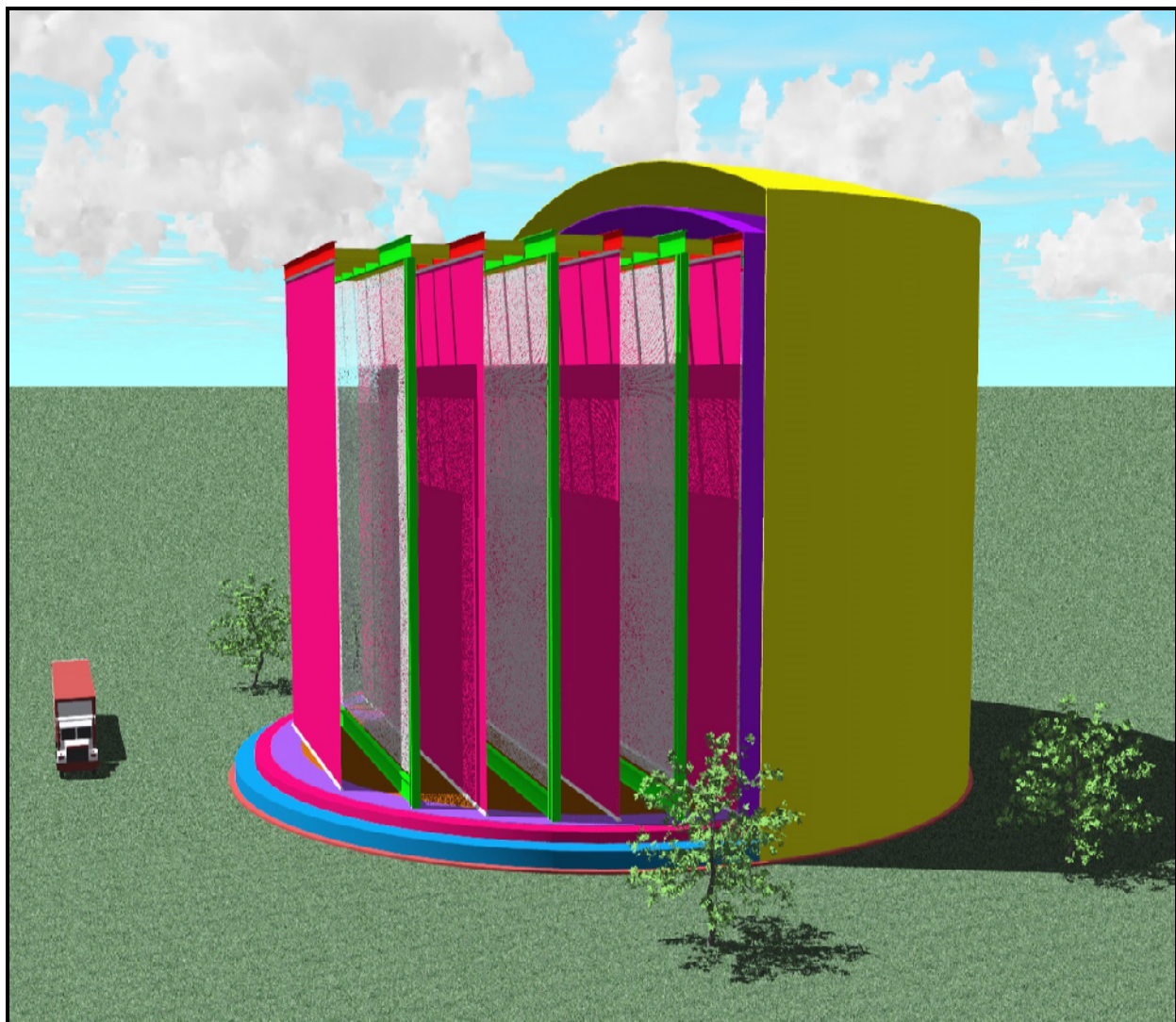




Engineering note number:

Date: 04/12/2005

Experiment	FLARE
Title	Sense wires numbers – Rev A.
Author(s)	Rafael Silva (FNAL)
Reviewer(s)	
Abstract	Estimate of loading on inner tank from wires

