USING A GRADED APPROACH TO THE DOE STD 1020-12 TORNADO MISSILE CRITERIA

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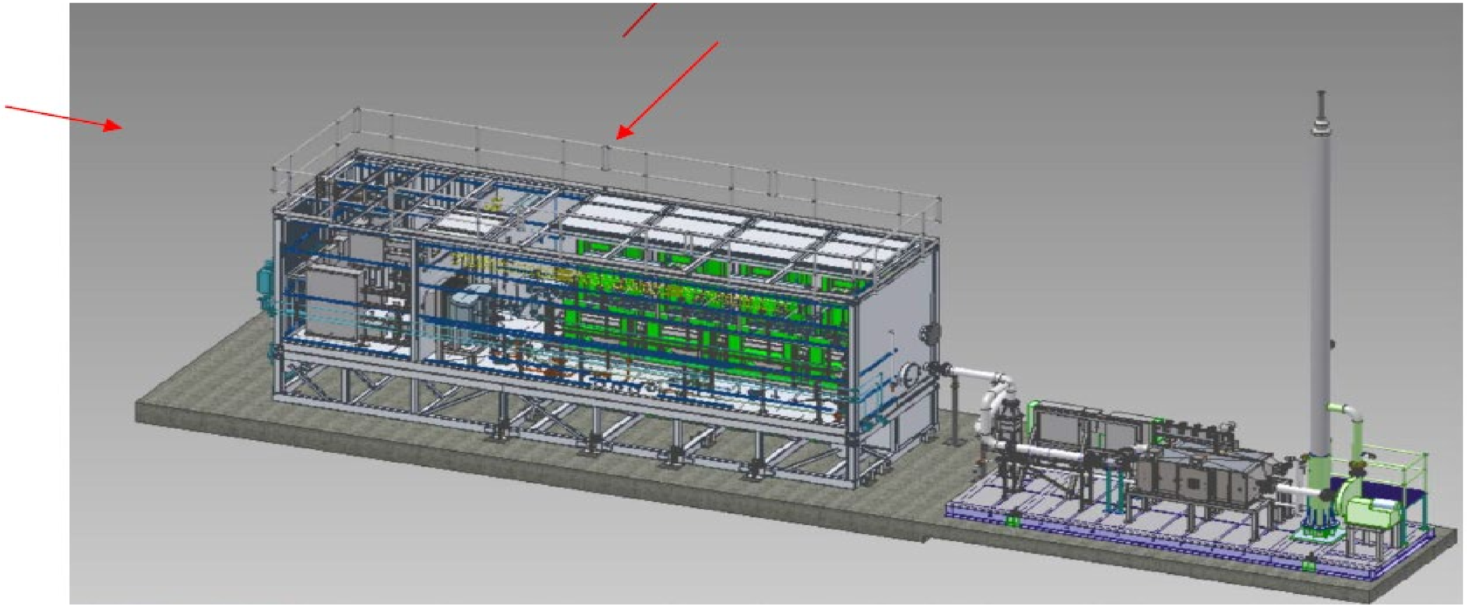
Objective

This a sequel to the comparison that was presented between the prior design tornado missile requirements of DOE-STD-1020-02 and the new design missile requirements per ANS 2.3 (RE: STD-1020-12) at the Savannah River Site (SRS).

For the rolling/tumbling automobile impact, the impact was taken entirely by the Bollards for DOE-STD-1020. But with the new criteria, the bollards are not effective with an impact happening at 30 ft. DOE-STD- 2012 automobile criteria impact would need to dissipate energy in the inelastic regime. What does this look like?

Case Study – Tank Closure Cesium Removal (TCCR) System

The TCCR system includes four ion exchange columns that contain ion exchange resin used for the removal of cesium during system operations. The TCCR is enclosed with a steel frame consisting of HSS framing members and corrugated steel siding. The system sits on, and is connected to, a concrete foundation pad



TCCR Analysis (DOE-STD-1020-2012)

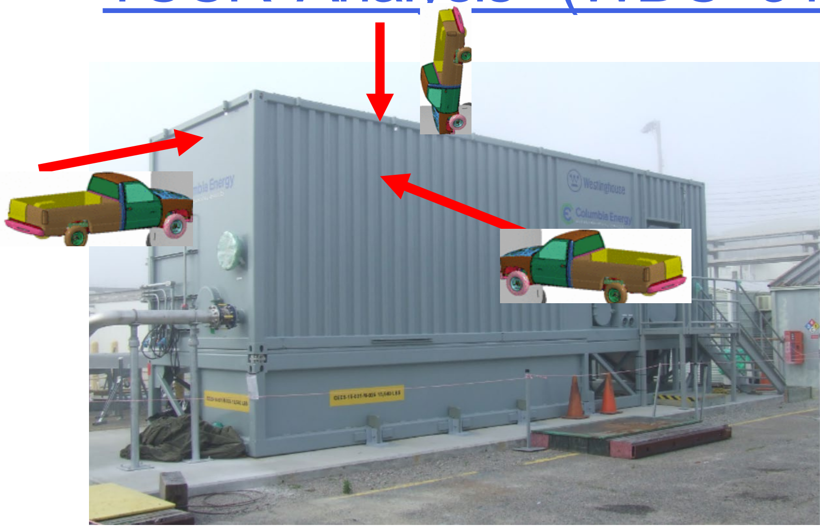
SDC-3 Seismic (Peak 0.49 g) SDC-2 wind 126 MPH. SDC-3 wind 125 MPH

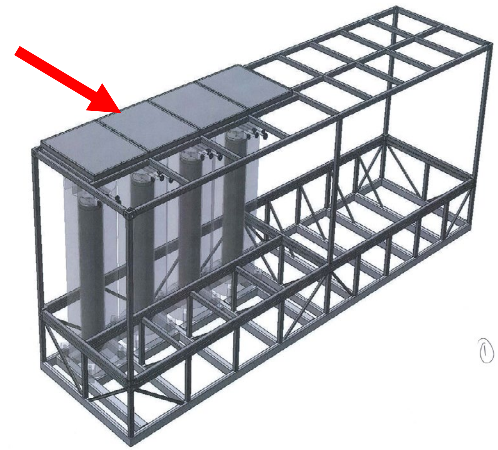
If SDC-3 Wind per Std 1060 rev 12 Tornado wind Speed = 161 MPH and Missile criteria needs to be evaluated.

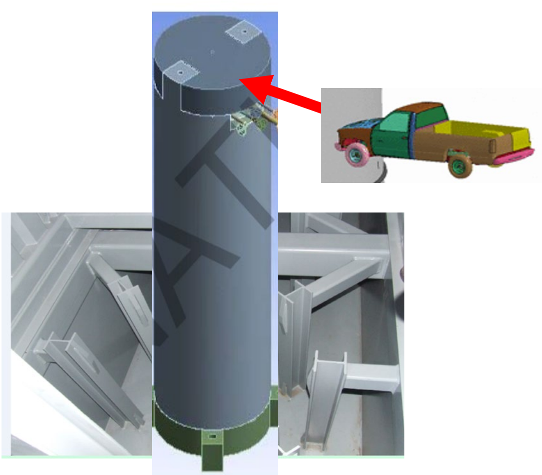
Table- 1 WDC-3 at SRS (Tornado Hazard Criteria Change)

