STRESS ANALYSIS

Tower Tech model TTXL-i4 & TTXR-i4

12' legs & 10' legs

FOR

TOWER TECH, Inc.

BY

J.R. KING ENGINEERING

I HEREBY CERTIFY THAT THESE CALCULATIONS WAS PREPARED BY ME AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF Florida.

SIGNED: Jerome King

DATE: 8/26/2016

REG. NO. 28201

J.R. KING ENGINEERING

10890 NORTHMARK DRIVE
EDEN PRAIRIE, MN 55344
952 944-1391
JRKINGENG@COMCAST.NET

Title:
Fiberglass modular cooling tower – TTXL-i4 & TTXR-i4
12' legs & 10' legs

Purpose:
Analyze and design the components of the fiberglass cooling tower.

References:

1. AISC, Steel Construction Manual, 8th edition
2. Structural Engineering Handbook, 2ND edition
   By Gaylord & Gaylord, 1973 McGraw-Hill
3. Aluminum Structures, 2nd edition
   By J. Randolph Kissell & Robert Ferry
4. Risa3d – Rapid interactive structural analysis,
   three dimensional, computer software

Specifications:

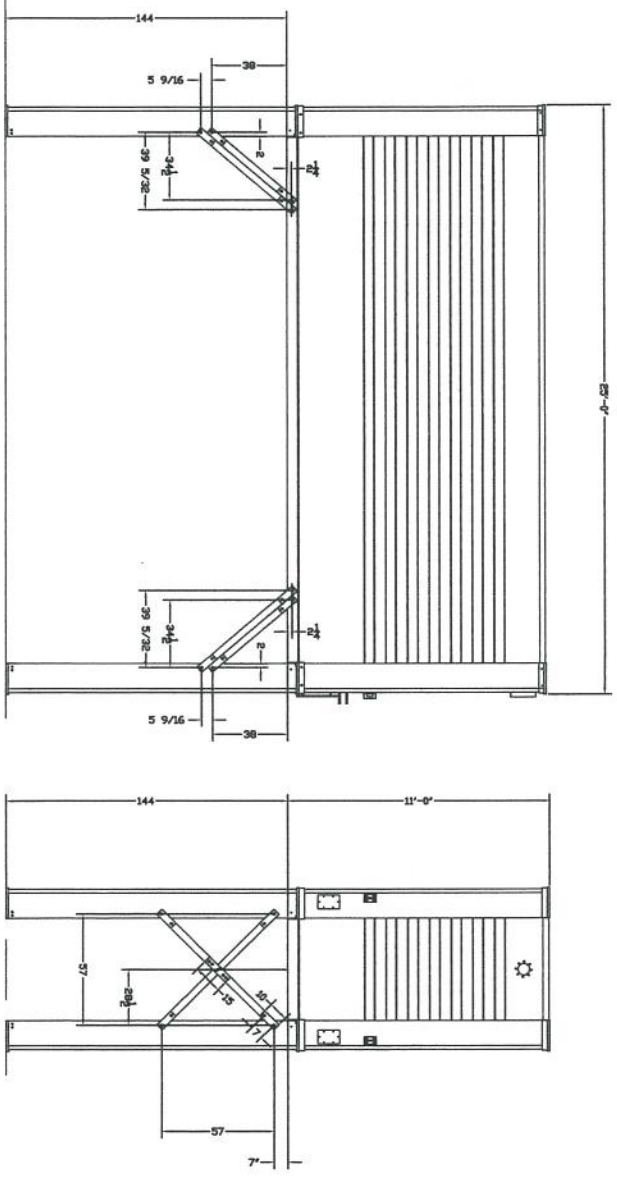
1. Tower Tech tests and material properties data
2. Creative Pultrusions, Inc. material properties data

Design Requirements:
The design loads shall be in accordance with the IBC (International Building Code). Wind, seismic and gravity loadings are applied. The illustrated tower shell and substructure is designed to withstand a wind pressure of 91.6 psf. (ASCE7-10 200 mph wind, exposure C) and a seismic force factors: SDC E, Ss = 3, S1 = 2, soil class D.

