

SECTION 13 20 00 revised RFI 1 (June 2013)
PRESTRESSED CONCRETE STORAGE TANK

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies the design and construction of an AWWA D110 Type II, wire-wound prestressed concrete storage tank with steel diaphragm complete including all reinforcing, concrete work, accessories, disinfection and testing directly related to the tank.
- B. The tank contractor is responsible for furnishing all labor, materials, tools and equipment necessary to design and construct the prestressed concrete storage tank as indicated on the drawings and as described in this specification.

1.2 RELATED WORK

- A. Section 31 20 00, Earth Moving
- B. Section 31 63 16, Auger Cast Grout Piles
- C. Section 22 05 11, Common Work Results for Plumbing
- D. Section 33 10 00, Water Utilities
- E. Appendix A - Geotechnical Report

1.3 APPLICABLE PUBLICATIONS

- A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by basic designation only.
- B. ACI 372R-03 - Design and Construction of Circular Wire- and Strand-Wrapped Prestressed Concrete Structures.
- C. AWWA D110-04 - Wire- and Strand-Wound, Circular, Prestressed Concrete Water Tanks.
- D. ACI 506R - Guide to Shotcrete.
- E. ASTM A 821/A821M - Standard Specification for Steel Wire, Hard Drawn for Prestressing Concrete Tanks.
- F. ASTM A 1008/A1008M - Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy With Improved Formability.
- G. ASCE Standard 7-05 - Minimum Design Loads for Buildings and Other Structures.
- H. ASTM C 881/C881M - Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.
- I. ASTM A 185 - Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete.

- J. ASTM A 615 - Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.
- K. ACI 305R - Hot Weather Concreting.
- L. ACI 306R - Cold Weather Concreting.
- M. ACI 350-06 - Building Code Requirements for Environmental Engineering Concrete Structures and Commentary.
- N. ASTM C 31/C31M - Test Methods for Making and Curing Concrete Test Specimens in the Field.
- O. ASTM C 39/C39M - Test Method for Compressive Strength of Cylindrical Concrete Specimens.
- P. ASTM C 231 - Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.
- Q. ASTM C 143 - Standard Test Method for Slump of Hydraulic-Cement.
- R. ASTM C 172 - Standard Practice for Sampling Freshly Mixed Concrete.
- S. ASTM C 33/C33M - Specification for Concrete Aggregates.
- T. AWWA C652 - Disinfection of Potable Water Storage Tanks.
- U. ASTM D 1056 - Standard Specification for Flexible Cellular Material.
- V. 2006 International Building Code (IBC)
- W. 2007 Physical Security Design Manual: Mission Critical Facilities

1.4 SUBMITTALS

- A. Shop Drawings: Provide shop drawings with a minimum size of 18" x 24" with a complete plan, elevation, and sectional views showing critical dimensions as follows:
 - 1. Size, location and number of all reinforcing bars.
 - 2. Thickness of all parts of the tank structure including floor, core wall, dome, and covercoat.
 - 3. Prestressing schedule including number and placement of prestressing wires on the tank wall and total applied force per foot of wall height.
 - 4. Location and details of all accessories required.
- B. Concrete Data: Submit concrete design mixes including ingredient proportions, minimum cementitious content, and water/cementitious ratio in accordance with Section 2.2 and 2.3 of this specification.
- C. Design Data: Submit the following structural calculations for the tank, signed and sealed by a professional engineer in accordance with Section 1.5.A.3 of this specification:

1. Structural design calculations for all portions of the tank with details of analysis in accordance with codes and standards for all gravity and seismic loads specified in Section 1.7.B.
 2. Structural dynamic response analysis for all portions of the tank with details of analysis and codes and standards used for blast loads specified in Section 1.7.B.10.
 3. Statement of conformance and analysis results from peer review firm described in Section 1.5.A.3.
- D. Coating Data: Submit color charts for review by the engineer and owner. Once a color is chosen, submit actual drawdown samples for final approval prior to application of coating.
- E. Test Reports: Submit concrete strength reports for 7-day and 28-day breaks taken in accordance with the requirements of Section 3.3.A.1.
- F. Warranty Document: Submit warranty document in Owner's name in accordance with Section 1.6 A. of this specification.
- G. Cleaning and Disinfection Plan: Submit a cleaning and disinfection plan which complies with Section 3.4 of this specification.
- H. Project Record Documents: Record actual location layout and final configuration of tank and accessories on shop drawings and submit to engineer after construction of the tank is complete.

