3E.1.27 Vent Stack

This critical section presents the analysis and structural design methodology and design results of the vent stack.

The vent stack is a steel cylinder located on top of the staircase tower roof between the Fuel Building (FB) and the Safeguard Building (SB) 4. The vent stack is a safety-related, Seismic Category I structure, as described in Section 3.8.4.1.2. The location of the vent stack is shown on Figure 3B-1.

The vent stack has a height of approximately 100 ft and outside diameter of 12 ft 6 in. A key plan of the vent stack is shown on Figure 3E.1.27-1—Key Plan Vent Stack. An Elevation View of the vent stack is shown on Figure 3E.1.27-2—Elevation View of Vent Stack (Section 1-1).

The vent stack has three segments with different thicknesses. The lower two segments are 33 ft 1¾ in tall, and the top segment is 33 ft 1½ in tall. The bottom third of the vent stack wall has a thickness of 1 in, the middle third has a thickness of ¾ in, and the top third has a thickness of ⅝ in. The thicknesses of the vent stack wall segments are shown in Table 3E.1.27-1—Vent Stack Wall Thicknesses. Cross section views of the bottom, middle, and top segments are shown on Figure 3E.1.27-3—Cross Section View of Vent Stack Bottom Segment (Section 2-2), Figure 3E.1.27-4—Cross Section View of Vent Stack Middle Segment (Section 3-3), and Figure 3E.1.27-5—Cross Section View of Vent Stack Top Segment (Section 4-4), respectively.

The design takes into account two platforms, ladders, miscellaneous steel equipment, and a tuned mass damper (TMD). The TMD controls the dynamic cross wind response of the vent stack during wind, tornado, and hurricane winds. The TMD is not required to function during or after a seismic event, and is not a safety-related or a Seismic Category I component. A description of the TMD, including performance requirements, is described in Section 3.8.4.1.2.

The material used for the stack is A588 Grade 50 high-strength, low alloy steel with atmospheric corrosion resistance. The remaining plate material strength is equal or higher than grade A588 Grade 50. Anchorage to concrete consists of an anchor chair with 76 A354 Grade BD bolts in a circular arrangement.

Design details for the vent stack are shown on Figure 3E.1.27-6—Vent Stack Connection to the FB Roof (Detail A). The vent stack is the only subcomponent within the scope of this critical section.

3E.1.27.1 Model

A GTSTRUDL stick model, described in Section 3.8.4.4.2, is used to design the vent stack critical section. This model is used to perform the response spectra analysis and static analysis. The stick model includes the vent stack geometric sections and material properties. The elevations where the thicknesses change are approximated to the nearest joint in the model. Damper and platform masses are lumped similarly to the nearest model joints.

3E.1.27.2 Load Combinations and Loads

Load combinations applied to the vent stack, based on ASME STS-1-2006, "Steel Stacks" and AISC N690-1994, are shown in Table 3E.1.27-2—Vent Stack Load Combinations. The primary loads applied to the stack are dead, live, wind, tornado, vortex shedding, and safe shutdown earthquake. The dead load is calculated based on the self-weight of the stack, platforms, ladders, and miscellaneous loads. Seismic loads from the three components of the earthquake are combined as described in Section 3.8.4.4.1. Load combination reduction was performed to eliminate loads combinations enveloped by other load combinations. Additional loads considered in the design of the vent stack include:

- Dead platform load at 25 psf.
- Live platform load at 100 psf.
- TMD weight at 2200 pounds.
- Ladders and miscellaneous loads at 101 lb/ft.
- Tornado and wind design parameters are used as described in Section 3.3.2.
- Seismic load is based on the in-structure response spectra (ISRS) for the FB roof.
- Wind loads are calculated using the guidance of ASME STS-1-2006 and ASCE 7-05.
- Tornado and hurricane missiles are used as described in Section 3.5.1.4.

3E.1.27.3 Analysis and Design Methods

Response spectra are used as an input for generation of seismic response in the design. The response spectra are based on the ISRS generated at the FB.

A GTSTRUDL stick model is used to determine the frequency and mode shapes of the vent stack. The GTSTRUDL stick model is used to perform the response spectra analysis and static analysis and apply load combinations. The seismic mass and three response spectra for global X, Y, and Z directions are input into the model. Three response spectrum analyses are performed, one for each direction, using square root of the sum of the squares (SRSS) of the modal contributions. Three pseudo-static loads, one for each direction, are created from each of the three response spectrum analyses.