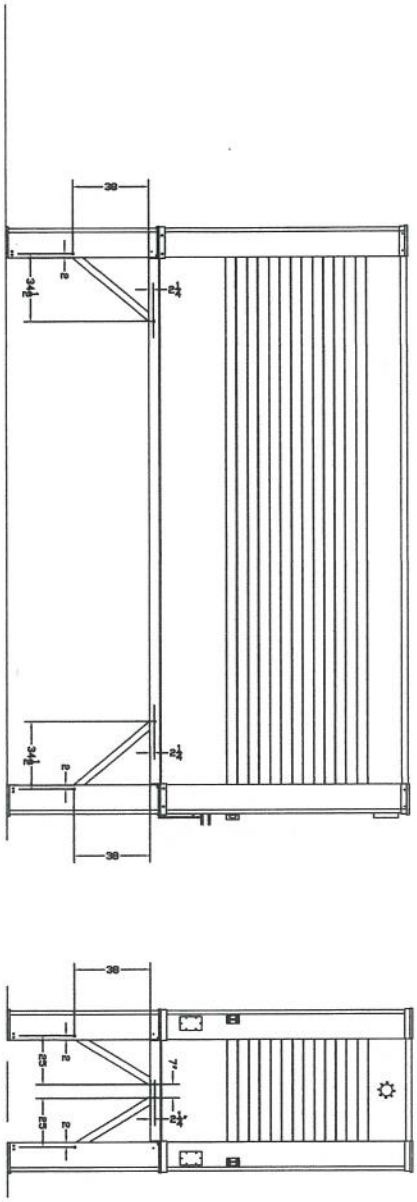
Procedures:
Procedures are the methodologies indicated in the listed references, as specifically presented within the calculations. To use the AISC equations and built-in sections within risa3d, the fiberglass properties have been put in place of the steel; the printouts that have "Steel" headings are calculated as fiberglass and should be interpreted as such. The properties of the fill material are based on actual in-house tests. Safety factors are calculated and compared to those for steel, aluminum, and wood.

Conclusions:
The analysis and design of the subject cooling tower and their appurtenances have been completed satisfactorily.

OPTIONAL BRACING UP TO 144 INCH SUBSTRUCTURE



STANDARD BRACING UP TO 120 INCH SUBSTRUCTURE



DATE:	24 Aug, 2016
DRAWING#:	
PROJECT#:	
DWG TYPE:	SPECIAL
DRAWN BY:	DMW
CHECKED BY:	
1	

CONSTRUCTION LIBRARY DRAWING

Bracing Scheme for Seismic and Wind Load Applications

TTXL–i4 & TTXR–i4

Model #

TOWER TECH, Inc.
THE TECHNOLOGY COMPANY
Oklahoma City, Oklahoma

Modular Cooling Tower

LATERAL FORCES

Lateral Wind

200 mph, exposure "C" RISK III OR IV

qz = .00256(200)*2x.9x.9=82.9

Fx=82.9x.85.1.3xAf=91.6Af

Seismic Forces

Largest spectral response accelerations

Ss = 300%g, S1 = 200%g Soil class "D" , Fa = 1.0, Fv = 1.5

Sms = 1 x 3.0 = 3.0 Sds = 2/3 x Sms = 2.0

Sm1 = 1.5 x 2 = 3.0 Sd1 = 2/3 x Sm1 = 2.0

Importance Factor = 1.0

Seismic Design Category = E

Select R = 3.0 Omega = 2 Cd = 2.5 (table 15.4-1)

Elevated tanks, vessels, on symmetrically braced legs (sec 15.7.10)

ASCE/SEI 7-10 (Chapter 15)