1.5 QUALITY ASSURANCE

A. Qualifications and Experience:

1. Tank Construction Company: Shall be a firm with ten years of experience in the design and construction of AWWA D110 Type II wire-wound, circular prestressed concrete tanks with satisfactory evidence that it has the skill, reliability, and financial stability to build and guarantee the tank in accordance with the quality required by these specifications. The company constructing the tank shall have built completely in its own name in the past five years, and be presently responsible for, a minimum of ten (10) dome covered prestressed composite tanks which meet these specifications and are now providing satisfactory service.
2. Construction: The entire tank, including all portions of the floor, wall, and dome shall be built by the tank construction company, using its own trained personnel and equipment.
3. Design: All design work for the tank shall be performed by a professional engineer with no less than five years of experience in the design and construction of AWWA D110 Type II wire-wound, circular prestressed concrete tanks. The professional engineer shall be a full-time staff member of the tank construction company and shall be licensed to work in the state where the project is located. All analysis work for the blast load shall be peer reviewed by an independent structural consultant. The firm responsible for peer review of the blast

response shall be one with demonstrated experience in blast analysis response for liquid containment structures and shall have a licensed professional engineer on its staff who is licensed in the state where the project is located.

4. The steel shell design and epoxy injection procedure shall have been used in the ten tanks required in Section 1.5 A. of this specification.

1.6 WARRANTY

- A. Provide a warranty document for workmanship and materials on the complete structural portion of the tank for a five-year period from the date of acceptance of the work. In case leakage or other defects appear within the five-year period, the tank construction company shall promptly repair the tank at its own expense upon written notice by the Owner that such defects have been found. Leakage is defined as a stream flow of liquid appearing on the exterior of the tank, the source of which is from the inside of the tank. The tank construction company shall not be responsible for, nor liable for, any subsurface condition. This warranty shall not apply to any accessory, equipment or product that is not a structural part of the tank and is manufactured by a company other than the tank construction company.

1.7 DESIGN CRITERIA

- A. The design shall be in conformance with applicable portions of American Concrete Institute (ACI) 372R-03 Design and Construction of Circular Wire- and Strand-Wrapped Prestressed Concrete Structures, AWWA D110-04 Wire- and Strand-Wound, Circular, Prestressed Concrete Water Tanks, and currently accepted engineering principles and practices for the design of such structures.
- B. The following loadings shall be utilized in the design:
 1. Capacity: 750,000 Gallons
 2. Dimensions: 60 foot Inside Diameter
35.5 foot Water Depth
 3. Fluid Loads: Shall be the weight of all liquid when the reservoir is filled to capacity. The unit weight of the liquid material shall be 62.4 lbs/ft³.
 4. Roof Loads: Consideration shall be given to all applicable roof design loads in accordance with AWWA D110, Section 3.3 and ASCE 7. The minimum roof loads to be considered in the design of the structure shall be as follows:
 - a. Roof Live Load 15 lbs/ft².
 5. Dead Loads: Consideration shall be given to all permanent imposed loads including concrete and steel.
 6. Seismic Loads: Seismic load shall be calculated using the effective mass procedure as specified in AWWA D110 with mapped spectral response accelerations in accordance with the 2006 International Building Code. Seismic design criteria to be used in the design of the tank is as follows:
 - a. Mapped MCE, 5 percent damped, spectral response acceleration at short periods, S_s 22.9%g