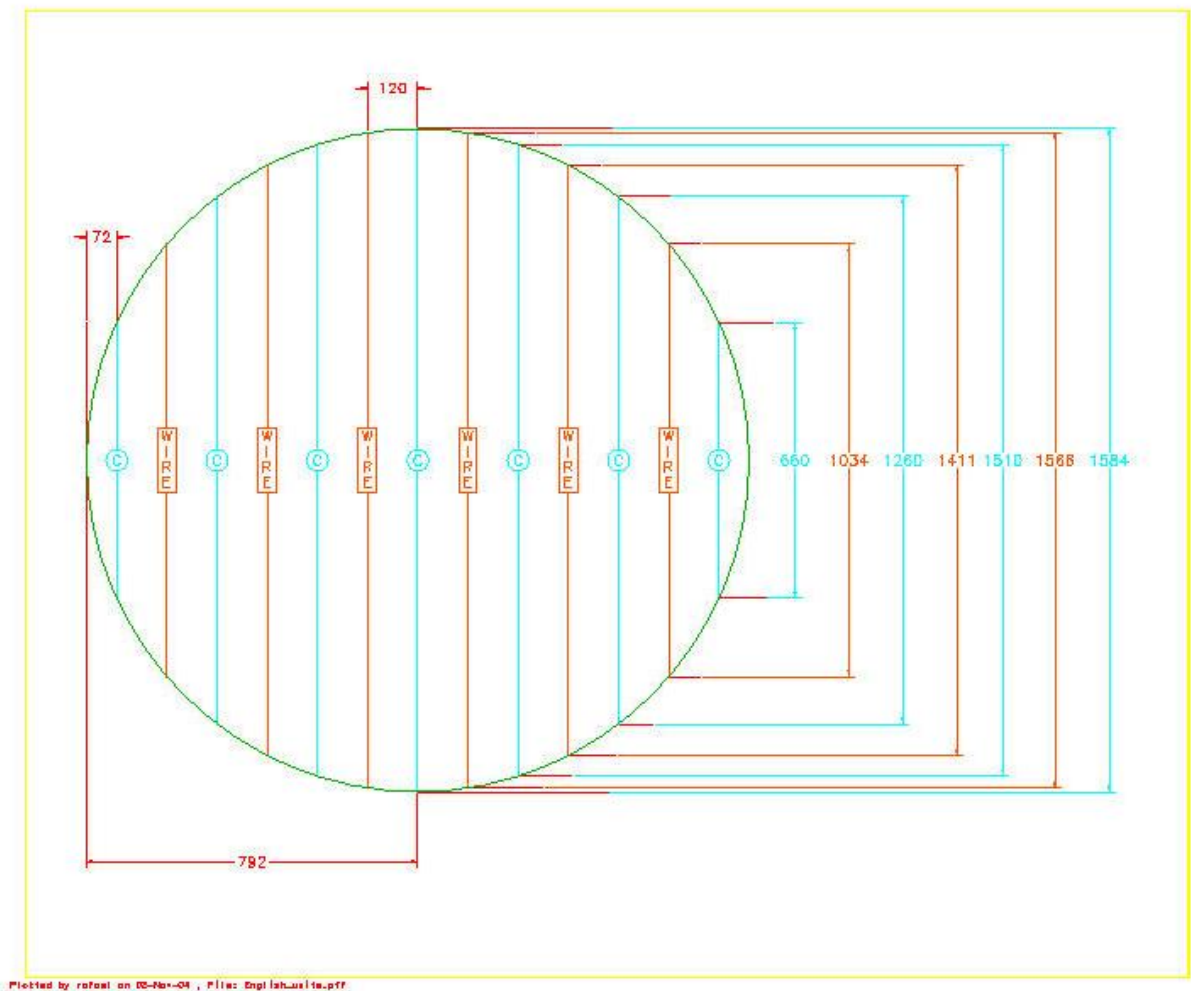


Model by Bartoszek Engineering

1. Detector layout

The current layout for the detector includes:

