


# ELEMENT 13

## CONSIDER IT COVERED

Specification for Aluminum Geodesic Domes

SP-D-1301

Rev	Date	Prepared By	Checker Approval	Operations Approval	Management Approval
E	August 2023	KHP	CAB	KRK	BEL

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## **PART 1 GENERAL**

### **1.01 SCOPE**


- A. This Section includes the work for the aluminum self-supporting structure as shown on the drawings and specified herein.

### **1.02 SUBMITTALS**

- A. Drawings shall be submitted showing dimensions, sizes, thickness, gauges, materials, finishes, joint attachment, and erection procedure.
- B. A complete set of design calculations for the dome shall also be submitted and stamped by a Professional Engineer. These calculations shall be signed by a registered professional engineer. All work shall be fabricated and erected in accordance with the approved drawings.
- C. Certification that the specified material alloys, sizes, and quantities have been furnished shall be submitted with materials upon delivery.

### **1.03 REFERENCES**


- A. The following codes and standards form a part of this section to the extent specified herein:
  1. ASTM C509 Standard Specifications for Elastomeric Cellular Preformed Gasket and Sealing Material
  2. ASTM C1115-00 Standard Specification for Dense Elastomeric Silicone Rubber Gaskets
  3. ASTM C920 Standard Specification for Elastomeric Joint Sealants
  4. Aluminum Association Specifications for Aluminum Structures
  5. Aluminum Association Aluminum Design Manual; Specifications and Guidelines for Aluminum Structures
  6. ASCE 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures
  7. ASCE 8 Specification for the Design of Cold-Formed Stainless Steel Structural Members
  8. ASTM F593 Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
  9. Federal Specification TT-S-00230C
  10. Federal Specification A-A-59588

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## **PART 2 PRODUCTS**

### **2.01 DESCRIPTION**

- A. The dome shall be a spherical structure conforming to the dimensions of the tank. The dome structure shall be a fully triangulated space truss complete with noncorrugated closure panels. The dome shall be clear span and designed to be self-supporting from the tank structure. The dome surface paneling shall be designed as a watertight system under all design load conditions. All raw edges of the aluminum panels shall be covered, sealed, and firmly lapped in an interlocking manner to prevent slipping or disengagement under all load conditions and temperature changes.
- B. The aluminum dome structure shall be comprised of aluminum or stainless steel members, parts, and accessories. No part of the dome structure existing above the dome's mounting bracket base plates shall be painted, galvanized, or plated with other materials. If dissimilar materials are used in the dome's supporting structure, they shall be isolated from the aluminum or stainless steel dome with an elastomeric gasket compatible with the dome's materials.
- C. The dome shall be designed such that it is a water-tight system under all code-specified temperatures and design load conditions. The design shall include all sealant joints to be tooled slightly concave after sealant is applied to the gusset covers' outside connections. Care shall be taken to keep sealant confined to the joint area, and any applied outside of the joint shall be removed so that the panels will be free from misplaced sealant. All sealants shall be placed only in a manner as recommended by the sealant manufacturer.
- D. Batten bars shall be used to continuously connect all aluminum closure panels to the structure's members. These continuous connections shall be made watertight via the use of a weather sealing gasket. Designs that incorporate overlapping panels and/or designs that incorporate fasteners which penetrate panels and attach to structural members are expressly prohibited.
- E. Roof panels shall be fabricated from continuous 3003-H16 aluminum sheeting.
- F. Gusset plates that are connected to the beam strut flanges (top and bottom) shall transfer all connection forces. These connections shall be designed as moment-to-moment connections. The gusset plates shall be connected to each strut flange using a minimum of four bolts.
- G. The structural analysis shall be performed using non-linear, second order stiffness analysis models. The structural design models shall include the effect of geometry irregularities such as sidewalls, dormers, excessive dome heights, and equipment hatches. All irregularities shall be designed with allowance for thermal expansion.

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- H. Fasteners shall be designed with a factor of safety of 2.34 on ultimate strength and 1.65 on yield strength.

## 2.02 EXPERIENCE / QUALIFICATIONS

- A. The cover must be manufactured in a US-based manufacturing facility. The use of a fabrication facility that is not US-based is expressly prohibited. Manufacturers that do not meet these qualifications will not be considered.