- b. Mapped MCE, 5 percent damped, spectral response acceleration at a period of 1 sec., S_1 8.6%g
 - c. Occupancy Category IV
 - d. Importance Factor, I: 1.5
7. Soil Pressure: Earth loads shall be determined by rational methods of soil mechanics. Soil pressure shall not be used in the design of the core wall to resist hydraulic loads or provide residual compression in the wall. The unit weight of soil shall be 120 lbs/ft³.
8. Differential Backfill Loads: Forces from differential backfill loads shall be considered in the design and shall be based on the at-rest coefficient. Passive resistance shall not be used to resist differential backfill loads.
9. Wind Loads: Wind loads shall be considered in the design in accordance with ASCE 7. Criteria to be used in the design of the tank is as follows:
- a. Basic Wind Speed, V: 90 miles/hour
 - b. Importance Factor, I: 1.15
 - c. Exposure Category, K_z "C"
10. Blast Load: All parts of the tank structure must be designed to resist the effects of blast in accordance with the Physical Security Design Manual for Mission Critical Facilities. The blast load to be considered produces the following pressures and impulses:
- a. 37.9 psi and 136 psi - msec at ground level.
 - b. 19.0 psi and 97.4 psi - msec at 45' above ground level. |
- C. Structural Floor: The design of the structural floor for the prestressed concrete tank shall conform to the following:
- 1. Concrete structural floors shall contain a minimum reinforcing steel amount equal to 0.50% of the gross cross sectional area. Reinforcing steel shall be placed orthogonally and distributed with at least 2/3 of the total minimum area required in the top face and 1/3 of the total minimum area in the bottom face.
 - 2. Concrete sections that are 24" or greater in thickness may have the minimum percentage of reinforcing based on a 12" concrete layer at each face.
 - 3. Minimum reinforcing size shall be #4 bar.
 - 4. Maximum spacing of reinforcing steel for the structural floor shall be 12".
 - 5. Concrete structural floors shall be designed to resist bending moments and shears induced by loadings required in section 1.7B. Moments and shears shall be calculated based on rational analysis utilizing an influence area derived from the pile spacing plus 2 times the pile spacing tolerance specified in section 1.7C8. In no case shall the dimensions and reinforcing steel for the concrete structural floor be less than the following:
 - a. Minimum floor thickness: 20".
 - b. Minimum top reinforcing steel: #6 at 6 1/2" c/c.
 - c. Minimum bottom reinforcing steel: #5 at 9" c/c.
 - 6. Circumferential steel shall be added to the outside edge of the structural floor as required to resist calculated bending moments in spans between perimeter piles. Circumferential steel required for bending moments shall be calculated by any rational one-way analysis with a minimum required amount of

0.75% placed in a minimum width of 2' 6". Minimum circumferential steel shall be distributed with 2/3 of the total area required in the top face and 1/3 in the bottom face.

- a. Top circumferential bars: 8 - #6 bars
- b. Bottom circumferential bars: 8 - #6 bars
- 7. Radial steel shall be added to the top and bottom mats of reinforcing steel at the edge of the structural floor to account for edge effects in the circular plate. Edge effects shall include moments at the mid-span of the outer most span and the outside face of the first interior support of a two way slab and shall be calculated by any rational analysis which considers these effects but in no case shall be less than:
 - a. Top radial bar: #6 at 12" c/c x 11' 4" long.
 - b. Bottom radial bar: #5 at 9" c/c X 8' 6" long.
- 8. Footing dimensions shall be sized appropriately to resist shear and moments. In no case shall the footing dimensions be less than the following:
 - a. Footing thickness: 23"
 - b. Footing width: 36"
- 9. Minimum pile embedment into the concrete structural floor shall be 3" for auger cast concrete piles.
- 10. Minimum spacing tolerance shall be 3" for all auger cast piles or as defined by the geotechnical design professional.

D. Core wall:

- 1. The wire-wound, prestressed concrete tank core wall shall be designed as a thin shell cylindrical element using shotcrete and an embedded, mechanically bonded, steel shell diaphragm.
- 2. The design of the core wall shall take into account appropriate edge restraint. To compensate for bending moments, shrinkage, differential drying, and temperature stresses, the following minimum reinforcing steel shall be incorporated into the design:
 - a. The top 2' of core wall shall have not less than 1% circumferential reinforcing.
 - b. The bottom 3' of core wall shall have not less than 1% circumferential reinforcing.
 - c. Remaining portions of the core wall shall have circumferential reinforcing as required to resist bending moments due to blast pressures and impulses.
 - d. Inside Face:
 - (1) The inside face of the core wall shall utilize the 26 gauge steel shell diaphragm as effective reinforcing.
 - (2) Additional vertical and horizontal reinforcing steel bars shall be used as required by design computations.
 - e. Outside Face:
 - (1) Vertical reinforcing steel in the outside face of the core wall shall be: minimum of #4 bars at 12" center to center.
 - (2) Additional vertical and horizontal reinforcing steel bars shall be used as required by design computations.
- 3. The minimum core wall thickness shall be 3½".