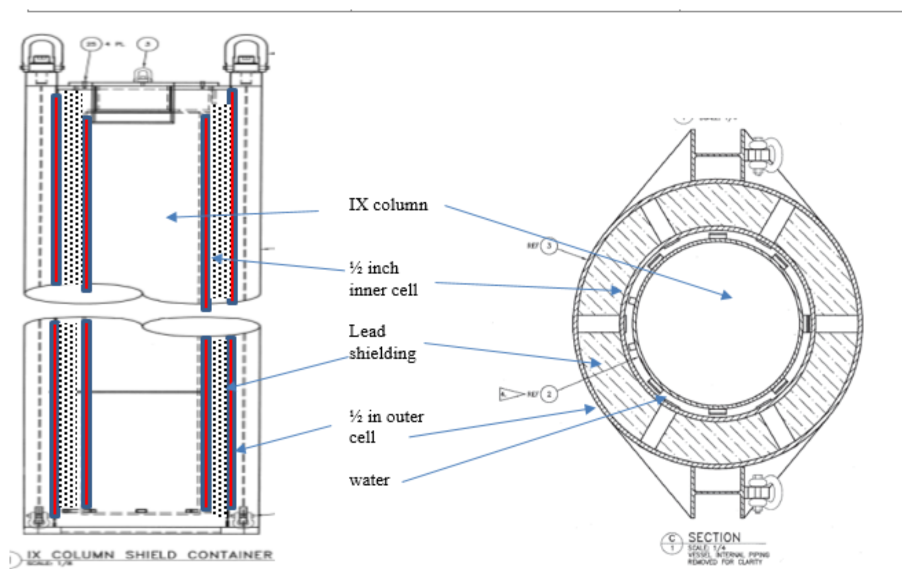
NPH Design Category	DOE-STD-1020-2002	DOE-STD-1020-2012 (ANS 2.3-2011)
	2x4 timber plank 15 lb @ 100 MPH (Horiz) max height 150 ft ; 70 mph (vert)	1.0" dia. Solid steel sphere , 0.147 lb @ 16 MPH (horiz) and 11 MPH (vert)
Missile Criteria	3 in dia std steel pipe, 75 lb @ 50 mph (horiz)max height 75 ft; 35 MPH (vert).	6 in dia Sch 40 steel pipe, 15 ft-length, 287 lb @ 64 mph (horiz) and 43 MPH (vert).
	3000 lb automobile @ 19 MPH rolls and tumble	4000 lb automobile @ 48 MPH , 20 ft^2 contact area, max elevation 30- ft.

TCCR Analysis (WDC -3 Missile per DOE-STD-1020-2012)









Acceptance Criteria

Any impact that does not topple nor move the IXC assemblies more than 10.68 degrees from the vertical is deemed acceptable. And such an impact must not perforate the skin of the IXC assembly

(Ref: TCCR DSA)

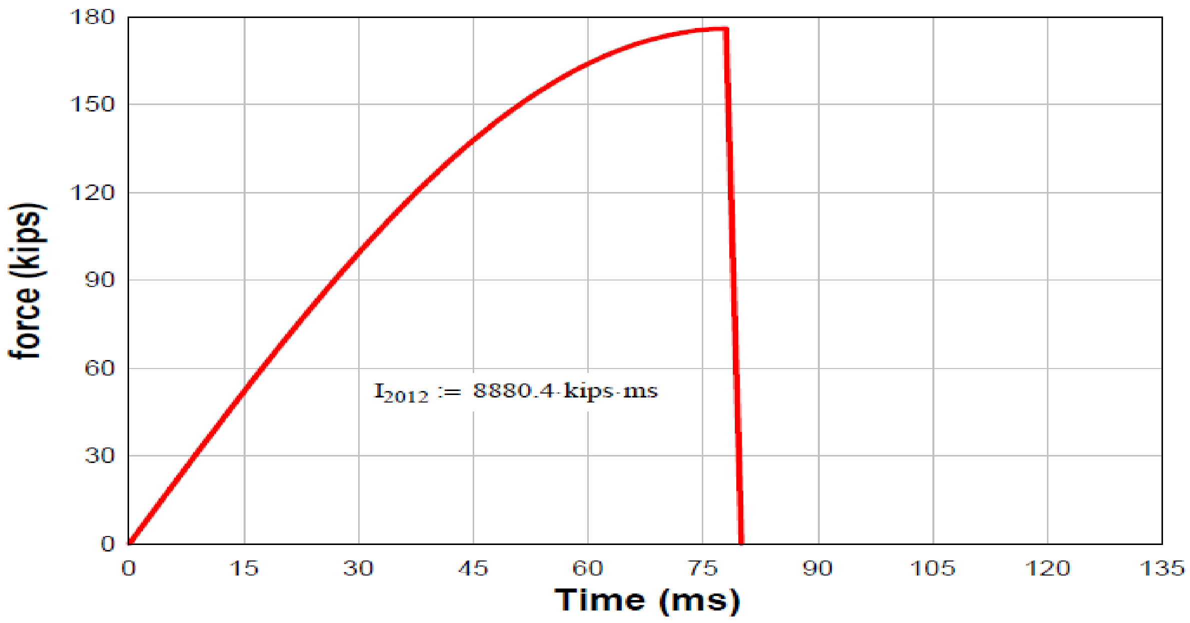
The framing around the IXC assemblies were permitted to be damaged during tornado missile impact (Ref: DOE-STD-1020-2012, Section 4.1.4)

Permitted to use inelastic deformation of the frame to dissipate the impact energy. (Ref: DOE-STD-1020-2012, Section 4.1.4)

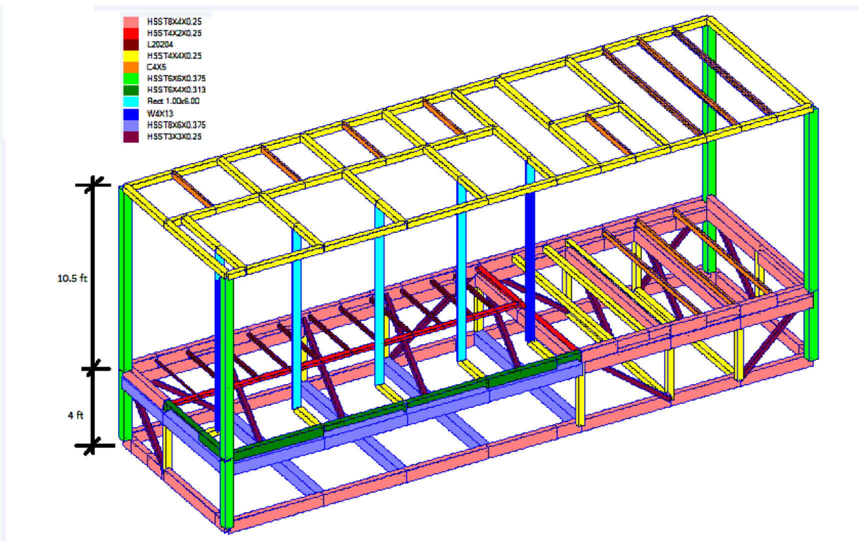
Methodology

The single degree of freedom analysis of each accident scenario was run to solve the equation of motion which is $P(t) = R(x) + (KLM)\,M(\ddot{x})$

