12 *Record of radiographic inspection.* A record shall be made of all films, with their identification marks, on a developed shell plate diagram.

Sec. 11.7 Procedure for Inspection of Groove Welds in Tension Member Bracing by Ultrasonic Inspection

11.7.1 *Ultrasonic testing (UT).* Personnel performing the examinations shall be qualified in accordance with ASNT SNT-TC-1A. For a full ultrasonic inspection, each groove weld shall be straight-beam inspected circumferentially around the entire weld and shall be angle-beam inspected axially in both directions circumferentially around the entire weld. Level II personnel shall perform the final acceptance.

1. The weld groove shall be of a configuration that ensures full ultrasonic coverage.
2. Ultrasonic technique details shall be as outlined in ASME BPVC Sec. V, Article 5.
3. Ultrasonic acceptance standards shall be as shown in ASME BPVC Sec. VIII, Div. 1, Appendix 12, paragraph 12-3.

Sec. 11.8 Inspection by Air Carbon Arc Gouging

In those areas where radiographic inspection is not feasible, an inspection of welds by an experienced inspector may be made by air carbon arc gouging. A form shall be prepared identifying the joint, justification for this type of inspection, length of inspection, and results of inspection.

11.8.1 *Testing procedure.* The number of test sections shall be determined by Sec. 11.5. A portion of the weld, approximately 2 in. (50 mm) long, shall be gouged out to the root of the weld. Visual inspection shall be made for sound welding, lack of penetration or fusion, cracks, or porosity. If unacceptable defects are found, additional areas shall be gouged to isolate the undesirable area.

11.8.2 *Repair procedure.* All gouged areas shall be repair welded using a procedure that will produce a weld to its specified size, contour, and quality.

Sec. 11.9 Repair of Defective Welds

Defective welds shall be removed by grinding, chipping with a round-nosed tool, or by air arc or oxygen gouging, from one or both sides of the joint, and then rewelded in compliance with approved procedures. Removal of defective welds is required only to the extent necessary to remove the defects present. Repairs shall be reinspected by the original test procedure.

Sec. 11.10 Testing

11.10.1 *Flat bottoms.* On completion of welding of the tank bottom and before painting, the tank bottom shall be tested for water tightness by one of the following methods.

11.10.1.1 Magnetic-particle testing. The joints may be tested by the magnetic-particle method.

11.10.1.2 Air-pressure or vacuum testing. Air pressure or vacuum may be applied to the joint, using soapsuds, linseed oil, or other suitable material for the detection of leaks. The gauge should register a vacuum of at least 2 psi (13.8 kPa).

11.10.2 *Shell-to-bottom joint.* Prior to painting, the inside fillet weld shall be tested for leaks by one of the following methods:

1. Test the inside fillet weld with penetrating oil before welding the outside fillet weld.
2. Vacuum box test the inside fillet weld at 2 psig (4.1 in. Hg) (13.8 kPa gauge) to 4 psig (8.2 in. Hg) (27.6 kPa gauge) either before or after welding the outside fillet weld.

11.10.3 *Shell, bottom, and roof.* Unless otherwise specified, the tank shall be hydrotested after painting by filling the tank with water to the MWL. Any leaks in the shell, bottom, or roof (if the roof contains water) shall be repaired by chipping, gouging, or oxygen gouging to remove any defective welds, and rewelded. No repair work shall be done on any joints unless the water in the tank is at least 2 ft (0.6 m) below the point being repaired.

SECTION 12: FOUNDATION DESIGN

Sec. 12.1 General Requirements

Construction drawings of the foundation shall be provided and shall include dimensions, loadings used in the design, design and construction standards used, materials of construction, and allowable soil pressure or deep foundation capacity. The type of foundation and foundation depth shall be based on a geotechnical investigation. The earth around the foundation shall be regraded sufficiently to permit efficient work during tank erection and to prevent ponding of water in the foundation area.

12.1.1 *Water load.* Water load, as defined in Sec. 3.1.3, shall be considered as live load, as defined by ACI 318 (see Sec. 12.8). The appropriate factors for all live loads shall be used in the foundation design.

12.1.2 *Design snow load.* Unless otherwise specified, the design snow load, if any, need not be combined with wind or seismic soil-bearing pressures for design of footings, slabs, or piers.

Sec. 12.2 Soil-Bearing Value

The design soil-bearing pressure shall be specified and shall include an appropriate factor of safety (Sec. 12.3) that is based on a geotechnical investigation and the method of pile capacity testing, if applicable. In no case shall the specified bearing pressure cause settlements that may impair the structural integrity of the tank.

