By
Tank Connection, L.L.C.

Geodesic Aluminum Dome & Cover Roof Specification
API 650 Appendix G

I. GENERAL

This specification covers the design, fabrication, and erection of a geodesic clear span aluminum dome roof structure(s) designed and manufactured with appurtenances as required on the contract drawings and specified herein. The structure shall be as manufactured by Tank Connection under the brand name of APEX Domes. This establishes minimum criteria for the design, fabrication, and erection of structurally supported aluminum dome roofs. When this appendix is applicable, the requirements of 5.10 and the paragraphs in Appendix F that deal with roof design is superseded. All other requirements of API Std. 650 shall apply, except that the maximum design temperature shall not exceed 90°C (200°F).

II. SCOPE OF WORK

The supplier shall furnish a design that includes all materials necessary to fabricate and deliver a geodesic aluminum dome roof as specified herein.

III. DESIGN

A. A structurally supported aluminum dome roof is a fully triangulated aluminum space truss with the struts joined at points arrayed on the surface of a sphere. Aluminum closure panels are firmly attached to the frame members. The roof is attached to and supported by the tank at mounting points equally spaced around the perimeter of the tank.

B. New Tanks

When this appendix is specified for a new tank, the tank shall be designed to support the aluminum dome roof. The roof Manufacturer shall supply the magnitude and direction of all the forces acting on the tank as a result of the roof loads, together with details of the roof-to-shell attachment.

The tank shall be designed as an open-top tank, and its wind girder shall meet the requirements of 5.9. The top of the tank shell shall be structurally suitable for attachment of the dome roof structure. The tank Manufacturer and the foundation designer shall be responsible for designing the tank and foundation, respectively, for the loads and moments transmitted from the roof, as provided by the roof manufacturer. If the Purchaser specifies a roof with fixed supports, the supports shall be rigidly attached directly to the tank and the top of tank and the tank shall be designed to sustain the horizontal thrust transferred from the 11 roof (see G, 5.2). The Purchaser or the tank Manufacturer shall report the as-built minimum and maximum diameter at the top of the tank to the roof manufacturer.

C. Existing Tanks

When this appendix is specified for an aluminum dome roof to be added to an existing tank (with or without an existing roof), the roof Manufacturer shall verify that the tank has sufficient strength to support a new roof and meet the applicable requirements of Section 5.11. Information on the existing tank shall be provided by the Purchaser including minimum tank shell course thicknesses, tank shell course heights, design corrosion allowance, and existing anchorage details. The Purchaser shall specify the existing or new appurtenances to be accommodated by tlle roof Manufacturer. The roof Manufacturer shall supply the values of the forces acting on the tank as a result of the roof loads. The Purchaser shall verify the adequacy of the foundations. Unless otherwise specified, any reinforcement required to enable the tank to support the roof shall be the responsibility of the Purchaser. The design and erection of the roof shall accommodate the actual tank shape. The responsibility for determining the tank shape shall be specified by the Purchaser. The existing tank shall be equipped with a wind girder that meets the requirements of 5.9 for an open-top tank.

D. Existing Tank Data Sheet

When an aluminum dome is ordered for an existing tank, the Purchaser shall complete a data sheet.

E. SPECIAL FEATURES

- Self-Supporting Structure The aluminum dome roof shall be supported only from the rim of the tank. The design of the connection between the roof and the tank rim shall allow for thermal expansion. A minimum temperature range of ±70°C (l20°F) shall be used for design unless a wider range is specified by the Purchaser.

- Finish unless otherwise specified, the aluminum dome roof materials shall have a mill finish.

F. The dome surface paneling is to be designed as a watertight system under all design load and temperature conditions. All raw edges of the aluminum panels should be covered, sealed, and firmly clamped with batten bars in an interlocking manner to prevent slipping or disengagement under design load and temperature changes.

Batten bar to roof panel gaskets shall be silicone. Roof panel designs which do not use batten bars, and an interlocking panel joint or that otherwise do not comply with The Aluminum Design Manual Part IX Section 4.1 as published by the Aluminum Association will not be considered.

G. The roof framing system shall be designed as a three dimensional truss with moment-resisting joints.

H. The structural analysis shall be performed using stiffness analysis models, which include the effect of geometric irregularities such as dormer openings and perimeter support members.

I. Connection forces shall be transferred through gusset plates connected to the top and bottom flanges of the beam-struts, with connections which are designed as moment connections; a minimum of four lock-bolts are to be used to connect the gusset plate to each strut flange.

J. All dome fasteners should be designed with a minimum safety factor of 2.34 on ultimate strength.

K. The vertical loads should be transferred from the roof to the tank in-line with the tank wall. The transfer of horizontal loads to the tank shall be minimized by means of low friction slide supports from both the upward and the downward forces on the tank shell. Designs which do not have a friction reducing slide which reduces horizontal force from uplift shall not be considered.

L. Dissimilar materials shall be isolated by an insulator to prevent galvanic corrosion.

M. The design of welded components shall be done in accordance with the Aluminum Structural Welding Code ANSI/AWS D1.2-90.