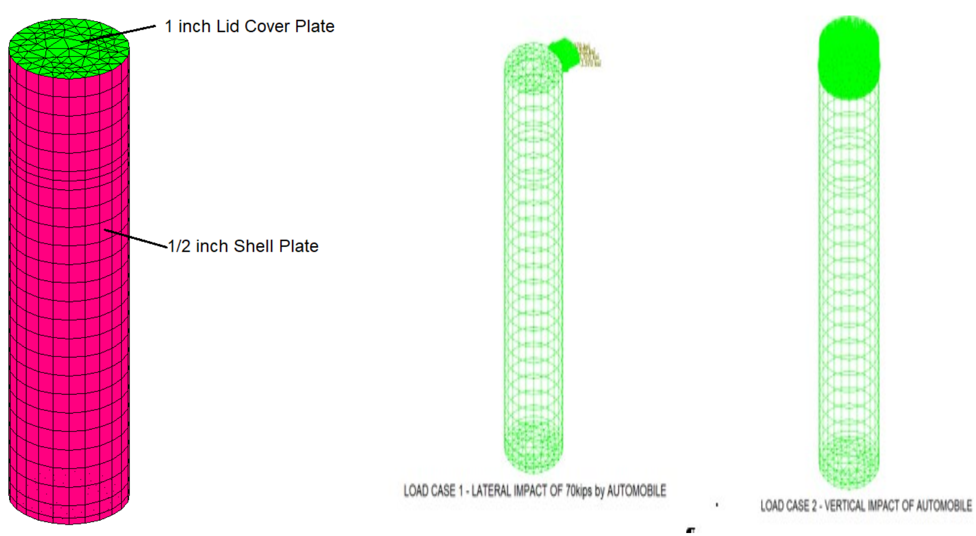
The forcing function P(t) is the impulse from a deformable automobile (Ref. BC-Top-9-A)



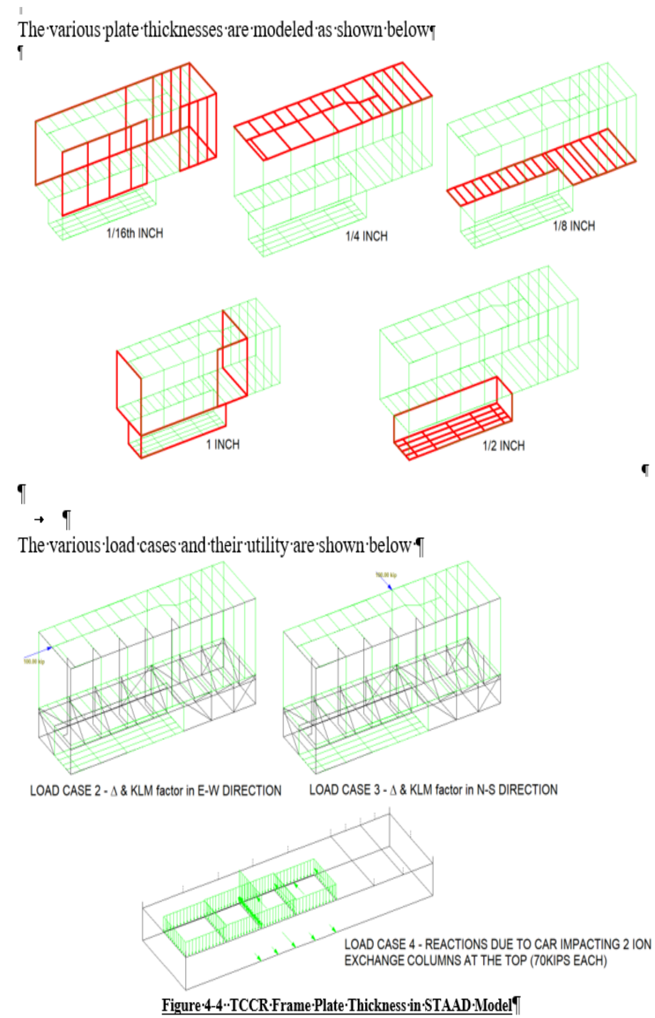
TCCR Frame/ IX column STAAD models



STAAD Frame Model



IX Column STAAD model



The various plate thicknesses are modeled as shown below

1/16th INCH

1/4 INCH

1/8 INCH

1 INCH

1/2 INCH

The various load cases and their utility are shown below

LOAD CASE 2 - Δ & KLM factor in E-W DIRECTION

LOAD CASE 3 - Δ & KLM factor in N-S DIRECTION

LOAD CASE 4 - REACTIONS DUE TO CAR IMPACTING 2 ION EXCHANGE COLUMNS AT THE TOP (70KIPS EACH)