Section 15.4 go to Section 12.8

Seismic base shear: V = Cs x W

Operational weight, W= 9,118 lbs

Cs = Sds/(R/I) = 2/3

V=Cs x W = 6,079 lbs

SECTION 1609 WIND LOADS

FIGURE 1609A ULTIMATE DESIGN WIND SPEEDS, V_{alt} FOR RISK CATEGORY II BUILDINGS AND OTHER STRUCTURES

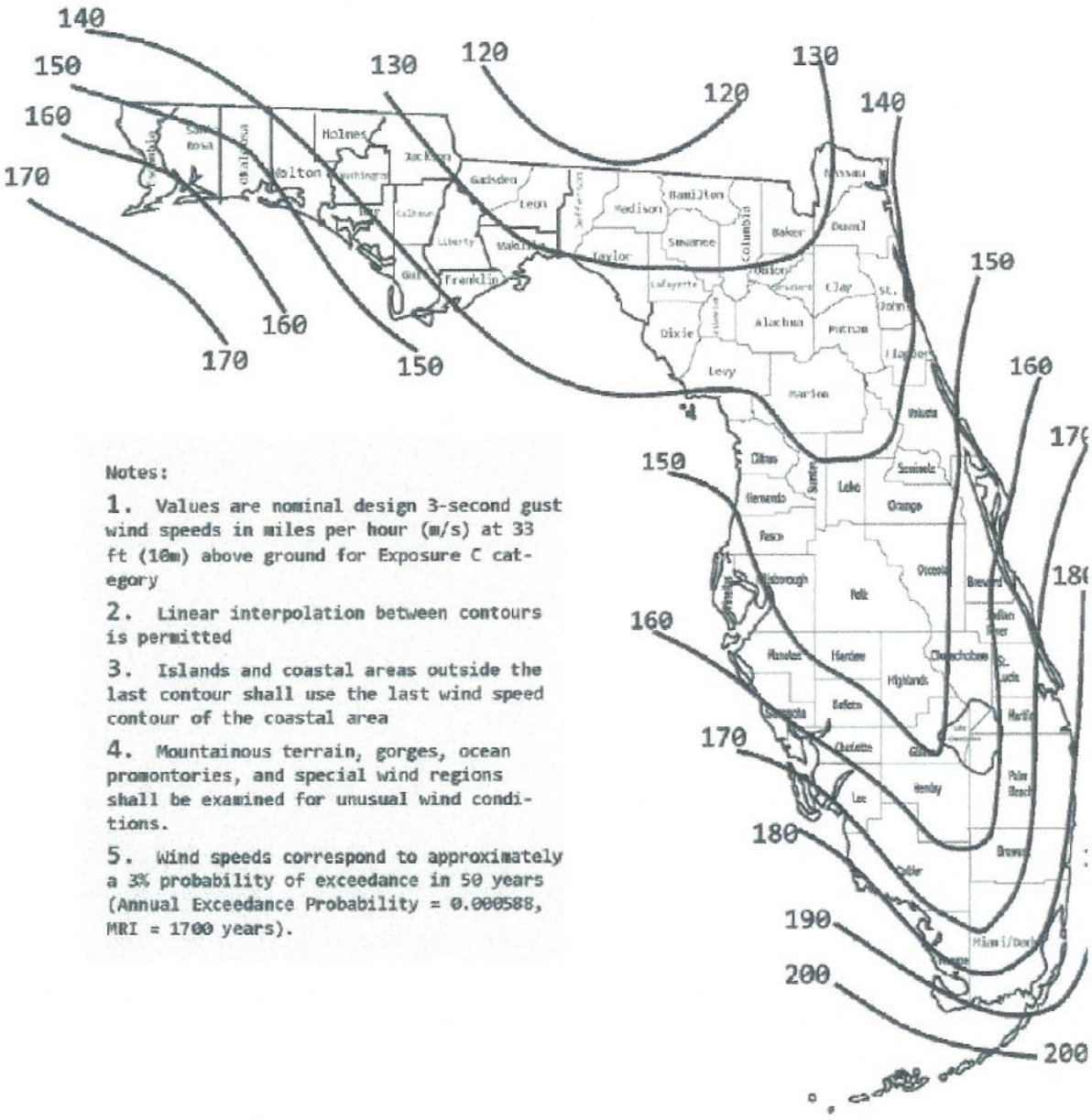


FIGURE 1609B ULTIMATE DESIGN WIND SPEEDS, V_{alt} FOR RISK CATEGORY III AND IV BUILDINGS AND OTHER STRUCTURES

Tower Tech Inc.		SK - 2
J.R. King Engineering	TTXL-i4 TTXRi4	Aug 22, 2016 at 2:54 PM
	10' LEGS OR LESS SINGLE BRACE	TTXL-i4 TTXR-i4.r3d

Hot Rolled Steel Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1...	Density[k/ft^3]	Yield[ksi]	Ry	Fu[ksi]	Rt
1	fiberglass	2000	500	.12	.44	.11	20	1.2	58	1.1

General Material Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1E5 F)	Density[k/ft^3]
1	FIBERGLASSPL	2000	500	.12	.44	.11
2	RIGID	1e+5		0	0	0
3	GM3	25	6	.12	.44	0

Hot Rolled Steel Section Sets

	Label	Shape	Type	Design List	Material	Design Ru...	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	C-1	HSS12x12x6	Column	Single Angle	fiberglass	Typical	16	357	357	561
2	C-2	L8x8x14	Column	Single Angle	fiberglass	Typical	13.3	79.7	79.7	3.46
3	B-1	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
4	B-2	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
5	B-3	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
6	B-4	L4x4x8	Beam	Single Angle	fiberglass	Typical	3.75	5.52	5.52	.322
7	B-5	L4x4x8	Beam	Single Angle	fiberglass	Typical	3.75	5.52	5.52	.322
8	B-6	W6x20	Beam	Wide Flange	fiberglass	Typical	5.87	13.3	41.4	.24
9	PIPE	PIPE 10.0	Beam	Pipe	fiberglass	Typical	11.5	151	151	302
10	BR-1	HSS3.5x3.5x4	VBrace	Tube	fiberglass	Typical	2.91	5.04	5.04	8.35
11	COLLECTOR	C8x11.5	Beam	Channel	fiberglass	Typical	3.37	1.31	32.5	.13