## 2.03 MATERIALS


- A. Materials provided to meet the provisions of this section shall be new and shall comply with all the requirements listed above in "References." All aluminum alloys shall be as defined by the Aluminum Association and published in the *Aluminum Standards and Data*.
1. Bolts and Fasteners - Threaded fasteners shall be 300 series stainless steel per ASTM F593, Alloy Group 1. Lockbolts shall be 7075-T73 aluminum, 304 or 305 stainless steel. Screws shall be aluminum or 300 series stainless steel.
  2. Plates and Sheets - Plate and sheet material shall be aluminum alloy 3003-H16, 3105-H154, 6061-T6, 5052-H32 or 5052-H36, with mill finish AA - M10 as fabricated. Minimum thickness for gussets shall be 5/16". Sheet materials shall be 0.050" or 1.2mm minimum thickness.
  3. Structures - Aluminum structural shapes shall be alloy 6061-T6, 6005A-T61, 6005A-T5. The aluminum structural members shall be a minimum of 6.0" deep.
  4. Tension Ring - Tension ring structural shapes shall be 6061-T6, 6005A-T61, 6005A-T5 aluminum. Design of the tension ring shall be based on the net cross section of the members and shall not include top flange protrusions used for panel attachment, bolt holes, or outstanding legs that are not connected through the joints.
  5. Miscellaneous Shapes (Door, Dormers, Vent, Hatches, etc.) - Miscellaneous aluminum shapes shall be alloy 6061-T6, 6005A-T61, 6005A-T5, 3003-H14, 3003-H16 or 5052-H32.
  6. Gaskets - All gaskets shall be ozone resistant Silicone or Neoprene only. If Neoprene gaskets are utilized, they must not be exposed to ultraviolet light in application. The gaskets shall have a minimum thickness of 1/8".
  7. Sealant - All sealants shall be silicone, resistant to ozone and ultraviolet light, remaining flexible over all allowable temperature ranges, and shall conform to Federal Specification TT-S-00230C.
  8. Other Penetration Seals – Any other seals penetrating the dome structures and parts shall be weatherproof rubber seals.

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9. Support Bearings - Acceptable bearing surfaces for sliding bearing are Teflon to stainless steel only. In order to avoid damage to the Teflon and to reduce the coefficient of bearing friction, Teflon shall not bear on aluminum surfaces. Dome supports shall utilize only bolted connections. The use of aluminum structural welding at the dome supports is expressly prohibited.
10. Skylights – Shall be provided with a 4” or higher curb. The total skylight area to be provided shall be specified by the client or other applicable codes. Skylight panels shall be 0.250” nominal thickness and constructed from acrylic or polycarbonate materials.

#### **2.04 DESIGN LOADS**


- A. The dome roof structural frame and closure panels shall be designed in accordance with the latest edition of The Aluminum Design Manual, designed for all applicable loads specified herein, and in accordance with the stress limitations of the Aluminum Association Specifications for Aluminum Structures. For members subjected to axial forces and bending moments due to load eccentricity or lateral loads, the combined member stresses shall be determined by adding the stress component due to axial load to the stress components due to bending in both the major and minor axes. In no case shall the dome be designed for any loads less than those specified by the local building code or local amendments.
- B. Unless more severe loads are specified by the purchaser, in addition to design loads specified in applicable AWWA standard for the type of tank being covered and local building code, the following loads shall be considered in the design of the aluminum dome roof:
  1. Dead Load – As determined by the latest applicable edition of ASCE 7 but not less than project specified load requirements.
  2. Live Load – As determined by the latest applicable edition of ASCE 7 Chapter 4 but not less than project specified load requirements.
  3. Unbalanced Load - Reduce the live load by 50 percent over one half of the dome.
  4. Snow Load – As required per the latest applicable edition of ASCE 7 Chapter 7 but not less than required by local building codes and/or local amendments.
    - a. Importance Factor ( $I_s$ ) = As determined by the latest applicable edition of ASCE 7, Chapter 1
    - b. Exposure Factor ( $C_e$ ) = 1.0 or greater per the latest applicable edition of ASCE 7
    - c. Thermal Factor ( $C_t$ ) = 1.0 or greater per the latest applicable edition of ASCE 7