Figure 4-4 TCCR Frame Plate Thickness in STAAD Model

Plates Modeled in Frame - STAAD

TCCR frame Plate Thickness

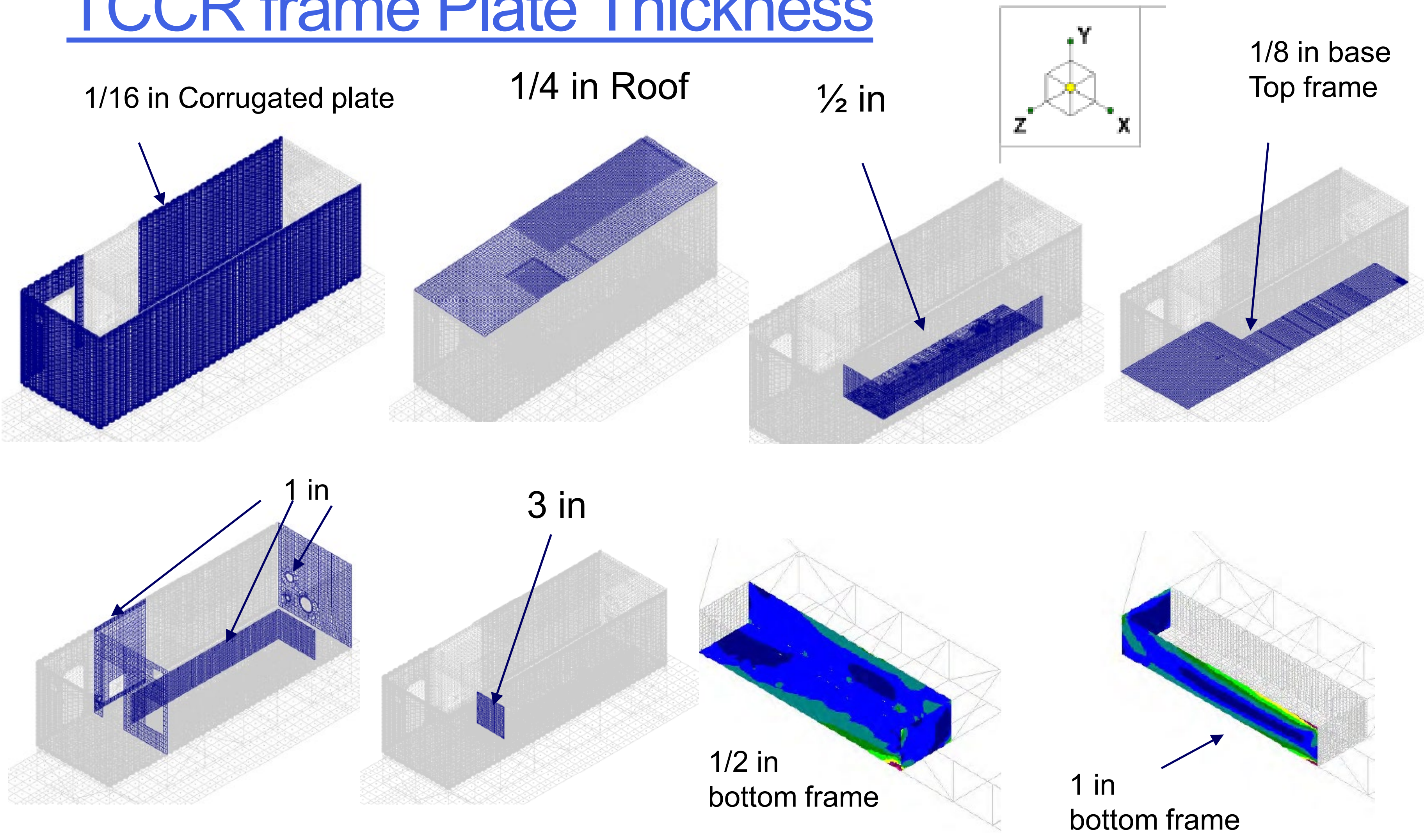


Figure 22. 1/2" A36 Plate Stresses, ATT-7

Figure 23. 1" A36 Plate Stresses,

TCCR Collapse Scenarios

Automobile Impact: Case 1 to Case 6

Case 1 – Single Degree of Freedom Analysis for the automobile impact directly on the 16-gage corrugated siding of the TCCR Process Building Enclosure.

Case 2 – Single Degree of Freedom Analysis for the automobile lateral impact on the TCCR Process Building Enclosure (East-West Direction at the roof). Racking Effects was investigated on the Cesium Ion Column Shielding Assemblies.

Case 3 – Single Degree of Freedom Analysis for the automobile lateral impact directly on the Cesium Ion Columns Shielding Assemblies (North South Direction).

Case 4 – Single Degree of Freedom Analysis for the automobile lateral impact directly on the Cesium Ion Columns Shielding Assemblies (East West Direction).

Case 5 – Single Degree of Freedom Analysis for the vertical automobile drop unto the roof of the TCCR Process Building Enclosure. (Drop unto the ¼” Roof Plates).

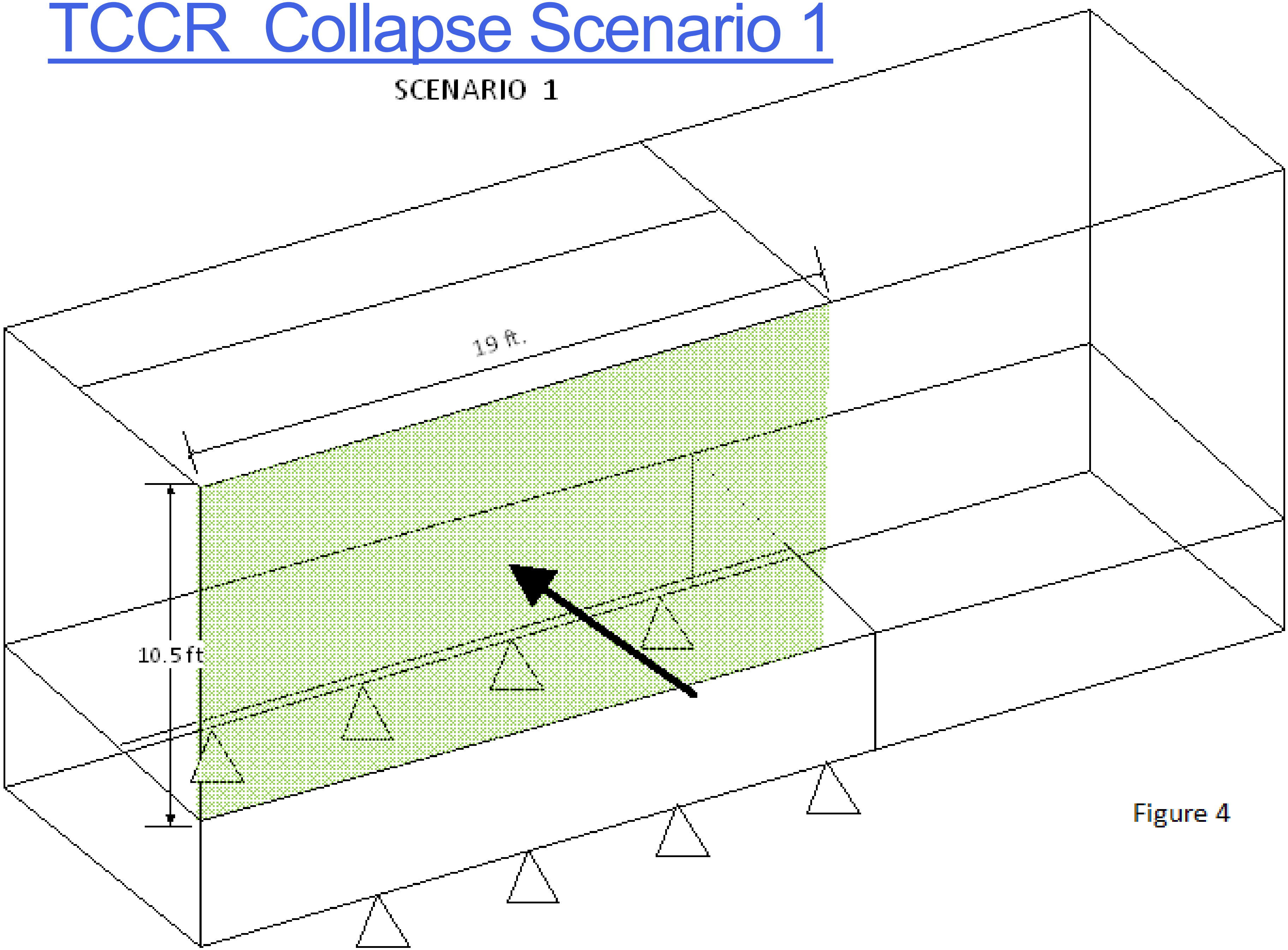
Case 6 – Single Degree of Freedom Analysis for the vertical automobile drop directly unto the Cesium Ion Column Shielding Assembly Lids.