The SRSS method is used to combine the pseudo-static responses and create a safe shutdown earthquake load that contains only member forces and moments.

3E.1.27.4 Critical Section Design

The design of the vent stack is in accordance with ASME STS-1-2006, AISC N690-1994, applicable standards, and steel specifications described in Section 3.8.4.2.2. The vent stack is designed for the resultant forces and moments determined based on the applied loadings.

The anchorage design includes base anchor chairs with top and bottom rings and vertical stiffeners to provide the necessary strength and stiffness for load transfer. The base anchor chair design is in accordance with AISC N690-1994.

The governing design data for the vent stack is shown in Table 3E.1.27-3—Governing Design Data for Vent Stack. Design checks are performed for the stack wall and anchorage to identify the controlling cases.

The allowable stresses and design results for the vent stack wall are shown in Table 3E.1.27-4—Vent Stack Wall Allowables and Design Results. The load cases and design results for the three vent stack thicknesses and the minimum required and provided section properties of the circumferential stiffeners are also shown in Table 3E.1.27-4.

The allowable stresses and design results for the anchor to the FB roof are shown in Table 3E.1.27-5—Vent Stack Allowables for Anchorage and Baseplate.

Table 3E.1.27-1—Vent Stack Wall Thicknesses

		Wall Thickness		
		⅝ in	¾ in	1 in
Elevation	Bottom of Segment (ft)	178	145	112
	Top of Segment (ft)	211	178	145

Table 3E.1.27-2—Vent Stack Load Combinations

Load Combination	Factor of Safety	Comments
D+L	1.5	
D+L+W	1.5	
$D+L+W_t$	1.5	
$D+L+W_h$	1.5	Hurricane wind velocity is identical to tornado wind
D+L+W/4	1.33	
D+L+Wt/4	1.33	Hurricane wind velocity is identical to tornado wind
D+L+Wh/4	1.33	
D+L+0.7VS	1.5	Reduction in vortex shedding loads permitted only for normal wind loads per criteria established in ASME STS-1- 2006, Section 5.2.2.a.2. Reduction in vortex shedding loads is not permitted for tornado or hurricane wind loads, therefore this load case is not controlling.
D+L+VS	1.5	
D+L±SSE	1.5	Directional seismic resultants are SRSS; directionality of lateral SSE is negligible for design
0.9D(self-weight) ± SSE	N/A	Used for Base Design

Table 3E.1.27-3—Governing Design Data for Vent Stack

Load Combination		Governing Design Data for Wall Thickness		
		⅝ in	¾ in	1 in
D+L; D+L+W; D+L+ W_t; D+L+ W_h D+L+0.7VS; D+L+VS	Max Axial (kips)	76	155	210
D+L D+L+W D+L+0.7VS	Max Shear (kips)	110	151	158
	Max Moment (kip-ft)	2540	6927	12054
D+L D+L+ W_t; D+L+ W_h D+L+VS	Max Shear (kips)	157	216	225
	Max Moment (kip-ft)	3628	9896	17220
D+L+SSE	Max Axial (kips)	149	277	350
	Max Shear (kips)	276	391	415
	Max Moment (kip-ft)	6550	17662	30987
0.9D-SSE (for Base Design)	Min Axial (kips)	Note 2	Note 2	-14
	Max Moment (kip-ft)	Note 2	Note 2	30987

Notes:

1. (+) indicates compression, (-) indicates tension.
2. Load combination applicable to base design only.

Table 3E.1.27-4—Vent Stack Wall Allowables and Design Results

Load Case	⅝ in		¾ in		1 in	
	Allowable (ksi)	***[Required (ksi)***	**Allowable (ksi)**	***[Required (ksi)***	**Allowable (ksi)**	***[Required (ksi)***
Longitudinal Compression Stress	20.28	*0.51*	23.67	*0.79*	26.16	*0.75*
Longitudinal Compression and Bending Stress	20.28	*7.72*	23.67	*17.03*	26.16	*22.19*
Circumferential Stress between Stiffeners	4.24	*0.19*	5.42	*0.15*	6.91	*0.11*
Shear Check	20.00	*1.89]**	20.00	*2.23]**	20.00	*1.78]**
	Interaction Ratio (Demand/Allowable)		**Interaction Ratio (Demand/Allowable)**		**Interaction Ratio (Demand/Allowable)**	
Combined Longitudinal + Wind Circumferential Stress	0.065		0.156		0.222	
Stiffener Circumferential Checks	***[Minimum Required***	**Actual Stiffener**	***[Minimum Required***	**Actual Stiffener**	***[Minimum Required***	**Actual Stiffener**
Moment of inertia (in^4)	*2.74*	45.77	*2.65*	50.35	*2.50*	57.90
Area (in^2)	*6.68*	9.30	*7.63*	12.09	*9.93*	19.19
Section Modulus (in^3)	*20.16]**	29.69	*19.48]**	37.73	*18.41]**	51.56