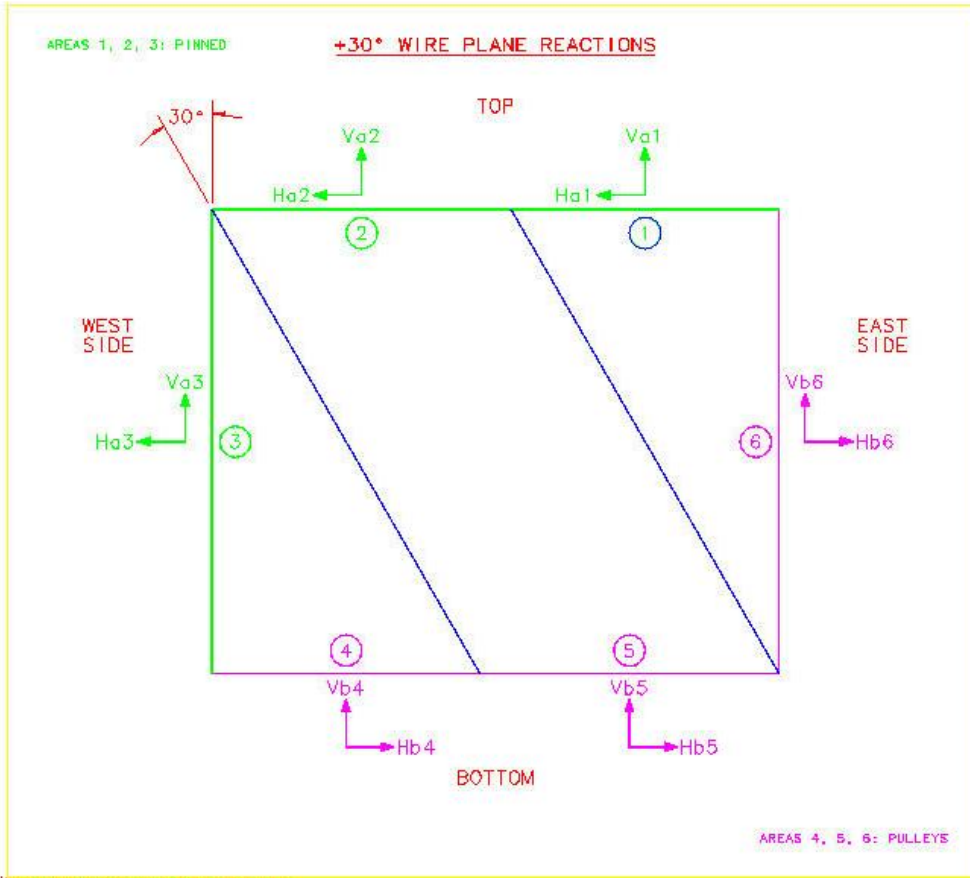
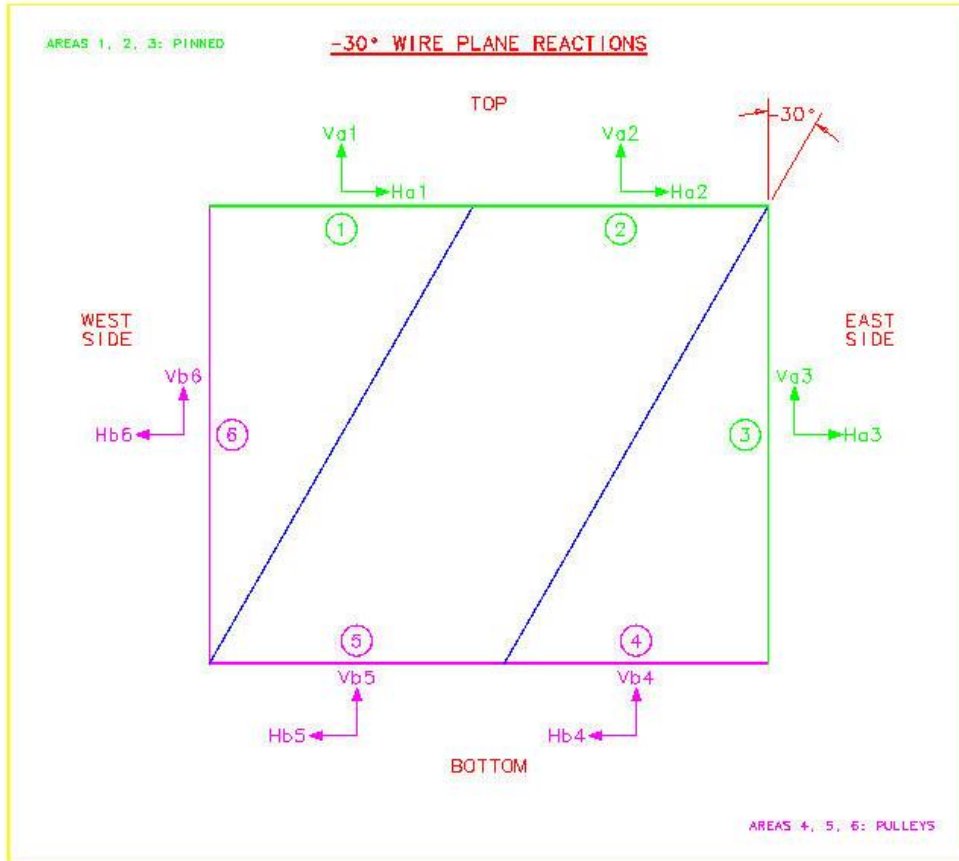
- 6 HV wire sectors,
- 7 cathode planes, and
- field shaping tubes in between them.