12.2.1 *Geotechnical investigation.* A geotechnical investigation shall be performed to determine the following:

1. The presence or absence of rock, old excavation, or fill.
2. Whether the site is suitable for the structure to be built thereon, and what remediation, if any, is necessary to make it suitable.
3. The classification of soil strata after appropriate sampling.
4. The type of foundation that will be required at the site.
5. The elevation of groundwater and whether dewatering is required.
6. The bearing capacity of the soil and depth at which foundation must be founded.
7. Whether a deep foundation will be required and the type, capacity, and required length of piles, caissons, piers, etc.
8. The elevations of the existing grade and other topographical features that may affect the foundation design or construction.
9. The homogeneity and compressibility of the soils across the tank site and estimated magnitude of uniform and differential settlement.
10. For standpipes and reservoirs, the minimum allowable foundation width for continuous and isolated footings, if applicable.
11. Site Class in accordance with Sec. 13.2.3.

Sec. 12.3 Safety Factors

The following safety factors shall be used as a minimum in determining the design soil-bearing pressure. The ultimate bearing capacity shall be based on sound principles of geotechnical engineering in conjunction with a geotechnical investigation.

Table 20 Minimum safety factor for design bearing capacity

Foundation Type and Method of Establishing Capacity	Load Combinations Without Wind or Seismic	Load Combinations with Wind or Seismic
Shallow foundations:		
Analysis using engineering principles	3.0	2.25
Deep foundations:		
Analysis using engineering principles	3.0	2.25
High-strain dynamic testing of piles in accordance with ASTM D4945	2.25	1.69
Static load testing in accordance with ASTM D1143 or high-strain dynamic testing of piles in accordance with ASTM D4945 using signal matching analysis or other in-situ load tests that determine end bearing, side friction, or both	2.0	1.5

Load combinations in Table 20 shall exclude overturning toe pressure caused by wind or seismic shear at the top of the footing, unless otherwise specified. A safety factor of 2.0 shall be provided based on calculated ultimate bearing capacity for gravity loads plus wind or seismic load, including overturning toe pressure caused by shear at the top of footing.

Sec. 12.4 Foundations for Cross-Braced Multicolumn Tanks

12.4.1 *Riser foundation.* The riser foundation shall accommodate the specified piping. The specified design soil-bearing values shall be such that differential settlement between the riser foundation and outer piers is minimized. The specified design soil-bearing values shall not be exceeded when the portion of dead and water loads carried by the riser, net weight (44 lb/ft^3 [705 kg/m^3]) of the concrete in the pier below the original ground line, and total weight of concrete and soil above the original ground line are included.

12.4.2 *Column foundations.* Column foundations may be of any suitable shape and shall be reinforced concrete. The weight of the pier plus the weight of the soil directly above the base of the pier or the tension allowable on a pile footing shall be sufficient to resist the maximum net uplift for tank-empty plus wind load or tank-full plus seismic load cases.

12.4.3 *Pier.* The size of the pier shall be such that the specified design soil-bearing value will not be exceeded when the following loads are included: net weight (44 lb/ft^3 [705 kg/m^3)] of concrete foundation below original ground line, full weight of concrete and soil above the original ground line, and portion of dead, water, and snow loads carried by the column pier. Maximum wind or seismic loads shall be combined with gravity loads, in accordance with Sec. 12.3. Peak toe pressure caused by shear at the top of the foundation shall be combined with gravity loads and wind or seismic loads, in accordance with Sec. 12.3.

12.4.4 *Batter.* For battered columns without bottom struts, the axis of column foundations shall have the same batter as the column. For battered columns with bottom struts attached to columns or with piers tied together and for vertical columns, the axis of the foundations shall be vertical.

12.4.5 *Size of top.* The tops of foundations shall project at least 3 in. (76 mm) beyond the column or riser base plates. The top corners shall be either neatly rounded or finished with suitable bevel.

12.4.6 *Tolerances on concrete foundation.* Tops of pedestals shall be troweled level to within ±¼ in. (±6 mm) of the theoretical elevation. Plan dimensions shall not be more than ½ in. (13 mm) less than specified dimensions. Centerline location of pedestals shall not vary more than ±½ in. (±13 mm) from the theoretical location.