4. Reinforcing steel used in the core wall shall be designed using a maximum allowable design tensile stress, f_s , of 18,000 psi.
 5. Allowable compressive stress in the core wall due to initial prestressing force, f_{gi} , shall be:
 - a. 1250 psi + 75t psi/in. with 0.5 f'_{gi} maximum or less (where f'_{gi} is defined as compressive strength at time initial prestressing force is applied and t is the thickness of the core wall in inches).
 - b. Maximum of 2250 psi.
 6. Allowable compressive stress in the core wall due to final prestressing force, f_g , shall be:
 - a. 1250 psi + 75t psi/in. with 0.45 f'_g maximum (where f'_g is defined as compressive strength required for final prestressing force and t is the thickness of the core wall in inches).
 - b. Maximum of 2000 psi.
- E. Dome:
1. The dome roof shall be constructed of reinforced concrete and shall be circumferentially prestressed.
 2. Dome shell reinforcement shall consist of reinforcing bars or welded wire fabric meeting ASTM A 185, not galvanized. Bolsters for wire fabric and reinforcing bars shall be plastic. Wire ties shall be galvanized.
 3. The dome ring girder shall be prestressed with sufficient wire to withstand the dome dead load and design live loads. The ring girder shall have cross section suitable to accept the applied prestressing forces.
 4. The high water level in the tank shall be permitted to encroach on the dome shell no higher than the upper horizontal plane of the dome ring girder.
 5. Overflow outlets or the overflow pipe shall be capable of providing an overflow open area three times the area of the largest influent pipe.
 6. Overflow outlets plus the dome ventilator shall be capable of providing an open area three times the area of the largest pipe.
 7. The dome shall be designed as a free-span, spherical thin shell with one-tenth rise in accordance with the following:
 - a. Typical Dome Design: The typical dome thickness and steel reinforcement shall meet the requirements of AWWA D110-04.
 - b. In all cases, the thickness of the dome shall be no less than 3".
 - c. Dome Edge Design: The dome edge and upper wall shall be designed to resist the moments, thrusts, and shears that occur in this region due to dome and wall prestressing and loading conditions. The design of the edge region shall conform to the following:
 - (1) Dome Edge Thickness:
 - (a) A determination of the buckle diameter shall be made, as defined by:

$$d_b = 2.5 \cdot \sqrt{r_d \cdot t_d} \text{ rounded up to the next foot}$$

Where: d_b = buckle diameter in feet

r_d = dome radius in feet

t_d = typical dome thickness in feet

(b) Dome edge thickening shall begin at a radial

location on the dome, defined as s_2 which is at least one buckle diameter away from the tank wall.

(c) A springline haunch shall be provided, which extends radially from the inside face of the tank

wall to radial location s_1 which is defined as:

$$s_1 = 0.6 \cdot \sqrt{1.5 \cdot r_d \cdot t_d} \text{ rounded up to the next foot}$$

Where: s_1 = distance from inside face of wall to haunch in feet

s_2 = distance from inside face of wall to typical dome thickness in feet.

This springline haunch shall begin at the inside face of the tank wall with a springline thickness as required by paragraph (f) below and shall end at radial location s_1 with the following thickness:

$$t_{d1} = 1.33 \cdot t_d$$

Where: t_{d1} = minimum thickness at s_1 in feet

t_d = typical dome thickness in feet at one buckle diameter from tank wall

(d) Beginning at s_1 and continuing to s_2 the dome shell shall have a uniform straight line taper.

(e) Parameters (b), (c), and (d) above are not required for domes where the calculated typical dome thickness is less than 75% of the actual typical dome thickness.

(f) Sufficient concrete thickness at the springline of the dome shall be provided so that no more than 2' of the springline haunch is considered in calculating the effective dome edge ring cross sectional area. Compressive stress in this area shall not exceed 1000 psi when subjected to initial prestressing, offset by dead load only.

(2) Dome Edge Steel Reinforcement:

(a) Throughout the dome edge, the percentage of steel reinforcement, both radially and circumferentially, shall be no less than 0.25% of the gross cross sectional area of concrete.