Local Impact: Case 7 and Case 8

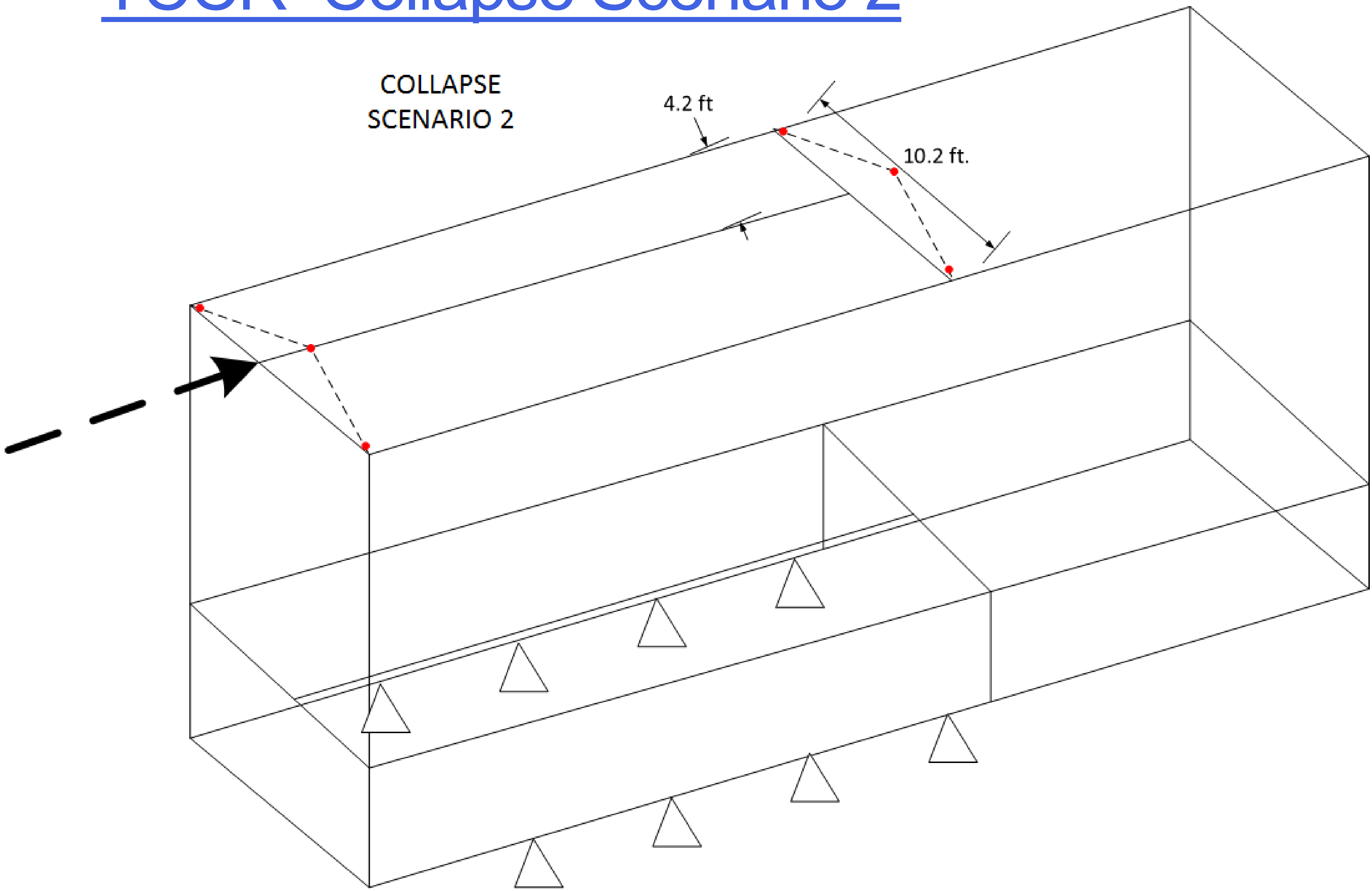
Case 7- Perforation Check under the 1 inch diameter solid steel sphere.

Case 8- Perforation Check under the 6 inch, Schedule 40 pipe missile impact.