IV. MATERIALS

A. Triangulated dome frame struts: AA6005A-T6 or AA6061-T6 aluminum.

B. Triangular dome panels: 0.050" nominal thickness, AA3003-H16 or H14 aluminum sheet, mill finish

C. Triangular skylight panels, (if specified) nominal thickness of 1/4" (6 mm) thick clear acrylic or polycarbonate.

D. Perimeter tension/compression ring: AA6005A-T6 or AA6061-T6 aluminum.

E. Fasteners: AA2024-T4 aluminum, AA7075-T73 aluminum or austenitic series 300 stainless steel as required by design.

F. Sealant: Low modulus silicone by Pecora, Dow, General Electric Silpruf or equal. Sealants shall be silicone or urea urethane compounds that conform to Federal Spec TT-S-00230C unless another material is required for compatibility with stored materials. Sealants shall remain flexible over a temperature range of -60°C to + 150°C (-80°F to +300°F) without tearing, cracking, or becoming brittle.

Elongation, tensile strength, hardness, and adhesion shall not change significantly with aging or exposure to ozone, ultraviolet light, or vapors from the product stored in the tank.

G. Standard gaskets: Silicone.

H. Dormers, doors, and hatches: AA6061-T6, AA6005A-T6, AA3003-H14, AA3003-H16 or AA5052- H34 aluminum.

I. Anchor Bolts: Series 300 stainless steel.

J. Connection Gussets AA6061-T6 or AA5052- H34

V. ALLOWABLE STRESSES & DESIGN PRINCIPLES

A. The roof framing system shall be designed as a three-dimensional space frame or truss with membrane covering (roof panels) providing loads along the length of the individual members. The design must consider the increased compression induced in the framing members due to the tension in the roof panels.

B. The actual stresses in the framing members and panels under all design load conditions shall be less than or equal to the allowable stresses per the Aluminum Design Manual as published by the Aluminum Association, Inc. (Washington, D.C.).

C. The allowable general buckling pressure pa shall equal or exceed the maximum pressure given in R.I (e).

$$Pa = \frac{1.6E\sqrt{I_x A}}{}$$

Where E modulus of elasticity of the dome frame members, I_x =moment of inertia of frame members for bending in a plane normal to the dome surface, A =cross-sectional area of frame members, R =spherical radius of the dome, L =average length of the frame members,

SF — safety factor = 1.65.

Alternatively, pa shall be determined by a non-linear finite element analysis with a safety factor of 1.65.

D. The net tension ring area (exclusive of bolt holes and top flange protrusions) shall not be less than:

$$A_n = \frac{D^2 p}{8F_t \tan\theta}$$

Where 09 A_n = net area of tension ring, D nominal tank diameter, p maximum pressure given in R.I (e), 9 $^{1/2}$ the central angle of the dome or roof slope at the tank shell. Ft least allowable stress for components of the tension ring.

Note: This formula does not include bending stresses due to loads from the panel attached to the beam. These stresses must also be considered in the tension ring design per G.3.1.

VI. DESIGN LOADS

A. Dome Design Loads:

The dome frame and skin shall be designed in accordance with the most recent edition of "The Aluminum Design Manual" as published by the Aluminum Association and is designed for full dead load plus snow load of 25 PSF unless a higher load is specified by the customer. Refer to API 650 G 5.2.1 and load combinations in Appendix R.1 sections a, b, c, e and f.

B. Panel Design Loads: (not acting simultaneously with the above loads).

Each aluminum panel shall be secured to the dome frame and capable of withstanding two concentrated loads of 250 pounds each, applied simultaneously on two separate one square foot areas of the panel or 60 PSF distributed over the total panel area..

C. Wind Loads:

Unless otherwise specified by the purchaser, the wind load is based on a load resulting from a wind velocity of 90 mph.

D. Seismic Loads:

If the tank is designed for seismic loads, the roof shall be designed for:

a. a horizontal seismic force Fh = AiWr

b. a vertical seismic force + A,Wr

Where Al', Av and WY are as defined in Appendix E. Forces shall be uniformly applied over the surface of the roof. Horizontal and vertical forces need not be applied simultaneously

E. Design Codes:.

The roof shall be designed to the design code as specified by the purchaser. Domes can be designed in accordance with The International Building Code, ASCE7, **API650-G**, AWWA D100, AWWA D103 and/or other local state or international codes.

G. Electrical Grounding:

The aluminum dome roof shall be electrically interconnected with and bonded to the steel tank shell or rim. As minimum, stainless steel cable conductors, 3 mm (^{1}/8 in.) in diameter shall be installed at every third support point. The choice of cable shall take into account strength, corrosion resistance, conductivity, joint reliability, flexibility, and service life.

VII. SHOP DRAWINGS, DESIGN CALCULATIONS AND SUBMITTALS

A. Before executing any fabrication, calculations and drawings shall be submitted for approval showing dimensions, sizes, thickness, gauges, materials, finishes, joint attachment and erection procedures.

B. All materials shall be fabricated and erected in accordance with the approved drawings.

VIII. FABRICATION AND ERECTION

A. The roof supplier shall perform all manufacturing work described herein with mechanics skilled and experienced in the fabrication of aluminum dome roof structures.

B. All field work shall be directed by a qualified supervisor who will remain on the job site until the dome construction is completed.

C. Field re-fabrication of structural components or panels will not be accepted. Forcing of the structure to achieve fit-up during construction is expressly forbidden and not acceptable. Any indication of improper fit-up of parts shall be immediately reported to the fabricator.

D. All sealant joints shall be tooled slightly concave after 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. All gasket materials shall be continuous, splices will not be allowed.

IX. GUARANTEE

The dome materials shall be guaranteed for a period of 3 years against defective materials and workmanship.