12.4.7 *Tolerances on anchor bolt installation.* Unless otherwise specified, design of anchor bolts and anchor bolt attachments shall accommodate, and installation of anchor bolts shall comply with, the following tolerances:

1. Location in plan shall be no more than ¼ in. (6 mm) from the specified location.
2. Projection above top of concrete shall be ±¼ in. (±6 mm) from the specified projection.
3. Vertical misalignment shall not exceed ⅛ in. (3 mm) in 12 in. (305 mm).

Sec. 12.5 Foundations for Single-Pedestal Tanks

Single-pedestal tank foundations may consist of a reinforced concrete slab or ringwall footing. The size shall be such that the specified design soil-bearing value will not be exceeded when the following loads are included: net weight (44 lb/ft^3 [705 kg/m^3]) of concrete foundation below original ground line, full weight of concrete and soil above original ground line, deadweight of the structure, water load, and design snow load. Wind or seismic loads shall be combined with gravity loads, in accordance with Sec. 12.3.

12.5.1 *Overturning stability.* The size of the foundation shall be sufficient to maintain bearing pressures below the ultimate bearing capacity of the soil when

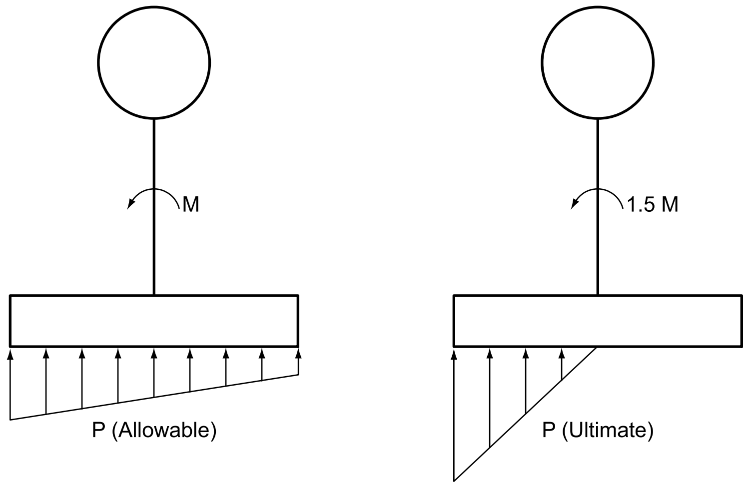

Figure 1 Diagram for checking overturning stability of pedestal-type elevated tanks (wind or seismic events)

subjected to an overturning moment equal to 1.5 times the overturning moment determined for wind or seismic loads (see Figure 1).

12.5.2 *Tolerances on concrete foundations.* Tops of ringwall footings shall be troweled level to within ±¼ in. (±6 mm) of the theoretical elevation. Plan dimensions shall not be more than ½ in. (13 mm) less than specified dimensions. Centerline location of ringwall footings shall not vary more than ±½ in. (±13 mm) from theoretical location.

12.5.3 *Tolerances on anchor bolt installation.* Unless otherwise specified, design of anchor bolts and anchor bolt attachments shall accommodate, and installation of anchor bolts shall comply with, the following tolerances:

1. Location in plan shall be no more than ¼ in. (6 mm) from the specified location.
2. Projection above top of concrete shall be ±¼ in. (±6 mm) from the specified projection.
3. Vertical misalignment shall not exceed ⅛ in. (3 mm) in 12 in. (305 mm).

Sec. 12.6 Foundations for Ground-Supported Flat-Bottom Tanks

Foundations for ground-supported flat-bottom tanks shall be one of the foundation types described in Sec. 12.6.1. The type of foundation shall be specified. Excavation, soil preparation, and compaction shall conform to accepted engineering practice for the bearing pressures predicted; refer also to Sec. 12.9. Site grading around the tank shall provide for positive drainage away from the tank. The top of the foundation shall be a minimum of 6 in. (152 mm) above the finished grade, unless otherwise specified. Unless otherwise specified, the foundation shall be graded to slope uniformly upward to the center of the tank with a minimum slope of 1 in. (25 mm) vertical to 10 ft (3.0 m) horizontal. Tanks that require anchorage and tanks conforming to Sec. 14 shall be supported only on Type 1 or 2 foundations (Sec. 12.6.1). Unless otherwise specified, an oiled sand cushion shall be used under the tank bottom. The resistivity of the sand before adding oil should be greater than 3,000 ohm-cm when saturated with distilled or deionized water. Where oiled sand mix is not available or not desired, a compacted cushion of well-graded crushed stone or gravel, clean sand, hydrated-lime–sand mix, asphaltic road mix, or similar material shall be specified. The chloride content of the under-bottom material shall be less than 100 ppm, and the sulfate content shall be less than 200 ppm.