Each wire sector has 6 wire planes oriented at:

- $+30^\circ$,
- -30° ,
- vertical,
- vertical,
- -30° , and
- $+30^\circ$, in this order.

The diagrams showing the reaction forces are below.



2. Reactions: formulas and nomenclature

Number of wires:	n
Load per wire (lb):	w
Wire - linear density (lb/in):	d
Vertical spacing between wires (in):	s
Wire - angle with vertical (deg):	θ
Length of wire "n" (in):	$l := \frac{n \cdot s}{\cos(\theta)}$
Summation of length of wires (in):	S $S := \frac{n \cdot s}{\cos(\theta)} \cdot \frac{(n + 1)}{2}$
Total load applied (lb):	W := w · n
Tension on wire "n" (lb):	T := w + n · $\frac{s \cdot d}{\cos(\theta)}$

Reactions

Pinned end, vertical (lb):	$V_a := (W + S \cdot d) \cdot \cos(\theta)$
Pinned end, horizontal (lb):	$H_a := -(W + S \cdot d) \cdot \sin(\theta)$
Pulley end, vertical (lb):	$V_b := (W + S \cdot d) \cdot (1 - \cos(\theta))$
Pulley end, horizontal (lb):	$H_b := (W + S \cdot d) \cdot \sin(\theta)$

3. Calculations

FLARE - wire planes load (1/2 tank)

item	symbol	unit	value
tank height	H	in	1296.0
tank diameter	D	in	1584.0
Stereo wires			
angle with vertical	θ	(°)	30.0
angle with vertical	θ_r	rad	0.524
wire material density (steel)	ρ	lb/cuin	0.284
wire diameter	ϕ_m	mm	0.150
wire diameter	ϕ	in	0.0059
wire cross sectional area	A	sqin	2.74E-05
wire linear density	d	lb/in	7.78E-06
load/wire	wkg	kg	1.3
load/wire	w	lb	2.866
wire spacing	wsmm	mm	5
wire spacing	ws	in	0.197
stereo wire horizontal spacing	hs	in	0.227
stereo wire vertical spacing	s	in	0.394
spacing between planes	pmm	mm	5
spacing between planes	p	in	0.197
max. wire offset from vert. @ top		in	748.2
longest wire			
max. wire length		in	1496.5
weight		lb	0.012
total weight (load+wire weight)		lb	2.878
perp. force on wire from own weight		lb	0.006
max. deflection		in	0.760
wire tension		ksi	105.1
wire elastic modulus (steel)		ksi	29000
elongation		%	0.4
elongation		in	5.4

For 1/2 tank:

number of wires hooked up to the top	111311
number of wires hooked up to the side	39492
total	150803
length of wires hooked up to the top	ft 8607226
length of wires hooked up to the side	ft 2462597
total	ft 11069823
cost at \$44/10000ft	\$ 48707

For the whole tank:

number of wires hooked up to the top	222622
number of wires hooked up to the side	78984
Total number of wires	301606
length of wires hooked up to the top	ft 17214453
length of wires hooked up to the side	ft 4925194
Total length of wires	ft 22139647