Table 3E.1.27-5—Vent Stack Allowables for Anchorage and Baseplate[1]

	Allowable	***[Required***	**Interaction Ratio**
Bolt Tension (ksi)	49.50	*34.46*	0.70
Bolt Shear (ksi)	25.50	*1.74*	0.07
Ring Circumferential Bending Stress	30.00	*12.71*	0.42
Top Ring Bending	37.50	*7.04*	0.19
Base Plate Bending	37.50	*14.24*	0.38
Stiffener	16.42	*3.64*	0.22
Concrete bearing (kip)	8754	*2808]**	0.32

Note

1. Anchor bolts shall be pre-tensioned with $0.70{*}Fu{*}A._{net.tensile}$ = 263 kips.

Figure 3E.1.27-1—Key Plan Vent Stack

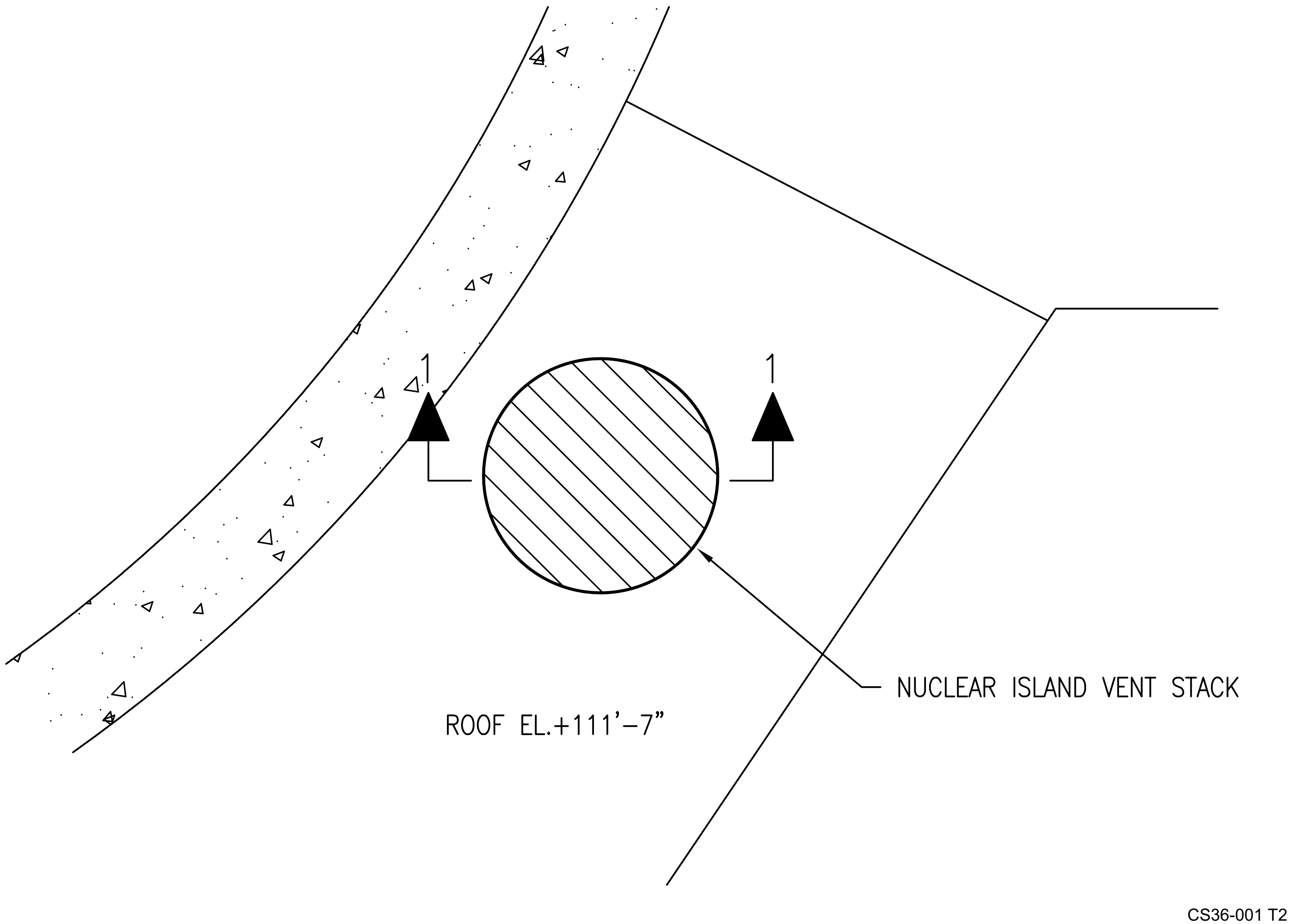

Figure 3E.1.27-2—Elevation View of Vent Stack (Section 1-1)

Figure 3E.1.27-3—Cross Section View of Vent Stack Bottom Segment (Section 2-2)