General Section Sets

	Label	Shape	Type	Material	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	GEN1	RE4X4	Beam	FIBERGLASSPL	16	21.333	21.333	31.573
2	RIGID		None	RIGID	1e+6	1e+8	1e+8	1e+6
3	FILL	RE2X2	Beam	GM3	4	1.333	1.333	1.973

Load Combinations

	Description	Sol...	PDelta	SRSS	BLC	Fa...	BLC	Factor	BLC	Fac...	BLC	Fa...	BLC	Fa...	BLC ...	...	...	...	...	...	BLC	Fact...	BLC	Fact...
1	IBC 16-12 (a) ...	Yes			DL	1	WLX	.6																
2	IBC 16-12 (a) ...	Yes			DL	1	WLZ	.6																
3	IBC 16-13 (a) ...	Yes			DL	1	WLX	.45	LL	.75														
4	IBC 16-13 (a) ...	Yes			DL	1	WLZ	.45	LL	.75														
5	IBC 16-15 (a)	Yes			DL	.6	WLX	.6																
6	IBC 16-15 (b)	Yes			DL	.6	WLZ	.6																
7	IBC 16-12 (b) ...	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	.21												
8	IBC 16-12 (b) ...	Yes			DL	1	Sds*DL	.14	SZ*SF	.7	SX*...	.21												
9	IBC 16-12 (b) ...	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	-.21												
10	IBC 16-12 (b) ...	Yes			DL	1	Sds*DL	.14	SZ*SF	.7	SX*...	-.21												
11	IBC 16-14 (a) ...	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	.158	LL	.75										
12	IBC 16-14 (a) ...	Yes			DL	1	Sds*DL	.105	SZ*SF	.525	SX*...	.158	LL	.75										
13	IBC 16-14 (a) ...	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	-.1...	LL	.75										
14	IBC 16-14 (a) ...	Yes			DL	1	Sds*DL	.105	SZ*SF	.525	SX*...	-.1...	LL	.75										
15	IBC 16-16 (a)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	.21												
16	IBC 16-16 (b)	Yes			DL	.6	Sds*DL	-.14	SZ*SF	.7	SX*...	.21												
17	IBC 16-16 (c)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	-.21												
18	IBC 16-16 (d)	Yes			DL	.6	Sds*DL	-.14	SZ*SF	.7	SX*...	-.21												
19	SEISMIC				SX*...	1	SZ*SF	1																
20	IBC 16-8				DL	1																		

Load Combinations (Continued)

	Description	Sol..PDelta	SRSS	BLC	Fa...	BLC	Factor	BLC	Fac...	BLC	Fa...	BLC	Fa...	BLC	...	...	...	...	...	BLC	Fact..	BLC	Fact...
21	IBC 16-9			DL	1	LL	1																

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distributed	Area(Mem...	Surface(...
1	DEAD	DL		-1						
2	FILL	DL						2		
3	WATER	LL						2		
4	WIND-Z	WLZ								264
5	WIND-X	WLX								99
6	DEFLECTION	None				1				

Envelope Joint Reactions

	Joint		X [k]	LC	Y [k]	LC	Z [k]	LC	MX [k-ft]	LC	MY [k-ft]	LC	MZ [k-ft]	LC
1	N3	max	1.385	1	7.414	10	3.634	6	0	1	0	1	0	1
2		min	-1.169	17	-17.655	6	-1.091	8	0	1	0	1	0	1
3	N4	max	1.321	5	7.414	8	3.634	6	0	1	0	1	0	1
4		min	-1.231	7	-17.655	6	-1.091	10	0	1	0	1	0	1
5	N2982	max	1.428	1	20.768	2	3.659	2	0	1	0	1	0	1
6		min	-1.169	15	-4.3	16	-1.067	18	0	1	0	1	0	1
7	N2983	max	1.362	5	20.768	2	3.659	2	0	1	0	1	0	1
8		min	-1.231	9	-4.3	18	-1.067	16	0	1	0	1	0	1
9	Totals:	max	5.465	5	13.018	12	14.573	2						
10		min	-4.71	9	2.491	17	-4.262	10						