- (b) Along the dome edge, steel reinforcement shall be distributed between the upper and lower layers unless finite element analysis calculations indicate that tensile stress does not exist in the concrete along the bottom face of the dome edge. In that case, only top bars are required radially and circumferentially. In addition, radial and circumferential reinforcing bars will not be required along the bottom face of the dome edge where the calculated typical dome thickness is less than 75% of the actual typical dome thickness.
- (c) Where reinforcing bars are required in the bottom layer, they shall be placed near the tank wall to insure adequate development at the intersection between dome and wall.
- (d) In all cases, the percentage of circumferential steel reinforcement in the effective dome ring shall be no less than one percent of the gross cross sectional area of concrete. The effective dome ring is defined as $\frac{1}{4}$ of the haunch length not to exceed 2'.
- (e) Where bottom dome edge steel reinforcement is required, vertical steel reinforcement along the inside face of the tank wall shall be no less than 0.5% of the cross sectional area of wall shotcrete.

F. Prestressing:

1. Circumferential prestressing of the tank shall be achieved by the application of cold-drawn, high-carbon steel wire complying with ASTM A 821 Type B, placed under high tension.
2. A substantial allowance shall be made for prestressing losses due to shrinkage and plastic flow in the shotcrete and due to relaxation in the prestressing steel.
3. The prestressing design shall conform to the following minimum requirements:
 - a. Working stress for the tank wall, f_s , shall be a maximum of 115,000 psi.
 - b. The allowable design tensile stress in the prestressing wire before losses, f_{si} shall be 145,600 psi or no greater than $0.63 f_u$, where f_u is defined as the ultimate strength of the wire.
 - c. Areas to be prestressed will contain not fewer than 10 wires per foot of wall for 8 gauge and 8 wires per foot of wall for 6 gauge.
 - d. A maximum of 24 wires per layer per foot for 8 gauge and 20 wires per layer per foot for 6 gauge will be allowed.

G. Wall Openings:

1. When it is necessary for a pipe to pass through the tank wall, the invert of such pipe or sleeve shall be no less than 18" above the floor slab, and the prestressing wires required at the pipe elevation shall be distributed above and below the opening leaving an unbanded strip around the entire tank.
2. Unbanded strips shall have a vertical dimension of no more than 36" unless an axi-symmetric shell analysis is performed

to account for compressive forces plus shear and moments caused by displacement of the prestressing wires into adjacent bands.

PART 2 - PRODUCTS

2.1 PERFORMANCE

- A. Performance of the materials used in the tank construction shall conform to the minimum requirements of this specification.
- B. Substitutions to the materials in this specification may only be made if submitted in writing and approved by the engineer.

2.2 CONCRETE

- A. Concrete shall conform to ACI 301.
- B. All concrete shall utilize Type I/II Portland cement.
- C. A maximum of 25% of cementitious material may be fly ash.
- D. Admixtures other than air-entraining and water reducing admixtures will not be permitted unless approved by the engineer.
- E. Course and fine aggregate shall meet the requirements of ASTM C 33.
- F. Concrete mixes used in the construction of the tank shall conform to the following:

Mix	Compressive Strength (psi)	Minimum Cement Content (lbs)	Maximum Aggregate Size (in)	Maximum W/C Ratio	Air Content (%)	Slump (in)
Floor	4000	560	3/4	0.45	6 +/-1 1/2%	4"+/-1"
Dome	4000	600	3/8	0.45	6 +/-1 1/2%	4"+/-1"

2.3 SHOTCRETE

- A. Shotcrete shall conform to the requirements of ACI 506.2 except as modified herein.
- B. All shotcrete mixes shall utilize Type I/II cement.
- C. A maximum of 25% of cementitious material may be fly ash.
- D. All shotcrete in contact with diaphragm or prestressing wire shall be proportioned to consist of not more than three parts sand to one part Portland cement by weight. All other shotcrete shall be proportioned to consist of not more than four parts sand to one part Portland cement by weight.
- E. Admixtures will not contain more than trace amounts of chlorides, fluorides, sulfides or nitrates.