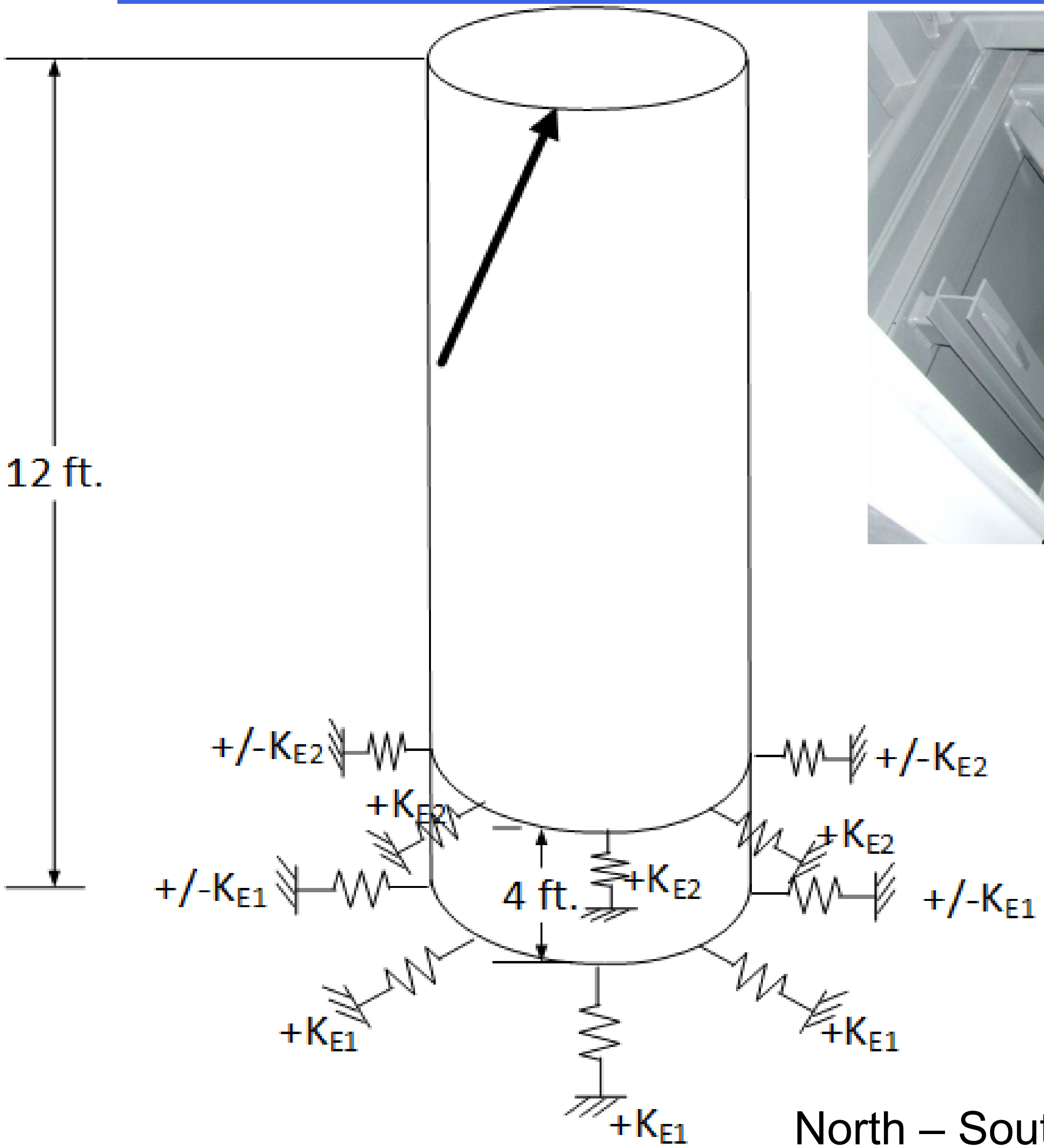
TCCR Collapse Scenario 1

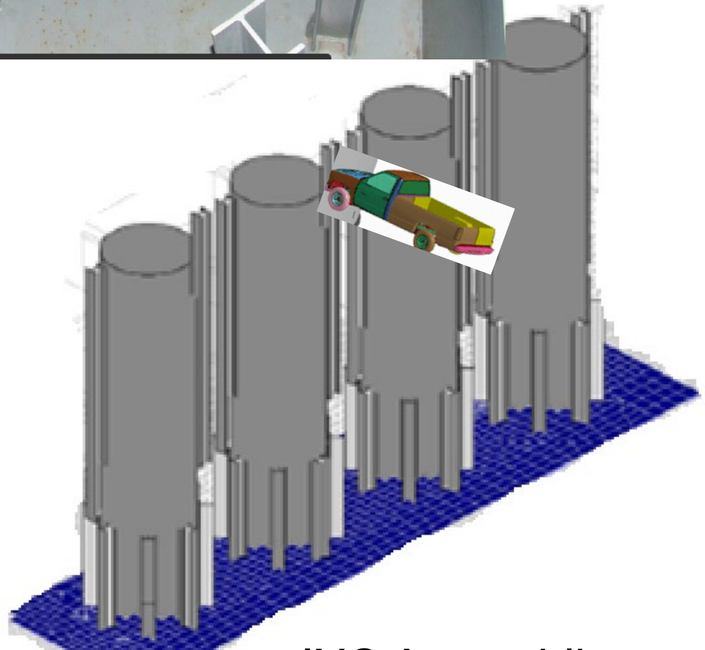


TCCR Collapse Scenario 2



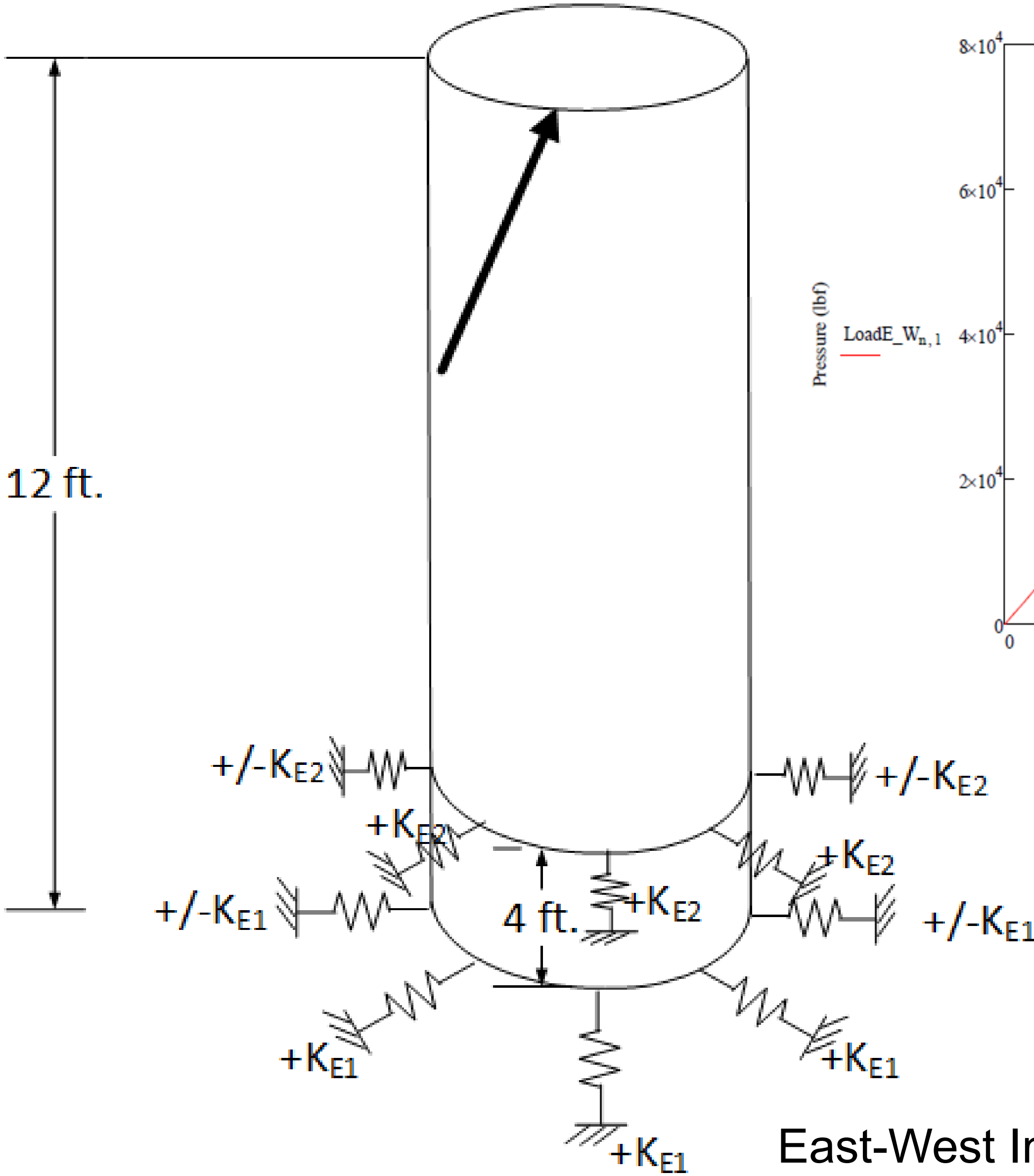
TCCR Collapse Scenario 3

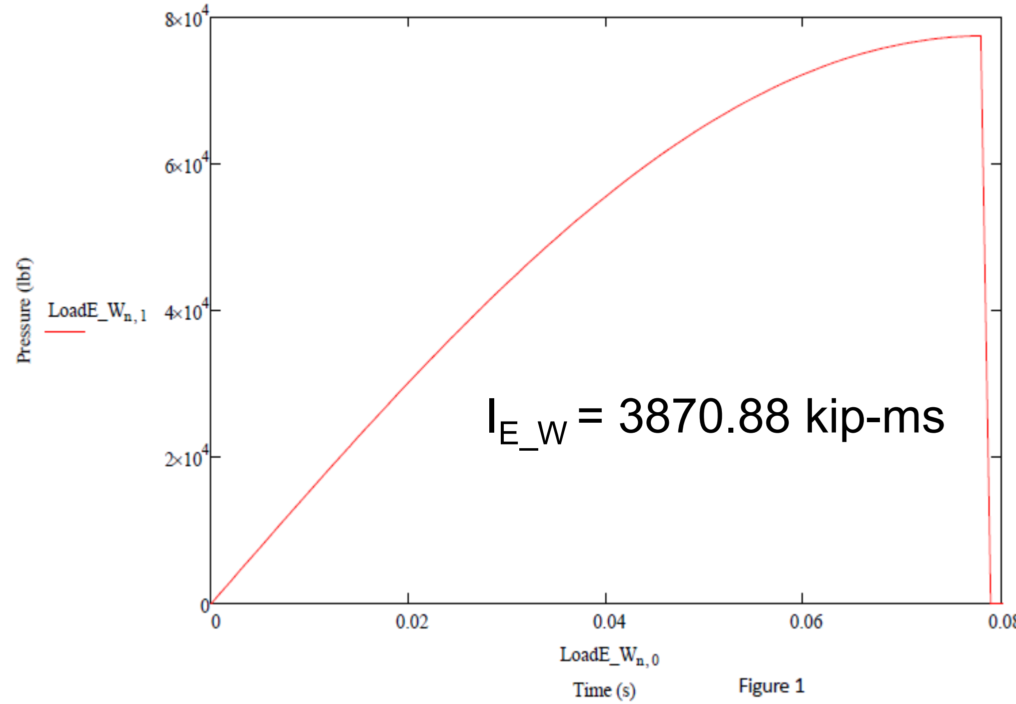