Envelope AISC ASD Steel Code Checks

	Member	Shape	Code Check	Loc[ft]	LC	Shear ...	Loc.....	LC	Fa [ksi]	Ft [ksi]	Fb y-y [ksi]	Fb z-...	Cb	Cmy	Cmz	ASD ...
1	M334	HSS3.5x3....	.939	2.211	2	.007	4.4...	y 1	6.146	12	13.2	13.2	1	.6	1	H1-1
2	M333	HSS3.5x3....	.939	2.211	2	.007	4.4...	y 1	6.146	12	13.2	13.2	1	.6	1	H1-1
3	M329	HSS12x12x6	.495	6.735	2	.114	6.8...	z 2	10.259	12	13.2	13.2	1.75	.6	.6	H1-2
4	M330	HSS12x12x6	.495	6.735	2	.114	6.8...	y 2	10.259	12	13.2	13.2	1.75	.6	.6	H1-2
5	M29A	HSS3.5x3....	.472	2.302	6	.007	4.4...	y 1	6.146	12	13.2	13.2	1	.6	1	H2-1
6	M31	HSS3.5x3....	.472	2.302	6	.007	4.4...	y 1	6.146	12	13.2	13.2	1	.6	1	H2-1
7	M2	HSS12x12x6	.471	6.735	6	.113	6.8...	y 6	10.259	12	13.2	13.2	1.75	.6	.6	H2-1
8	M1	HSS12x12x6	.471	6.735	6	.113	6.8...	z 6	10.259	12	13.2	13.2	1.75	.6	.6	H2-1
9	M275A	PIPE 10.0	.448	12	2	.048	0	2	1.63	12	13.2	13.2	1	1	.85	H1-2
10	M332	HSS3.5x3....	.364	2.076	1	.018	0	y 2	6.146	12	13.2	13.2	1	.6	1	H1-1
11	M29	HSS3.5x3....	.353	2.076	1	.018	0	y 2	6.146	12	13.2	13.2	1	.6	1	H1-1
12	M331	HSS3.5x3....	.311	2.076	9	.018	4.4...	y 2	6.146	12	13.2	13.2	1	.6	1	H1-1
13	M30A	HSS3.5x3....	.311	2.076	7	.018	0	y 2	6.146	12	13.2	13.2	1	.6	1	H1-1
14	M261B	W6x20	.098	6	2	.006	3	z 2	4.501	12	15	13.2	1....	.206	.85	H1-2
15	M269A	W6x20	.098	6	2	.006	3	z 2	4.501	12	15	13.2	1....	.206	.85	H1-2
16	M268A	W6x20	.077	6	2	.004	3	z 2	4.501	12	15	13.2	2.3	.201	.85	H1-2
17	M262	W6x20	.077	6	2	.004	3	z 2	4.501	12	15	13.2	2.3	.201	.85	H1-2
18	M261A	HSS20x8x10	.069	21.061	5	.012	0	z 2	1.385	12	13.2	13.2	1	.873	.85	H1-1

Envelope Joint Displacements

	Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [rad]	LC	Y Rotatio...	LC	Z Rotatio...	LC
1	N745	max	.798	15	.228	6	3.075	8	5.398e-3	16	4.982e-4	1	1.795e-5	1
2		min	-.924	1	-.108	12	-23.195	6	-1.527e-2	2	-8.961e-6	18	-6.165e-7	18
3	N2026	max	.819	17	.061	6	3.075	8	1.676e-3	8	5.759e-3	5	3.134e-5	1
4		min	-1.876	1	-.078	12	-23.184	6	-6.948e-3	6	-1.085e-4	7	-1.076e-6	18

Envelope Joint Displacements (Continued)

	Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [rad]	LC	Y Rotatio...	LC	Z Rotatio...	LC
5	N1984	max	.82	9	-.012	17	3.075	8	1.673e-3	16	1.13e-3	5	2.827e-5	5
6		min	-1.939	5	-.063	14	-23.18	6	-6.949e-3	2	-4.624e-8	10	-1.188e-6	10
7	N1942	max	.819	7	.008	16	3.075	8	1.672e-3	16	1.088e-4	17	2.575e-5	5
8		min	-1.915	5	-.12	2	-23.178	6	-6.952e-3	2	-4.232e-3	1	-1.076e-6	10
9	N1858	max	.798	9	.048	16	3.075	8	5.434e-3	8	5.934e-4	1	1.475e-5	5
10		min	-.949	5	-.287	2	-23.176	6	-1.431e-2	6	-2.875e-5	15	-6.165e-7	10
11	N746	max	.798	15	.228	6	3.063	10	5.43e-3	10	2.089e-3	18	2.611e-5	1
12		min	-.924	1	-.108	12	-23.101	6	-1.587e-2	6	-1.557e-2	2	2.069e-6	18
13	N744	max	.798	9	.228	6	3.063	8	5.43e-3	8	1.557e-2	2	1.411e-5	5
14		min	-.923	5	-.108	14	-23.101	6	-1.587e-2	6	-2.089e-3	16	-1.319e-5	14
15	N2027	max	.822	15	.061	6	3.063	10	1.676e-3	8	5.884e-3	5	4.558e-5	1
16		min	-1.881	1	-.078	14	-23.091	6	-6.948e-3	6	-1.119e-2	2	3.612e-6	18
17	N2504	max	.822	9	.061	6	3.063	8	1.676e-3	10	1.119e-2	2	2.463e-5	5
18		min	-1.872	5	-.078	12	-23.091	6	-6.948e-3	6	-1.51e-3	16	-2.303e-5	14
19	N1985	max	.82	15	-.012	17	3.063	10	1.672e-3	16	1.41e-3	8	4.275e-5	1
20		min	-1.945	1	-.063	14	-23.087	6	-6.949e-3	2	-1.087e-2	6	3.072e-6	18
21	N2462	max	.82	9	-.012	18	3.063	8	1.672e-3	18	1.087e-2	6	2.154e-5	5
22		min	-1.933	5	-.063	11	-23.087	6	-6.949e-3	2	-1.41e-3	10	-2.288e-5	14