F. Shotcrete mixes used in the tank construction shall conform to the following:

Mix	Compressive Strength (psi)	Maximum W/C Ratio	Air Content (%)	Slump (in)	Fiber Reinforcement (lbs/cyd)
Core Wall	4000	0.42	6 +/-1 1/2%	4"+/-1"	-
Covercoat	4000	0.42	6 +/-1 1/2%	4"+/-1"	

2.4 PRESTRESSED REINFORCEMENT

- A. The prestressing wire shall conform to the requirements of ASTM A 821, Type B.
- B. The prestressing wire size shall be 0.162" (8 gauge), 0.192" (6 gauge) or larger, but no larger than 0.250".
- C. The ultimate tensile strength, f_u shall be, 231,000 psi or greater for 8 gauge wire, 222,000 psi or greater for 6 gauge.

2.5 NON-PRESTRESSED REINFORCEMENT

- A. Non-prestressed mild reinforcing steel shall be new billet steel meeting the requirements of ASTM A 185 with a minimum yield strength, f_y , of 60,000 psi.
- B. Welded wire reinforcing shall be plain wire conforming to the requirements of ASTM A 185 with a minimum yield strength, f_y , of 65,000 psi.

2.6 STEEL DIAPHRAGM

- A. The steel diaphragm used in the construction of the core wall shall be 26 gauge conforming to the requirements of ASTM A 1008.
- B. The steel shell is to be formed with re-entrant angles and erected so that a mechanical key is created between the shotcrete and diaphragm.
- C. The sheets of steel diaphragm shall be continuous from bottom to top of wall; horizontal joints or splices will not be permitted.
- D. All vertical joints in the diaphragm shall be rolled seamed, crimped and sealed watertight using epoxy injection.
- E. In all tanks designed to use a waterstop at the floor/wall joint, the steel shell diaphragm shall be epoxy bonded to the waterstop.

2.7 PVC WATERSTOPS, BEARING PADS AND SPONGE FILLER

- A. Plastic waterstops shall be extruded from an elastomeric plastic material of which the base resin is virgin polyvinyl chloride.
- B. The profile and size of the waterstop shall be suitable for the hydrostatic pressure and movements to which it is exposed.

- C. Bearing pads used in floor/wall joints shall consist of neoprene, natural rubber or polyvinyl chloride.
- D. Sponge filler at the floor/wall joint shall be closed-cell neoprene.

2.8 EPOXY

A. Epoxy Sealants:

- 1. Epoxy used for sealing the steel shell shall conform to the requirements of ASTM C 881.
- 2. Epoxy used for sealing the steel shell shall be, Type III, Grade 1, and shall be a 100% solids, moisture insensitive, low modulus epoxy system.
- 3. When pumped, maximum viscosity of the epoxy shall be 10 poises at 77°F.
- 4. The epoxy sealants used in the tank construction shall be suitable for bonding to concrete, shotcrete, PVC and steel.

B. Bonding Epoxy:

- 1. Epoxy resins used for enhancing the bond between fresh concrete and hardened concrete shall conform to the requirements of ASTM C 881.
- 2. Epoxy resins shall be a two-component, 100% solids, moisture-insensitive epoxy and shall be Type II, Grade 2.

2.9 SEISMIC RESTRAINT CABLES

- A. When required by design, seismic restraint cables shall be seven-wire strand conforming to ASTM A 416.
- B. The strand shall be protected with a fusion-bonded, grit-impregnated epoxy coating conforming to ASTM A 882.
- C. The minimum yield strength of the seven-wire strand shall be 270,000 psi.

2.10 TANK ACCESSORIES

- A. Minimum of one, 1' 5" x 4' 4" rectangular Type 316 stainless steel wall manhole for access to the interior of the tank. The cover and the bolts shall also be of Type 316 stainless steel. The wall manhole shall be designed to resist hydraulic loading without excessive deflection.
- B. Interior ladder shall be fabricated from fiberglass with Type 316 stainless steel fasteners and shall conform with all applicable OSHA standards. The ladder shall have a safety climbing device manufactured from Type 316 stainless steel as required to meet applicable OSHA standards.
- C. Roof hatch will be fabricated from T-6061 aluminum and will be designed to resist roof loads in accordance with section 1.7.B.4.

D. Roof ventilators shall be designed to allow proper air flow and venting in tank. In no case shall open area of roof ventilators be less than 4 times the largest pipe diameter.