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- d. Slope factor ( $C_s$ ) = As determined by the latest edition of ASCE 7
- 5. Unbalanced Roof Snow Load – As required per the latest applicable edition of ASCE 7 Section 7.6 but not less than required by local building codes and/or amendments.
- 6. Wind Load – As required per the latest applicable edition of ASCE 7 Chapter 26 but not less than required by local building codes and/or amendments.
  - a. Importance Factor ( $I_s$ ) = As determined by the latest applicable edition of ASCE 7, Chapter 1
  - b. Basic Wind Speeds = As determined by the latest edition of ASCE 7
  - c. Exposure Category = C
  - d. Internal wind pressure coefficient = As determined by the latest applicable edition of ASCE 7
- 7. Seismic = As required per the latest applicable edition of ASCE 7 Chapter 11 but not less than required by local building codes and/or amendments.
- 8. Load Combinations = As determined by the latest applicable edition of ASCE 7 Chapter 2
- 9. Temperature – The load combinations listed above shall be considered for a temperature change of 100°F below the installation temperature and 100°F above the installation temperature and for a material temperature range of 40°F below 0°F to 140°F above 0°F.
- 10. Panel Design Load – There are two load cases that shall be considered in addition to the loads and load combinations listed above. These loads shall be taken to act separately from each other and not simultaneously with other design loads.
  - a. Two 250-lb (113-kg) loads concentrated on two separate 1ft<sup>2</sup> (0.093 m<sup>2</sup>) areas of any aluminum panel.
  - b. A 60-psf (293-kg/m<sup>3</sup>) uniform load distributed over the total panel area.

## 2.05 DESIGN


- A. Analysis of the cover shall be performed in accordance with the latest applicable edition of the Aluminum Design Manual (ADM) Chapter C. Stability shall be provided for the structure as a whole and for each of its components. The available strengths of members and connections determined in accordance with Section C.3 shall equal or exceed the required strengths determined in accordance with Section C.2

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- B. The required strengths of members and connections of the structure shall be determined from an elastic analysis that considers the effects of each of the following:
1. Non-linear second order analysis. Structural members shall be sub-divided a minimum of four times to account for the second order effects.
  2. Flexural, shear, and axial deformations, including all member and connection deformations that contribute to displacements of the structure.
  3. Second-order effects including P- $\Delta$  effects (the effect of loads acting on the displaced location of joints or nodes in a structure) and P- $\delta$  effects (the effect of loads acting on the deflected shape of a member between joints or nodes).
  4. Geometric imperfections. The effect of geometric imperfections on the stability of the structure shall be accounted for by analyzing the structure with the members' points of intersection displaced from their nominal locations by the tolerances specified in the contract documents. The displacements shall be placed to cause the greatest destabilizing effect.
  5. Member stiffness reduction due to inelasticity. The effect of member stiffness reduction due to inelasticity on the stability of the structure shall be accounted for by using a reduced stiffness as follows:
    - a. A factor  $t_b$  shall be applied to the flexural stiffnesses of all members whose flexural stiffnesses contribute to the stability of the structure, where:
 
$$t_b = 1.0 \text{ for } \epsilon * P_r / P_y \leq 0.5$$

$$t_b = 4(P_r / P_y) (1 - \epsilon * P_r / P_y) \text{ for a } \epsilon * P_r / P_y > 0.5 P$$
    - b. Uncertainty in stiffness and strength shall be addressed by applying a factor of 0.8 to all axial, shear and flexural stiffnesses in the structure.
    - c. The effective length factor  $k$  of all members shall be taken as 1.0
- C. The analysis shall include all gravity loads and a separate analysis shall be performed for each load case or load combination.
- D. Snap-Through Buckling (General Shell Buckling) shall be determined in accordance with the following formula:

$$w = \frac{2258 \times 10^6 \sqrt{I_x A}}{(SF)R^2 L}$$

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Where:

$w$  = Allowable load [pressure psf]

$I_x$  = Moment of inertia of strut about the strong axis [in<sup>4</sup>]

$A$  = Cross sectional area of strut [in<sup>2</sup>]


$R$  = Spherical radius of dome [in]

$L$  = Average member length [in]

$SF$  = Safety factor (1.65)

1. The allowable buckling pressure shall be compared to the maximum intensities of symmetrical and nonsymmetrical load conditions.
  2. Alternatively, the stability of the roof may be determined using nonlinear analysis modelling. If the alternative modelling analysis is utilized, a minimum safety factor of 1.95 shall be used in it.
- E. The minimum web thickness for structural members shall be 0.125”.
- F. Cross sectional area of structural members shall be reduced as required by the latest applicable edition of the ADM Section D.3 to account for effective net area due to the connection of the structural member. In lieu of this requirement, testing can be performed in accordance with the latest applicable edition of the ADM to justify a greater effective net area.
- G. Torsional and Flexural-Torsional Buckling of Compression Members: Structural members with an axial compression load must be designed to meet Chapter E of the latest applicable edition of the ADM, unless by finite element analysis it can be proven that flexural buckling is the controlling buckling mode for an individual member. It is prohibited to assume that the panels will brace the structural members so that major axis flexural buckling is the controlling failure mode. Lateral buckling of the member bottom flange shall be investigated even if the top flange is braced. Pinned end connections, in both the major and minor axis, must be used in the finite element analysis model. In lieu of this requirement, designing axial compression members for only flexural buckling is allowed if  $k$  is no less than 1.0 and the smallest radius of gyration of the structural section is used to determine the controlling slenderness ratio.
- H. Lateral-Torsional Buckling: Design of members for flexure must meeting Chapter F of the latest applicable edition of the ADM.
- I. Connections shall be designed as required by the latest applicable edition of the ADM Chapter J. Block shear strength of the connection must meet the requirements of Section J.7.