Envelope Plate/Shell Principal Stresses

	Plate		Surf...	Sigma1 [ksi]	LC	Sigma2 [ksi]	LC	Tau Max [ksi]	LC	Angle [rad]	LC	Von Mises [ksi]	LC
1	P206	max	T	1.045	1	.094	5	4.289	6	1.77	15	9.01	6
2		min		-.82	2	-9.389	2	.097	13	-.165	17	.203	11
3		max	B	9.419	6	.571	6	4.428	2	1.724	17	9.15	2
4		min		-.161	1	-1.143	1	.074	11	-.199	15	.17	11
5	P393	max	T	.98	8	.078	18	4.289	6	1.926	11	9.01	6
6		min		-.82	2	-9.389	2	.112	3	-.528	13	.262	13
7		max	B	9.419	6	.571	6	4.428	2	1.972	13	9.15	2
8		min		-.076	8	-1.003	8	.144	17	-.434	11	.275	17
9	P207	max	T	1.103	1	.127	5	4.297	6	1.738	15	8.981	6
10		min		-.74	2	-9.324	6	.102	11	-.13	17	.195	11
11		max	B	9.353	2	.553	6	4.404	2	1.693	17	9.093	2
12		min		-.178	1	-1.203	1	.076	11	-.167	15	.169	11
13	P394	max	T	.994	8	.072	18	4.297	6	1.898	11	8.981	6
14		min		-.74	2	-9.324	6	.121	3	-.493	13	.243	13
15		max	B	9.353	2	.553	6	4.404	2	1.96	13	9.093	2
16		min		-.079	8	-.999	8	.134	17	-.385	11	.259	17

Envelope Only Solution

Tower Tech Inc.		SK - 1
J.R. King Engineering	TTXL-i4 TTXRi4 12'	Aug 26, 2016 at 10:21 AM
	12' LEGS	TTXL-i4 TTXR-i4 12 LEGS.r3d

Hot Rolled Steel Properties

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5	B-3	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
6	B-4	L4x4x8	Beam	Single Angle	fiberglass	Typical	3.75	5.52	5.52	.322
7	B-5	L4x4x8	Beam	Single Angle	fiberglass	Typical	3.75	5.52	5.52	.322
8	B-6	W6x20	Beam	Wide Flange	fiberglass	Typical	5.87	13.3	41.4	.24
9	PIPE	PIPE_10.0	Beam	Pipe	fiberglass	Typical	11.5	151	151	302
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3	FILL	RE2X2	Beam	GM3	4	1.333	1.333	1.973