E. Through-wall pipe sleeves shall be Type 316 stainless steel sleeves with neoprene modular seal units using stainless steel tightening bolts.

2.11 COATINGS

A. Exterior coating system shall consist of the following:

1. Tnemec Series 156 Enviro-Crete Modified Waterborne Acrylate.

B. Interior coating system shall consist of the following:

2. Tnemec Series N140 Pota-Pox Plus Polyamidoamine Epoxy.

PART 3 - EXECUTION

3.1 EXAMINATION

A. All subgrade elevations shall be verified prior to starting tank construction.

3.2 INSTALLATION

A. Floor:

1. The subgrade shall be prepared by fine grading to ensure proper placement of reinforcing steel with proper bottom cover.
2. A 6-mil polyethylene vapor-barrier shall be placed after subgrade preparation has been completed.
3. Form and screed boards shall be of proper thickness and sufficiently braced to ensure that the floor is constructed within proper thickness tolerances.
4. Plate bolsters shall be used to support reinforcing steel in the construction of the floor to ensure positive control of placement of reinforcing steel.
5. The floor shall be vibratory screeded to effect consolidation of concrete and proper encasement of floor reinforcing steel.
6. The floor shall be continuously water cured until tank construction is completed.
7. The floor shall receive a light broom finish.

B. Core Wall:

1. The wall shall be constructed in a predesigned manner utilizing steel shell diaphragm, layers of shotcrete and prestressing wire with each conforming to the following:
 - a. Diaphragm Erection:
 - (1) The diaphragm shall be protected against damage before, during, and after erection. Nail or other holes shall not be made in the steel shell for erection or

other purposes except for inserting wall pipes or sleeves, reinforcing steel, bolts, or other special appurtenances. Such penetrations shall be sealed with an epoxy sealant which complies with Section 2.8 Epoxy.

b. Shotcrete:

- (1) All shotcrete shall be applied by or under direct supervision of experienced nozzlemen certified by the American Concrete Institute (ACI) as outlined in ACI certification publication CP-60.
- (2) Each shotcrete layer shall be broomed prior to final set to effect satisfactory bonding of the following layer.
- (3) No shotcrete shall be applied to reinforcing steel or diaphragm that is encrusted with overspray.
- (4) No less than $\frac{3}{8}$ " thick shotcrete shall separate reinforcing steel and prestressing wire.
- (5) The steel shell diaphragm shall be encased and protected with no less than 1" of shotcrete in all locations.

c. Curing:

- (1) Interior and exterior portions of the shotcrete wall shall be water cured for a minimum of 7 days or until prestressing is started.

C. Epoxy Injection:

1. Epoxy injection shall be carried out from bottom to top of wall using a pressure pumping procedure.
2. Epoxy injection shall proceed only after the steel shell has been fully encased, inside and outside, with shotcrete.

D. Dome:

1. All concrete shall be consolidated by means of a vibrator for proper encasement of reinforcing steel and welded wire fabric.
2. All surfaces at the joint between the wall and the dome shall be coated with bonding epoxy which complies with Section 2.8 Epoxy.
3. Plastic bolsters shall be used to support reinforcing steel and welded wire reinforcement to ensure positive control on placement of steel.
4. The exterior surface of the dome shall receive a light broom finish.
5. The dome shall be water cured for 7 days after casting.

E. Prestressing:

1. The initial tension in each wire shall be read and recorded to verify that the total aggregate force is no less than that required by the design. Averaging or estimating the force of the wire on the wall shall not be considered satisfactory evidence of correct placement of prestressing wires.
2. Placement of the prestressing steel wire shall be in a continuous and uniform helix of such pitch as to provide in each lineal foot of core wall height an initial force and unit compressive force equal to that shown on the design drawings. Splicing of the wire shall be permitted only when completing

the application of a full coil of wire or when removing a defective section of wire.