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## **PART 3 EXECUTION**

### **3.01 INSTALLATION**

- A. No installation work shall be performed by any personnel that are not supervised by a person(s) experienced in erecting and installing domes.
- B. The dome(s) shall be erected in such a way that they are aligned per the approved drawing package and are plumb and level when installed.
- C. The roof shall be installed so as to minimize internal stresses when assembling the various members or components of the structure. Field cutting, trimming, relocating of holes, or applying force to the parts or components to achieve fit-up shall not be allowed.
- D. No splicing or other modification of the gaskets shall be allowed in any way such that the gasketing is not continuous.
- E. All sealants shall be placed and applied as directed by the sealant manufacturer and per their environmental requirements for use. All sealant joints shall be tooled to be slightly concave after the sealant is installed. Care shall be taken to keep sealant confined to the joint in a neat manner. Any sealant applied outside of the joint shall be removed so that the panels will be free from misplaced sealant.

### **3.02 WARRANTY**

- A. The dome manufacturer shall warrant that the work described herein shall be free from defects, workmanship, and material. The dome manufacturer shall replace or repair only faulty workmanship or defective material furnished by it that is reported to it within one year from the date of completion of this scope of work. Materials and workmanship are guaranteed for a period of one (1) year from the date of material delivery. A limited structural warranty is guaranteed for a period of three (3) years from the date of material delivery. Structural defects, faulty workmanship, or defective material shall be reported to be repaired or replaced to the dome manufacturer within 10 working days from discovery, or the suggested structural defects, faulty workmanship, or defective material shall not be subject to this warranty. Faulty workmanship of installation shall not be covered if the dome manufacturer does not perform the installation of materials.
- B. This warranty does not cover defects in any component parts or labor of the aluminum tank products which are not considered the structural components or which were not manufactured by the dome manufacturer; defects in any items or labor which are covered by a separate warranty from the original manufacturer of any part that is used by the dome manufacturer in the structural components; deterioration due to normal wear, tear and exposure; repairs or replacements made necessary by negligence, negligent use of, misuse of, abuse of, loading the unit beyond its gross weight limitations, accidents, acts of


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God, modifications or alterations in or to the structural components by anyone, and failure to maintain or care for the structural components, and any and all matters which were not within the control of the dome manufacturer; neglect of the product or structural components; repairs or replacements made necessary by reason of a failure of the original retail consumer purchaser or others to follow ordinary maintenance procedures as recommended by the dome manufacturer or the manufacturer or dealer of the Structural components; any defects in work, labor, materials or parts not actually manufactured by, performed by or made by the dome manufacturer; delamination caused by water intrusion from lack of required exterior seal maintenance; routine maintenance and adjustments; damage that has occurred as a result of misuse, abuse, neglect, or lack of maintenance; damage caused by unregulated water pressure, tank over-fill or plumbing system modifications resulting in flooding; damage caused by overloading or improper weight distribution.

- C. If the dome manufacturer did not perform the installation of materials, and structural defects or faulty workmanship is discovered, the Client can provide a change order for the dome manufacturer to visit the worksite and determine the nature of faulty workmanship. The dome manufacturer will not be responsible for repairs or additional installation requirements at that point but will provide recommendations for repairs and the option to repair at the Client's expense.
- D. Any warranty work performed will not extend the term of the original warranty period. The dome manufacturer's warranty is limited in scope and liability to repairing or redoing the nonconforming Work or materials. The dome manufacturer shall not be obligated under warranty or otherwise to repair or replace defects caused by operating abuse, neglect, erosion, corrosion, acts of God, or other similar causes or normal wear and tear. No credit shall be allowed for any cost or expense Customer may incur in replacing or connecting materials or workmanship hereunder, unless prior written notice to The dome manufacturer is provided and the dome manufacturer has had the reasonable opportunity to perform and has agreed not to perform in exchange for a credit. Except as expressly provided in herein, the dome manufacturer provides no Warranties, express or implied, of merchantability, fitness for use or otherwise.

**PART 4 SPECIAL PROVISIONS**

Not used.

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