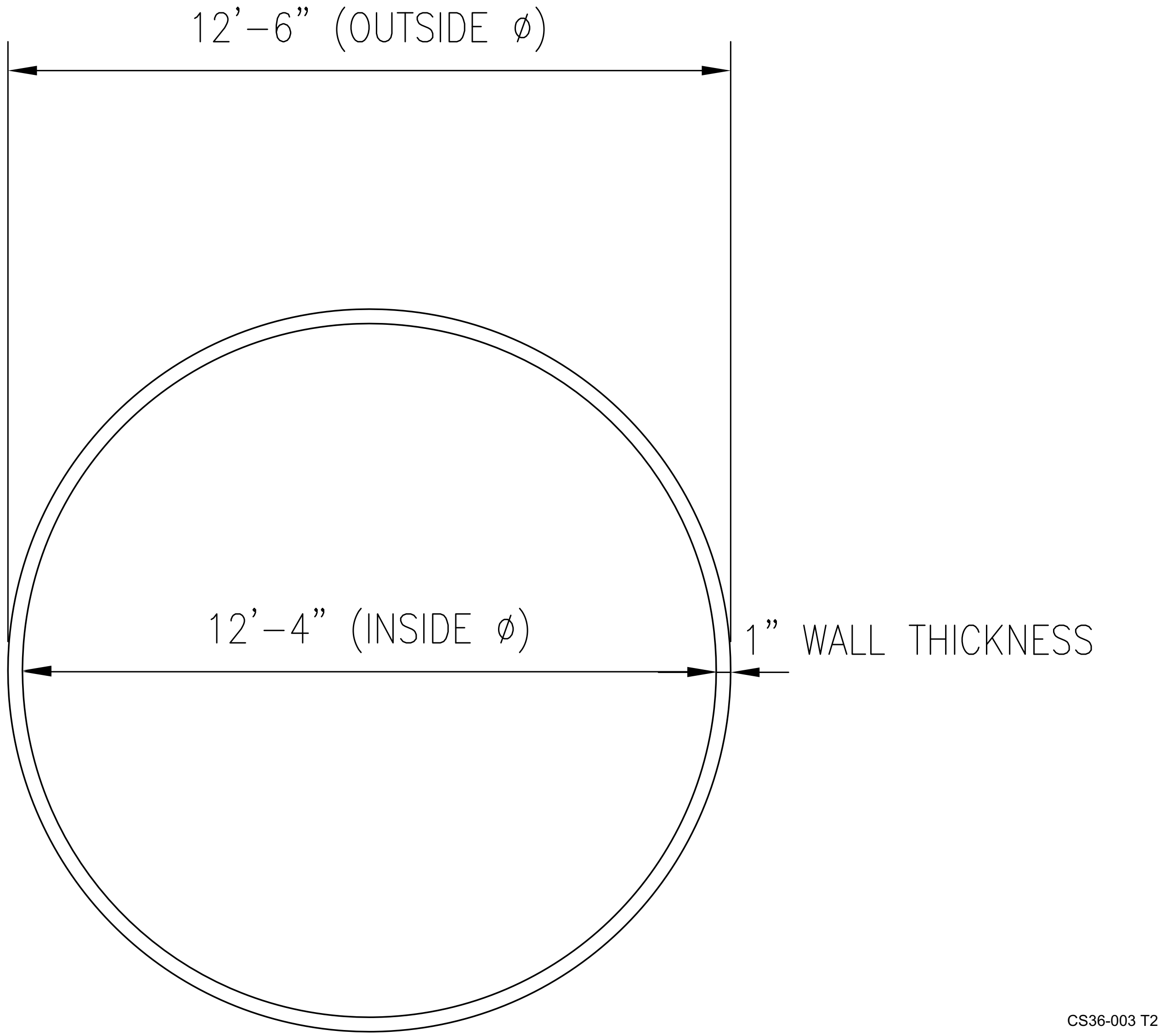

Figure 3E.1.27-4—Cross Section View of Vent Stack Middle Segment (Section 3-3)