3. Shotcrete shall be used to completely encase each individual wire and to protect it from corrosion. To facilitate this encasement, the clear space between adjacent wires is to be no less than one wire diameter.
4. Prestressing shall be accomplished by a machine capable of continuously inducing a uniform initial tension in the wire before it is positioned on the tank wall. Tension in the wire shall be generated by methods not dependent on cold working or re-drawing of the wire. In determining compliance with design requirements, the aggregate force of all tensioned wires per foot of wall shall be considered rather than the force per individual wire, and such aggregate force shall be no less than that required by the design and as shown on approved drawings.
5. The tank construction company shall supply equipment at the construction site to measure tension in the wire after it is positioned on the tank wall. The stress measuring equipment shall include: electronic direct reading stressometer accurate to within 2%, calibrated dynamometers and a test stand to verify the accuracy of the equipment.
6. After circumferential prestressing wires have been placed, they shall be protected by encasement in shotcrete. This encasement shall completely encapsulate each wire and permanently bond the wire to the tank wall.
7. When multiple layers of wire are required, shotcrete cover between layers shall be no less than $\frac{1}{8}$ " thick.

F. Covercoat:

1. After all circumferential prestressing wires have been placed, a shotcrete cover having a thickness of no less than 1" shall be placed over the prestressing wires.
2. Horizontal sections of the wall shall form true circles without flat areas, excessive bumps or hollows.
3. The covercoat shall receive a sliced trowel finish.

G. Wall Openings:

1. All wall pipes, sleeves and manholes passing through the wall shall be sealed to the steel shell diaphragm by epoxy injection.

H. Coatings:

1. Exterior Coatings:
 - a. Exterior coatings shall be applied to all above grade portions of the tank structure in a minimum of two coats with a thickness of 4.0 to 8.0 MDFT per coat. The minimum total thickness shall be 10.0 MDFT.
 - b. Exterior coatings shall be applied a minimum of 28 days after final application of concrete or shotcrete.
2. Interior Coatings:
 - a. Interior coatings shall be applied to the wall, dome, and floor surfaces in one coat. The minimum total thickness shall be 6.0 MDFT.

3. All surface preparation application procedures for interior and exterior coatings shall be in accordance with manufacturer's recommendations.

3.3 FIELD QUALITY CONTROL

A. Inspection and Testing:

1. Concrete and Shotcrete Testing:

a. Compression Tests:

- (1) Compression test specimens shall be taken during construction from the first placement of each class of concrete specified herein and at intervals thereafter as selected by the Engineer to insure continued compliance with these Specifications. At least one set of test specimens shall be made for each 50 yards of concrete/shotcrete placed. Each set of test specimens shall be a minimum of 5 cylinders.
- (2) Compression test specimens for concrete/shotcrete shall conform to ASTM C 172 for sampling and ASTM C 31 for making and curing test cylinders. Test specimens shall be 6-inch diameter by 12-inch high or 4-inch diameter by 8-inch high cylinders.
- (3) Compression test shall be performed in accordance with ASTM C 39. Two test cylinders will be tested at 7 days and two at 28 days. The remaining cylinder will be held to verify test results, if needed.

b. Air Content Tests:

- (1) Air content tests shall conform to ASTM C 231 (Pressure Method for Air Content).
- (2) Tests for air content shall be made prior to concrete placement and whenever compression test specimens are made.

c. Slump Tests:

- (1) Slump tests shall be made in accordance with ASTM C 143.
- (2) Slump tests shall be made whenever compression test specimens are made.

2. Hydrostatic Testing:

- a. On completion of the tank and prior to any specified backfill placement at the footing or wall, the tank shall be tested for watertightness.
- b. The testing for watertightness shall be completed as follows:
 - (1) Fill the tank with water to the maximum water level and let it stand for a minimum of 24 hours.
 - (2) Inspect the exterior of the tank wall and footing for damp spots. Damp spots shall be defined as spots where moisture can be picked up on a dry hand, the source of which is from inside the tank.
 - (3) Leakage through the wall or wall-base joint shall be repaired and the tank shall be retested using the above procedure.

3.4 CLEANING AND DISINFECTION

- A. The interior of the tank shall be cleaned to remove debris, construction items, and equipment prior to testing and disinfection.
- B. The following disinfection procedure shall be used to disinfect storage tanks used for potable water:
 - 1. Method 2 or 3 will be used for disinfection of the tank in accordance with AWWA C652.
 - 2. When Method 3 is used, the disinfection plan required by Section 1.4 H. shall address any compatibility issues with the form of chlorine used for disinfecting the storage tank with the type of disinfectant used in the normal production of the water used to fill the tank.

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