Top										
+30° stereo planes	Distance from center	Plane width	Area 1				Area 2			
			n1	S1	Va1	Ha1	n2	S2	Va2	Ha2
			in	in	lb	lb	in	lb	lb	lb
Large wire sector	120.0									
First stereo	119.5	1565.9	3291	2462597	8185	-4726	3597	2941760	8948	-5166
Fourth stereo	120.5	1565.6	3291	2462597	8185	-4726	3596	2940125	8945	-5164
		Total	6582	4925194	16370	-9451	7193	5881885	17893	-10330
Intermediate wire sector	360.0									
First stereo	359.5	1411.4	3291	2462597	8185	-4726	2918	1936088	7256	-4189
Fourth stereo	360.5	1410.4	3291	2462597	8185	-4726	2913	1929460	7243	-4182
		Total	6582	4925194	16370	-9451	5831	3865547	14499	-8371
Small wire sector	600.0									
First stereo	599.5	1035.1	3291	2462597	8185	-4726	1262	362300	3135	-1810
Fourth stereo	600.5	1032.8	3291	2462597	8185	-4726	1252	356583	3110	-1795
		Total	6582	4925194	16370	-9451	2514	718883	6245	-3605
+30° stereo planes total			19746	14775583	49109	-28353	15538	10466316	38636	-22306

-30° stereo planes	Distance from center	Plane width	Area 2				Area 1			
			n2	S2	Va2	Ha2	n1	S1	Va1	Ha1
			in	in	lb	lb	in	lb	lb	lb
Large wire sector	120.0									
Second stereo	119.7	1565.8	3597	2941760	8948	5166	3291	2462597	8185	4726
Third stereo	120.3	1565.6	3596	2940125	8945	5164	3291	2462597	8185	4726
		Total	7193	5881885	17893	10330	6582	4925194	16370	9451
Intermediate wire sector	360.0									
Second stereo	359.7	1411.2	2917	1934761	7253	4188	3291	2462597	8185	4726
Third stereo	360.3	1410.6	2914	1930784	7246	4183	3291	2462597	8185	4726
		Total	5831	3865546	14499	8371	6582	4925194	16370	9451
Small wire sector	600.0									
Second stereo	599.7	1034.6	1260	361153	3130	1807	3291	2462597	8185	4726
Third stereo	600.3	1033.3	1254	357723	3115	1798	3291	2462597	8185	4726
		Total	2514	718876	6245	3605	6582	4925194	16370	9451
-30° stereo planes total			15538	10466307	38636	22306	19746	14775583	49109	28353

0° vertical planes	Distance from center	Plane width	Area 2	
			n2	Va2
			in	lb
Large wire sector	120.0			
First vertical	119.9	1565.7	7953	22873
Second vertical	120.1	1565.7	7953	22873
		Total	15906	45746
Intermediate wire sector	360.0			
First vertical	359.9	1411.0	7167	20613
Second vertical	360.1	1410.8	7166	20610
		Total	14333	41222
Small wire sector	600.0			
First vertical	599.9	1034.2	5253	15108
Second vertical	600.1	1033.7	5251	15102
		Total	10504	30210
0° vertical planes total			40743	117179

			West Side			
			Area 3			
+30° stereo planes	Distance from center	Plane width	n3	S3	Va3	Ha3
	in	in		in	lb	lb
Large wire sector	120.0					
First stereo	119.5	1565.9	3291	2462597	8185	-4726
Fourth stereo	120.5	1565.6	3291	2462597	8185	-4726
		Total	6582	4925194	16370	-9451
Intermediate wire sector	360.0					
First stereo	359.5	1411.4	3291	2462597	8185	-4726
Fourth stereo	360.5	1410.4	3291	2462597	8185	-4726
		Total	6582	4925194	16370	-9451
Small wire sector	600.0					
First stereo	599.5	1035.1	3291	2462597	8185	-4726
Fourth stereo	600.5	1032.8	3291	2462597	8185	-4726
		Total	6582	4925194	16370	-9451
+30° stereo planes total			19746	14775583	49109	-28353
			Area 6			
-30° stereo planes	Distance from center	Plane width	n6	S6	Vb6	Hb6
	in	in		in	lb	lb
Large wire sector	120.0					
Second stereo	119.7	1565.8	3291	2462597	1266	-4726
Third stereo	120.3	1565.6	3291	2462597	1266	-4726
		Total	6582	4925194	2532	-9451
Intermediate wire sector	360.0					
Second stereo	359.7	1411.2	3291	2462597	1266	-4726
Third stereo	360.3	1410.6	3291	2462597	1266	-4726
		Total	6582	4925194	2532	-9451
Small wire sector	600.0					
Second stereo	599.7	1034.6	3291	2462597	1266	-4726
Third stereo	600.3	1033.3	3291	2462597	1266	-4726
		Total	6582	4925194	2532	-9451
-30° stereo planes total			19746	14775583	7597	-28353
0° vertical planes	Distance from center	Plane width				
	in	in				
Large wire sector	120.0					
First vertical	119.9	1565.7				
Second vertical	120.1	1565.7				
		Total				
Intermediate wire sector	360.0					
First vertical	359.9	1411.0				
Second vertical	360.1	1410.8				
		Total				
Small wire sector	600.0					
First vertical	599.9	1034.2				
Second vertical	600.1	1033.7				
		Total				
0° vertical planes total						