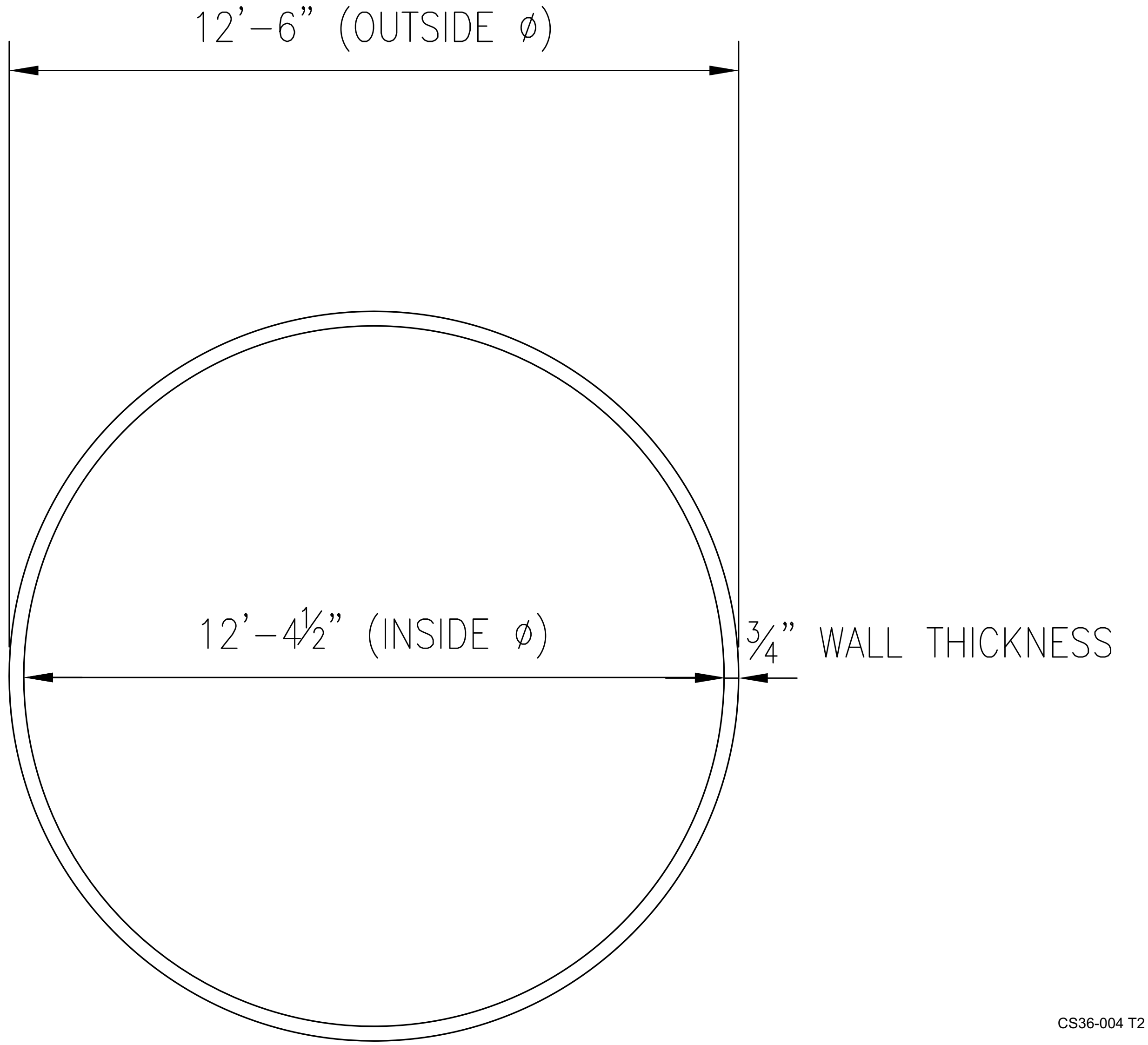

Figure 3E.1.27-5—Cross Section View of Vent Stack Top Segment (Section 4-4)