Load Combinations

	Description	Sol...	PDelta	SRSS	BLC	Fa...	BLC	Factor	BLC	Fac...	BLC	Fa...	BLC	Fa...	BLC	...	...	...	...	...	BLC	Fact...	BLC	Fact...
1	IBC 16-12 (a) ...	Yes			DL	1	WLX	.6																
2	IBC 16-12 (a) ...	Yes			DL	1	WLZ	.6																
3	IBC 16-13 (a) ...	Yes			DL	1	WLX	.45	LL	.75														
4	IBC 16-13 (a) ...	Yes			DL	1	WLZ	.45	LL	.75														
5	IBC 16-15 (a)	Yes			DL	.6	WLX	.6																
6	IBC 16-15 (b)	Yes			DL	.6	WLZ	.6																
7	IBC 16-12 (b) ...	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	.21												
8	IBC 16-12 (b) ...	Yes			DL	1	Sds*DL	.14	SZ*SF	.7	SX*...	.21												
9	IBC 16-12 (b) ...	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	-.21												
10	IBC 16-12 (b) ...	Yes			DL	1	Sds*DL	.14	SZ*SF	.7	SX*...	-.21												
11	IBC 16-14 (a) ...	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	.158	LL	.75										
12	IBC 16-14 (a) ...	Yes			DL	1	Sds*DL	.105	SZ*SF	.525	SX*...	.158	LL	.75										
13	IBC 16-14 (a) ...	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	-.1...	LL	.75										
14	IBC 16-14 (a) ...	Yes			DL	1	Sds*DL	.105	SZ*SF	.525	SX*...	-.1...	LL	.75										
15	IBC 16-16 (a)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	.21												
16	IBC 16-16 (b)	Yes			DL	.6	Sds*DL	-.14	SZ*SF	.7	SX*...	.21												
17	IBC 16-16 (c)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	-.21												
18	IBC 16-16 (d)	Yes			DL	.6	Sds*DL	-.14	SZ*SF	.7	SX*...	-.21												
19	SEISMIC				SX*...	1	SZ*SF	1																
20	IBC 16-8				DL	1																		

Load Combinations (Continued)

	Description	Sol..	PDelta	SRSS	BLC	Fa...	BLC	Factor	BLC	Fac...	BLC	Fa...	BLC	Fa...	BLC	...	...	...	...	...	...	BLC	Fact..	BLC	Fact...
21	IBC 16-9				DL	1	LL	1																	

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distributed	Area(Mem...	Surface(...
1	DEAD	DL		-1						
2	FILL	DL						2		
3	WATER	LL						2		
4	WIND-Z	WLZ								264
5	WIND-X	WLX								99
6	DEFLECTION	None				1				

Envelope Joint Reactions

	Joint		X [k]	LC	Y [k]	LC	Z [k]	LC	MX [k-ft]	LC	MY [k-ft]	LC	MZ [k-ft]	LC
1	N3	max	1.38	1	7.14	10	3.636	6	0	1	0	1	0	1
2		min	-.96	17	-20.064	6	-.956	8	0	1	0	1	0	1
3	N4	max	1.336	5	7.14	8	3.636	6	0	1	0	1	0	1
4		min	-1.003	7	-20.064	6	-.956	10	0	1	0	1	0	1
5	N2982	max	1.407	1	23.229	2	3.655	2	0	1	0	1	0	1
6		min	-.96	15	-3.975	16	-.937	18	0	1	0	1	0	1
7	N2983	max	1.362	5	23.229	2	3.655	2	0	1	0	1	0	1
8		min	-1.003	9	-3.975	18	-.937	16	0	1	0	1	0	1
9	Totals:	max	5.465	5	13.175	12	14.573	2						
10		min	-3.859	7	2.532	17	-3.755	18						

Envelope AISC ASD Steel Code Checks

	Member	Shape	Code Check	Loc[in]	LC	Shear ...	Loc.....		LC	Fa [ksi]	Ft [ksi]	Fb y-y [ksi]	Fb z-...	Cb	Cmy	Cmz	ASD ...
1	M223A	HSS3.5x3....	.563	48.166	2	.010	48....	y	1	6.934	12	13.2	13.2	1.75	.6	1	H1-1
2	M225A	HSS3.5x3....	.563	48.166	2	.009	0	y	1	6.934	12	13.2	13.2	1.75	.6	1	H1-1
3	M329	HSS12x12x6	.500	79.347	2	.068	105..	z	2	10.288	12	13.2	13.2	1.75	.6	.6	H1-2
4	M330	HSS12x12x6	.500	79.347	2	.068	105..	y	2	10.288	12	13.2	13.2	1.75	.6	.6	H1-2
5	M2	HSS12x12x6	.478	79.347	6	.068	105..	y	6	10.288	12	13.2	13.2	1.75	.6	.6	H2-1
6	M1	HSS12x12x6	.478	79.347	6	.068	105..	z	6	10.288	12	13.2	13.2	1.75	.6	.6	H2-1
7	M275A	PIPE 10.0	.448	144	2	.048	0		2	1.63	12	13.2	13.2	1	1	.85	H1-2
8	M332	HSS3.5x3....	.430	25.455	1	.008	0	y	2	6.146	12	13.2	13.2	1	.6	1	H1-1
9	M29	HSS3.5x3....	.422	24.913	1	.008	0	y	2	6.146	12	13.2	13.2	1	.6	1	H1-1
10	M226A	HSS3.5x3....	.324	48.166	2	.009	0	y	1	6.934	12	13.2	13.2	1.75	.6	1	H2-1
11	M224A	HSS3.5x3....	.324	48.166	2	.009	48....	y	1	6.934	12	13.2	13.2	1.75	.6	1	H2-1
12	M331	HSS3.5x3....	.304	24.913	9	.008	0	y	2	6.146	12	13.2	13.2	1	.6	1	H1-1
13	M30A	HSS3.5x3....	.304	24.913	7	.008	53....	y	2	6.146	12	13.2	13.2	1	.6	1	H1-1