Bottom										
+30° stereo planes			Area 4				Area 5			
			n4	S4	Vb4	Hb4	n5	S5	Vb5	Hb5
Distance from center	Plane width									
in	in		in	lb	lb	in	lb	lb		
Large wire sector	120.0									
First stereo	119.5	1565.9	3291	2462597	1266	4726	3597	2941760	1384	5166
Fourth stereo	120.5	1565.6	3291	2462597	1266	4726	3596	2940125	1384	5164
		Total	6582	4925194	2532	9451	7193	5881885	2768	10330
Intermediate wire sector	360.0									
First stereo	359.5	1411.4	3291	2462597	1266	4726	2918	1936088	1122	4189
Fourth stereo	360.5	1410.4	3291	2462597	1266	4726	2913	1929460	1121	4182
		Total	6582	4925194	2532	9451	5831	3865547	2243	8371
Small wire sector	600.0									
First stereo	599.5	1035.1	3291	2462597	1266	4726	1262	362300	485	1810
Fourth stereo	600.5	1032.8	3291	2462597	1266	4726	1252	356583	481	1795
		Total	6582	4925194	2532	9451	2514	718883	966	3605
+30° stereo planes total			19746	14775583	7597	28353	15538	10466316	5977	22306
-30° stereo planes			Area 5				Area 4			
			n5	S5	Vb5	Hb5	n4	S4	Vb4	Hb4
Distance from center	Plane width									
in	in		in	lb	lb	in	lb	lb		
Large wire sector	120.0									
Second stereo	119.7	1565.8	3597	2941760	1384	-5166	3291	2462597	1266	-4726
Third stereo	120.3	1565.6	3596	2940125	1384	-5164	3291	2462597	1266	-4726
		Total	7193	5881885	2768	-10330	6582	4925194	2532	-9451
Intermediate wire sector	360.0									
Second stereo	359.7	1411.2	2917	1934761	1122	-4188	3291	2462597	1266	-4726
Third stereo	360.3	1410.6	2914	1930784	1121	-4183	3291	2462597	1266	-4726
		Total	5831	3865546	2243	-8371	6582	4925194	2532	-9451
Small wire sector	600.0									
Second stereo	599.7	1034.6	1260	361153	484	-1807	3291	2462597	1266	-4726
Third stereo	600.3	1033.3	1254	357723	482	-1798	3291	2462597	1266	-4726
		Total	2514	718876	966	-3605	6582	4925194	2532	-9451
-30° stereo planes total			15538	10466307	5977	-22306	19746	14775583	7597	-28353
0° vertical planes			Distance from center	Plane width						
			in	in						
Large wire sector	120.0									
First vertical	119.9	1565.7								
Second vertical	120.1	1565.7								
		Total								
Intermediate wire sector	360.0									
First vertical	359.9	1411.0								
Second vertical	360.1	1410.8								
		Total								
Small wire sector	600.0									
First vertical	599.9	1034.2								
Second vertical	600.1	1033.7								
		Total								
0° vertical planes total										