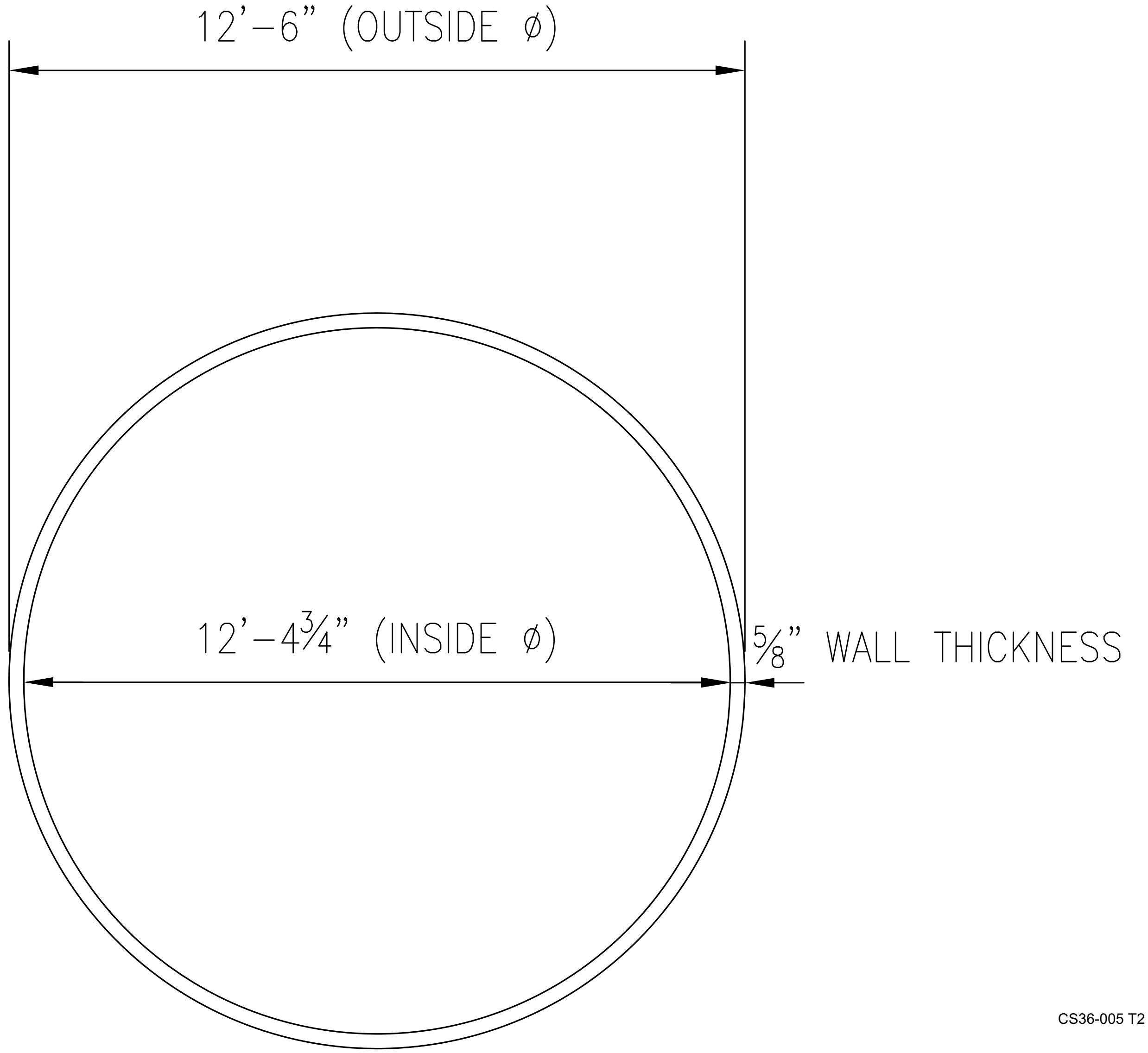

Figure 3E.1.27-6—Vent Stack Connection to the FB Roof (Detail A)