Note 1: Oiled sand mixture consists of approximately 18 gal (68 L) of oil per cubic yard (89 L/m^3) of sand. The oils used in the oiled sand mixture shall be either a slow-curing asphalt cutback grade complying with the requirements of ASTM D2026 or a medium-curing asphalt cutback grade complying with the requirements of ASTM D2027. The sand has the correct amount of oil when the sand can be formed into a ball without dripping oil. Sand should be coated but not running with excess oil.

Note 2: Hydrated lime may be added to clean sand to obtain a pH of at least 10.5. The resistivity of the sand before hydrated lime is added should be greater than 3,000 ohm-cm when saturated with distilled or deionized water. When the underside of the tank bottom surface is painted, compatibility of the paint with the lime shall be checked with the paint supplier.

12.6.1 *Types of foundations.* Foundations for ground-supported flat-bottom tanks shall be one of the following types:

1. Type 1—Tanks supported on ringwall footings. Tanks may be supported on a ringwall footing under the shell with an oiled sand cushion within the ringwall. The oiled sand cushion inside the ringwall shall be provided above the earthen interior under the tank bottom and shall consist of a minimum of 3-in. (76-mm) cushion of clean sand or fine crushed stone containing an optimum amount of asphalt cutback grade oil as described in Sec. 12.6, Note 1. The shell of mechanically anchored tanks shall be supported by grout. For self-anchored tanks where the foundation under the shell meets the tolerances of Sec. 12.6.2, the shell may be supported with ½-in. (13-mm)–thick cane-fiber joint filler meeting the requirements of ASTM D1751. For self-anchored tanks where the foundation

under the shell does not meet the tolerances of Sec. 12.6.2, the shell shall be supported with grout. When grouted, a 1-in. (25-mm) minimum space between the tank bottom and the top of the ringwall shall be grouted full with either a 1:1.5 cement–sand grout or commercial grout, unless otherwise specified. The grout shall extend from the outside edge of the tank bottom to the outside edge of the sand cushion, but in no case shall the width of grout be less than 6 in. (152 mm). The top of the foundation shall be cleaned and thoroughly wetted before grout is placed.

2. Type 2—Tanks supported on concrete slabs. Tanks may be supported on a sand cushion, not less than 1 in. (25 mm) thick between the flat bottom and the concrete slab foundation. In lieu of a sand cushion, the bottom may be supported on ½-in. (13-mm)–thick cane-fiber joint filler meeting the requirements of ASTM D1751. The shell of mechanically anchored tanks shall be supported by grout. For self-anchored tanks where the foundation under the shell meets the tolerances of Sec. 12.6.2, the shell may be supported with ½-in. (13-mm)–thick cane-fiber joint filler meeting the requirements of ASTM D1751. For self-anchored tanks where the foundation under the shell does not meet the tolerances of Sec. 12.6.2, the shell shall be supported with grout. When grouted, a 1-in. (25-mm) minimum space between the tank bottom and the top of the concrete shall be filled with either a 1:1.5 cement–sand grout or commercial grout, unless otherwise specified. The grout shall extend from the outside edge of the tank bottom to the outside edge of the sand cushion or cane-fiber joint filler, but in no case shall the width of grout be less than 6 in. (152 mm). The top of the foundation shall be cleaned and thoroughly wetted before grout is placed.

3. Type 3—Tanks within ringwalls. Tanks may be placed on an oiled sand cushion within a concrete ringwall. The oiled sand cushion shall consist of a minimum of 6-in. (152-mm) cushion of clean sand or fine crushed stone containing an optimum amount of an asphalt cutback grade oil as described in Sec. 12.6, Note 1. The top of the sand within the ringwall should slope uniformly upward from the top of the ringwall to the center of the tank. The inside of the ringwall shall be a minimum of ¾ in. (19 mm) outside the bottom plates of the tank. Adequate provisions for drainage inside the ringwall shall be made.

4. Type 4—Tanks supported on granular berms. Tanks may be supported on a berm without the use of a retainer ring. The berm shall consist of a minimum of 6-in. (152-mm) well-graded crushed stone or gravel. The berm shall extend a minimum of 3 ft (1 m) beyond the tank shell and, from there, have a maximum