			East Side			
			Area 6			
+30° stereo planes	Distance from center	Plane width	n6	S6	Vb6	Hb6
	in	in		in	lb	lb
Large wire sector	120.0					
First stereo	119.5	1565.9	3291	2462597	1266	4726
Fourth stereo	120.5	1565.6	3291	2462597	1266	4726
		Total	6582	4925194	2532	9451
Intermediate wire sector	360.0					
First stereo	359.5	1411.4	3291	2462597	1266	4726
Fourth stereo	360.5	1410.4	3291	2462597	1266	4726
		Total	6582	4925194	2532	9451
Small wire sector	600.0					
First stereo	599.5	1035.1	3291	2462597	1266	4726
Fourth stereo	600.5	1032.8	3291	2462597	1266	4726
		Total	6582	4925194	2532	9451
+30° stereo planes total			19746	14775583	7597	28353
			Area 3			
-30° stereo planes	Distance from center	Plane width	n3	S3	Va3	Ha3
	in	in		in	lb	lb
Large wire sector	120.0					
Second stereo	119.7	1565.8	3291	2462597	8185	4726
Third stereo	120.3	1565.6	3291	2462597	8185	4726
		Total	6582	4925194	16370	9451
Intermediate wire sector	360.0					
Second stereo	359.7	1411.2	3291	2462597	8185	4726
Third stereo	360.3	1410.6	3291	2462597	8185	4726
		Total	6582	4925194	16370	9451
Small wire sector	600.0					
Second stereo	599.7	1034.6	3291	2462597	8185	4726
Third stereo	600.3	1033.3	3291	2462597	8185	4726
		Total	6582	4925194	16370	9451
-30° stereo planes total			19746	14775583	49109	28353
0° vertical planes	Distance from center	Plane width				
	in	in				
Large wire sector	120.0					
First vertical	119.9	1565.7				
Second vertical	120.1	1565.7				
		Total				
Intermediate wire sector	360.0					
First vertical	359.9	1411.0				
Second vertical	360.1	1410.8				
		Total				
Small wire sector	600.0					
First vertical	599.9	1034.2				
Second vertical	600.1	1033.7				
		Total				
0° vertical planes total						

+30° stereo planes	Distance from center in	Plane width in	Total Vertical				
			Top	Bottom	East Side	West Side	Total Vertical
			lb	lb	lb	lb	lb
Large wire sector	120.0						
First stereo	119.5	1565.9	17132	2650	1266	8185	29234
Fourth stereo	120.5	1565.6	17130	2650	1266	8185	29231
		Total	34262	5300	2532	16370	58465
Intermediate wire sector	360.0						
First stereo	359.5	1411.4	15440	2389	1266	8185	27280
Fourth stereo	360.5	1410.4	15428	2387	1266	8185	27266
		Total	30868	4775	2532	16370	54546
Small wire sector	600.0						
First stereo	599.5	1035.1	11320	1751	1266	8185	22522
Fourth stereo	600.5	1032.8	11295	1747	1266	8185	22493
		Total	22614	3498	2532	16370	45015
+30° stereo planes total			87745	13574	7597	49109	158025

-30° stereo planes	Distance from center in	Plane width in	Total Vertical				
			Top	Bottom	East Side	West Side	Total Vertical
			lb	lb	lb	lb	lb
Large wire sector	120.0						
Second stereo	119.7	1565.8	17132	2650	8185	1266	29234
Third stereo	120.3	1565.6	17130	2650	8185	1266	29231
		Total	34262	5300	16370	2532	58465
Intermediate wire sector	360.0						
Second stereo	359.7	1411.2	15438	2388	8185	1266	27277
Third stereo	360.3	1410.6	15430	2387	8185	1266	27269
		Total	30868	4775	16370	2532	54546
Small wire sector	600.0						
Second stereo	599.7	1034.6	11315	1750	8185	1266	22516
Third stereo	600.3	1033.3	11300	1748	8185	1266	22499
		Total	22614	3498	16370	2532	45015
-30° stereo planes total			87745	13574	49109	7597	158025

0° vertical planes	Distance from center in	Plane width in	Total Vertical	
			Top	Total Vertical
			lb	lb
Large wire sector	120.0			
First vertical	119.9	1565.7	22873	22873
Second vertical	120.1	1565.7	22873	22873
		Total	45746	45746
Intermediate wire sector	360.0			
First vertical	359.9	1411.0	20613	20613
Second vertical	360.1	1410.8	20610	20610
		Total	41222	41222
Small wire sector	600.0			
First vertical	599.9	1034.2	15108	15108
Second vertical	600.1	1033.7	15102	15102
		Total	30210	30210
0° vertical planes total			117179	117179

+30° stereo planes	Distance from center	Plane width	Total Horizontal					
			Top	Bottom	East Side	West Side	Total Horizontal	
			in	in	lb	lb	lb	lb
Large wire sector	120.0							
First stereo	119.5	1565.9	-9891	9891	4726	-4726	0	
Fourth stereo	120.5	1565.6	-9890	9890	4726	-4726	0	
		Total	-19781	19781	9451	-9451	0	
Intermediate wire sector	360.0							
First stereo	359.5	1411.4	-8914	8914	4726	-4726	0	
Fourth stereo	360.5	1410.4	-8907	8907	4726	-4726	0	
		Total	-17822	17822	9451	-9451	0	
Small wire sector	600.0							
First stereo	599.5	1035.1	-6535	6535	4726	-4726	0	
Fourth stereo	600.5	1032.8	-6521	6521	4726	-4726	0	
		Total	-13056	13056	9451	-9451	0	
+30° stereo planes total			-50659	50659	28353	-28353	0	