North – South Impact on two IXC Assemblies

TCCR Collapse Scenario 4

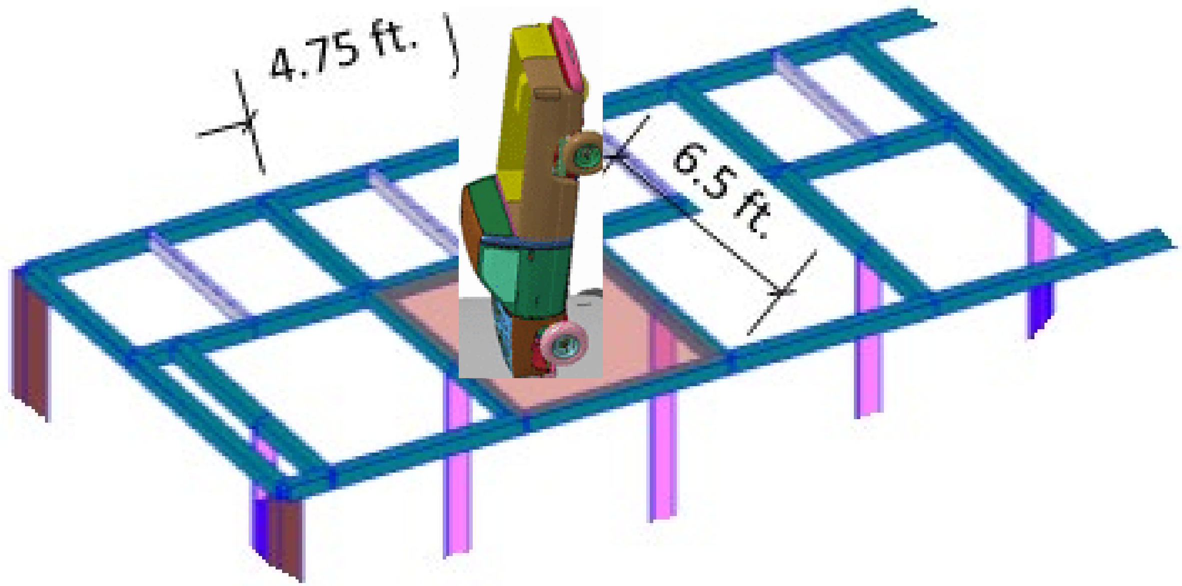


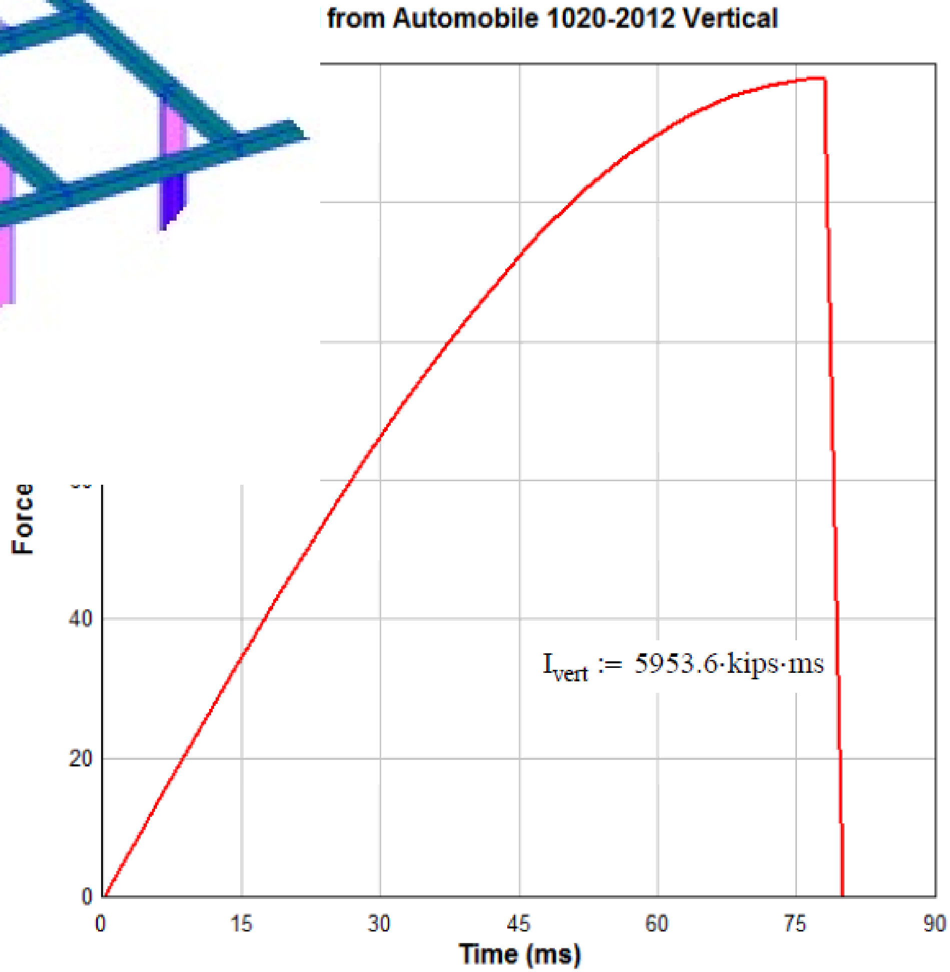


I_{total} = 8880.71 kip-ms

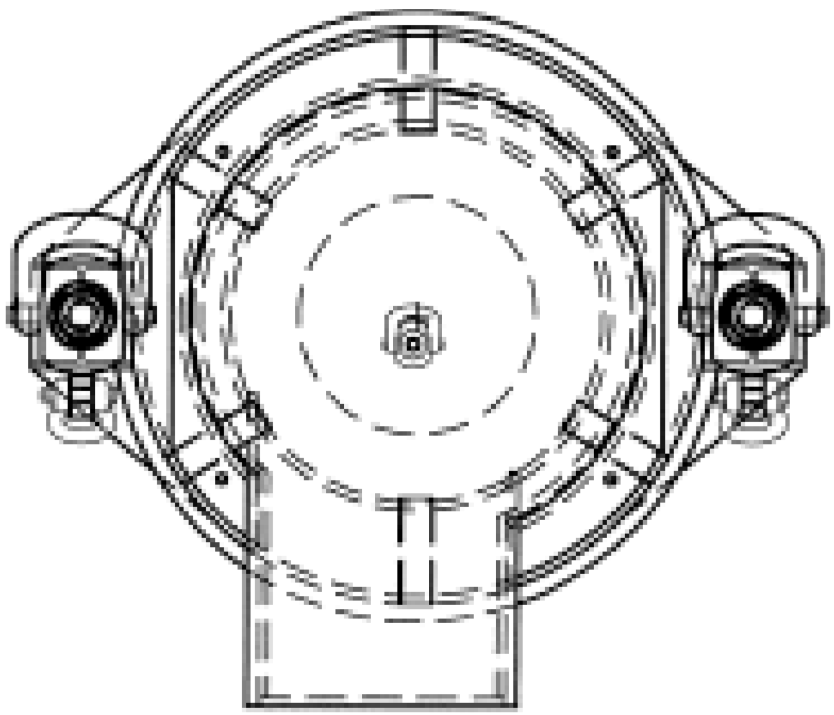
East-West Impact on one of the IXC Assemblies