-30° stereo planes	Distance from center	Plane width	Total Horizontal				
			Top	Bottom	East Side	West Side	Total Horizontal
			in	in	lb	lb	lb
Large wire sector	120.0						
Second stereo	119.7	1565.8	9891	-9891	4726	-4726	0
Third stereo	120.3	1565.6	9890	-9890	4726	-4726	0
		Total	19781	-19781	9451	-9451	0
Intermediate wire sector	360.0						
Second stereo	359.7	1411.2	8913	-8913	4726	-4726	0
Third stereo	360.3	1410.6	8909	-8909	4726	-4726	0
		Total	17822	-17822	9451	-9451	0
Small wire sector	600.0						
Second stereo	599.7	1034.6	6532	-6532	4726	-4726	0
Third stereo	600.3	1033.3	6524	-6524	4726	-4726	0
		Total	13056	-13056	9451	-9451	0
-30° stereo planes total			50659	-50659	28353	-28353	0

0° vertical planes	Distance from center	Plane width		
			in	in
			Large wire sector	120.0
First vertical	119.9	1565.7		
Second vertical	120.1	1565.7		
		Total		
Intermediate wire sector	360.0			
First vertical	359.9	1411.0		
Second vertical	360.1	1410.8		
		Total		
Small wire sector	600.0			
First vertical	599.9	1034.2		
Second vertical	600.1	1033.7		
		Total		
0° vertical planes total				

Loads on 1/2 Tank

Notes:

- 1) On the sides, Vertical = Horizontal only because $\theta = 30^\circ$
- 2) For the design of the trusses, the horizontal forces acting on the top and bottom of the planes (wich when added yield null) have to be considered.

	Top		Bottom	
	Vertical	Horizontal	Vertical	Horizontal
Large wire sector	114271	0	10601	0
Intermediate wire sector	102959	0	9551	0
Small wire sector	75438	0	6997	0
Total	292668	0	27148	0

	West Side		East side	
	Vertical	Horizontal	Vertical	Horizontal
Large wire sector	18902	-18902	18902	18902
Intermediate wire sector	18902	-18902	18902	18902
Small wire sector	18902	-18902	18902	18902
Total	56706	-56706	56706	56706

Total Vertical				
Top	Bottom	East Side	West Side	Total Vertical
lb	lb	lb	lb	lb
292668	27148	56706	56706	433229

Total Horizontal				
Top	Bottom	East Side	West Side	Total Horizontal
lb	lb	lb	lb	lb
0	0	56706	-56706	0

4. Results

Stereo wires are guided through a system of insulated pulleys. There is a 1.3 kg weight hanging from the end of each wire, vertical or stereo.

For a given wire plane, the number of wires in areas 1, 3, 4, and 6 is the same: the same number of wires that start from the top has to arrive at the respective side. By the same token, areas 2 and 5 have the same number of wires within the same wire plane.

In fact, areas 1, 3, 4, and 6 have the same number of wires, 3291, in all planes, so only areas 2 and 5 have different and unique number of wires per plane.

The calculations are done in a spread sheet. Note that the +30° stereo plane, large wire sector, first stereo, area 2, has the same number as -30° stereo plane, large wire sector, second stereo, area 2, only because of the way the numbers are rounded. Same for 4th and 3rd stereos.

The number of wires in areas 2 and 5 has to be different in different planes, and equal in the same plane.

Also:

- All vertical forces are down,
- All horizontal forces are inwards.

The total loads to be applied in the analysis of the tank are at bottom right of the spreadsheet, in a red box. All the horizontal loads at the side wall are 18,902 lb. The vertical loads are 114,271 lb; 102,959 lb; and 75,438 lb.

Using a distributed load in lb/ft:

Large sector: $114,271/130.47 = 875.864$ lb/ft

Intermediate sector: $102,959/117.53 = 875.998$ lb/ft

Small sector: $75,438/ 86.07 = 876.507$ lb/ft

These numbers are very close, as they should be. **Hence, 876 lb/ft may be used for all sectors.**

The horizontal forces at the top and bottom cancel each other due to the proximity of stereo planes with opposed orientations.