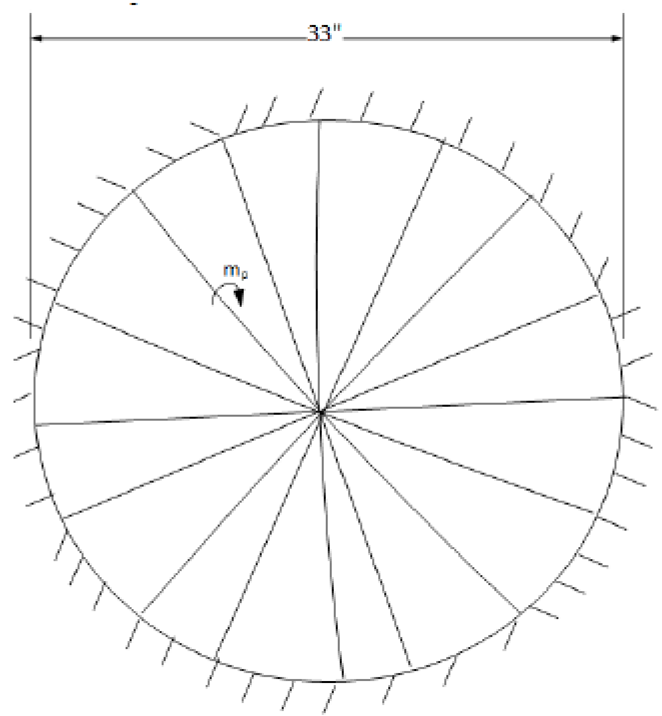
TCCR Collapse Scenario 5



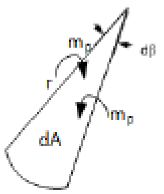


TCCR Collapse Scenario 6





Simply supported edge (i.e. Negative yieldline will not form)



Direct drop on the IXC assembly lid

TCCR WDC_3 Impact Analysis Results

Case #	Conclusion	Damage (Ductility & Rotation)	Consequence on IX Columns	Local Response (Perforation threshold)	Results from Appendix D
Case 1 Automobile Impact N-S Siding impact	The1/16 in thick corrugated siding cannot be qualified for WDC-3 tornado missile hazard.	>20 & >12°	Automobile engages the IXC Shielding Assembly directly See Case 3 for analysis.	NA	NG. The 1/16 in thick corrugated plates completely collapses and the automobile engages the IXC Shielding Assembly directly.
Case 2 Automobile Impact E-W Roof Frame impact	The process building enclosure frames cannot be qualified for WDC-3 tornado missile hazard	>20 & >12°	Automobile engages the IXC Shielding Assembly directly See Case 4 for analysis.	NA	NG. Roof Frames completely collapses but impacting the E-W Steel Frame Roof edge does not result in the IXC Shielding Assembly failing in tilt/racking.
Case 3 Automobile Impact N-S Impact on IXC Shielding Assembly	The IXC Shielding Assembly will survive the WDC-3 missile impact and fail safe (i.e. within acceptable parameters set forth in the TR&C)	2.6 <20 & 1.3°<12°	This means that the IXC Shielding Assembly clamp at the bottom of IXC Shielding Assembly will yield but the clamp will hold on to the IXC Shielding Assembly and will not allow a rotation greater than 1.3°.	NA	OK - IXC Shielding Assembly acceptance criteria are met. No yield of the outer shell of the IXC Shielding Assembly. Tilt angle OK. Punching Shear OK.

TCCR WDC_3 Impact Analysis Results

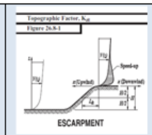
Case #	Conclusion	Damage (Ductility & Rotation)	Consequence on IX Columns	Local Response (Perforation threshold)	Results from Appendix D
Case 4 Automobile Impact E-W Impact on IXC Shielding Assembly	The IXC Shielding Assembly will survive the WDC-3 missile impact and fail safe (i.e. within acceptable parameters set forth in the TR&C)	2.3 <20 & 1.1°<12°	This means that the IXC Shielding Assembly clamp at the bottom of IXC Shielding Assembly will yield but the clamp will hold on to the IXC Shielding Assembly and will not allow a rotation greater than 1.1°.	NA	OK - IXC Shielding Assembly acceptance criteria are met. No yield of the outer shell of the IXC Shielding Assembly. Tilt angle OK. Punching Shear OK.
Case 5 Vertical Automobile Impact on the TCCR Encl. Roof.	The process building enclosure roof plates cannot be qualified for WDC-3 tornado missile hazard	>20 & >12°	Automobile engages the IXC Shielding Assembly directly See Case 5 for analysis	NA	NG. Roof plate completely collapses and automobile will impact the lid of the Cesium Ion Column Shielding Assembly.
Case 6 Vertical Automobile Impact on the IXC Shielding Assembly Lids.	The IXC Shielding Assembly will survive the WDC-3 missile impact with only minor repairable damage.	0.32 <20 & 0.34°<12°	The IXC Shielding Assembly Lid and the outer shell remains intact and responds elastically.	NA	OK. The acceptance criterion of no rupture in the outer shell of the IXC Shielding Assembly is met. No buckling of the IXC shielding assembly.

TCCR_WDC_3 Impact Analysis Results

Case #	Conclusion	Damage (Ductility & Rotation)	Consequence on IX Columns	Local Response (Perforation threshold)	Results from Appendix D
Case 7 1 inch dia. Solid steel sphere	IXC Shielding Assembly Building enclosure will survive an impact from a 1 inch diameter sphere.	NA	NA	0.0026 in < 1/16 in	OK - Will not perforate 1/16 inch corrugate siding nor the ¼ inch roof plates.
Case 8 6 in dia. Sch 40 pipe	IXC Shielding Assembly will survive an impact from a 6 inch diameter Sch 40 pipe.	NA	IXC Assembly Bot. valve has an unobstructed line of sight from the roof but the roof thickness (i.e. ¼ in) is adequate to protect this valve.	0.39 in < ½ in 0.23 in < ¼ in	OK - Will not perforate 1/2 in outer shell of IXC Shielding Assembly.

TCCR Seismic vs Wind Analysis

WDC-2 126 MPH qz =42 psf WDC-3 161 MPGH qz = 69 psf , (69/42) =1.64

	Per ASCE-7-10 D/C Ratios for WDC-2 (126 MPH) to WDC-3 Tornado Wind (161 MPH) Increase by 1.64 factor							
Description	V Basic Wind Speed (MPH)	Wind Directionality (Kd)	Gust Factor (G)	Velocity Pressure Coefficient (Kh)	Topographic Factor (Kzt)		$q_h := 0.00256 \cdot \left(\frac{hr^2 \cdot lbf}{mi^2 \cdot ft^2}\right) \cdot K_h \cdot K_{zt} \cdot K_d \cdot V^2$	Increase in Wind D/C ratios for members
WDC-2 WIND	**126**	0.85	0.85	0.85	**1.43**	With Hill Effect	**42 psf**	
WDC-3 Tornado WIND	**161**	0.85	0.85	0.85	**1.43**	With Hill Effect	**69 psf**	1.64
WDC-3 Tornado WIND	**161**	0.85	0.85	0.85	**1.00**	No hill effect at Tanks 9H to 12H	**48 psf**	1.14

	SDC-3 Seismic vs. WDC-2 (126 MPH) Base shear for TCCR Frame							
Description	Maximum Base shear SDC-3 Seismic (kips)	Maximum Base shear WDC-2 Wind 126 MPH (kips)	Ratio (Seismic / WDC-2 wind	WDC_2 D/C Ratio Reduce by	If D/C Ratio 1.0 for SDC-3 Seismic	WDC- wind D/C Ratio use conservative value	Ratio Increase from WDC3 / WDC 2 (1.67)	Increase in Wind D/C ratios for members
Base shear with (4) IX Tanks (144 kips)	**134**	10	(10)/(134)	by (1/13)	**1.00**	0.08	**0.13**	with IX columns
Base shear without (4) IX Tanks	**60**	10	(10)/(60)	by (1/6)	**1.00**	0.17	**0.28**	Without IX columns

Neither Normal Wind nor Tornadic Wind controlled the design of the Enclosure Unit

Questions?