Envelope Joint Displacements

	Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [rad]	LC	Y Rotatio...	LC	Z Rotatio...	LC
1	N745	max	1.149	15	.276	6	1.75	10	2.51e-3	18	5.333e-4	1	2.1e-5	1
2		min	-1.631	1	-.111	12	-23.616	6	-1.667e-2	2	-2.432e-6	18	-1.65e-6	18
3	N2026	max	1.162	15	.077	6	1.75	10	1.671e-3	8	5.793e-3	5	3.666e-5	1
4		min	-2.585	1	-.081	12	-23.606	6	-8.313e-3	6	-6.296e-5	7	-2.88e-6	18
5	N1984	max	1.163	7	-.012	17	1.75	10	1.668e-3	16	1.164e-3	5	3.233e-5	5
6		min	-2.648	5	-.066	14	-23.602	6	-8.314e-3	2	-1.229e-8	10	-3.015e-6	10
7	N1942	max	1.162	7	.008	16	1.75	10	1.668e-3	16	6.307e-5	17	2.868e-5	5
8		min	-2.624	5	-.139	2	-23.599	6	-8.316e-3	2	-4.199e-3	1	-2.88e-6	10
9	N1858	max	1.149	7	.048	16	1.75	10	2.527e-3	10	6.274e-4	5	1.643e-5	5

Envelope Joint Displacements (Continued)

	Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [rad]	LC	Y Rotatio...	LC	Z Rotatio...	LC
10		min	-1.659	5	-.338	2	-23.597	6	-1.571e-2	6	-7.809e-6	7	-1.65e-6	10
11	N746	max	1.149	15	.276	6	1.745	10	2.527e-3	10	7.645e-4	18	2.934e-5	1
12		min	-1.632	1	-.111	14	-23.523	6	-1.728e-2	6	-1.557e-2	2	1.13e-6	18
13	N744	max	1.15	9	.276	6	1.745	8	2.527e-3	8	1.557e-2	2	1.727e-5	5
14		min	-1.631	5	-.111	12	-23.523	6	-1.728e-2	6	-7.645e-4	16	-1.406e-5	14
15	N2027	max	1.163	15	.077	6	1.745	10	1.671e-3	8	5.918e-3	5	5.121e-5	1
16		min	-2.59	1	-.081	14	-23.512	6	-8.312e-3	6	-1.119e-2	2	1.972e-6	18
17	N2504	max	1.163	9	.077	6	1.745	8	1.671e-3	10	1.119e-2	2	3.015e-5	5
18		min	-2.58	5	-.081	12	-23.512	6	-8.312e-3	6	-5.619e-4	16	-2.454e-5	14

Envelope Plate/Shell Principal Stresses

	Plate		Surf...	Sigma1 [ksi]	LC	Sigma2 [ksi]	LC	Tau Max [ksi]	LC	Angle [rad]	LC	Von Mises [ksi]	LC
1	P206	max	T	1.047	1	.087	5	4.289	6	1.977	15	9.011	6
2		min		-.819	2	-9.389	2	.037	13	-.364	17	.093	13
3		max	B	9.418	6	.573	6	4.427	2	1.91	17	9.148	2
4		min		-.162	1	-1.148	1	.029	11	-.404	15	.072	11
5	P393	max	T	.395	8	.033	18	4.289	6	2.085	11	9.011	6
6		min		-.819	2	-9.389	2	.086	17	-.729	13	.162	17
7		max	B	9.418	6	.573	6	4.427	2	2.118	13	9.148	2
8		min		-.042	10	-.414	8	.095	17	-.664	11	.168	17
9	P207	max	T	1.105	1	.122	5	4.297	6	1.935	15	8.982	6
10		min		-.739	2	-9.325	6	.043	13	-.308	17	.097	11
11		max	B	9.352	2	.553	6	4.404	2	1.858	17	9.092	2
12		min		-.179	1	-1.207	1	.033	11	-.364	15	.074	11
13	P394	max	T	.397	8	.031	18	4.297	6	2.071	11	8.982	6
14		min		-.739	2	-9.325	6	.077	17	-.704	13	.145	17
15		max	B	9.352	2	.553	6	4.404	2	2.118	13	9.092	2
16		min		-.039	10	-.407	8	.084	17	-.625	11	.15	17
17	P196	max	T	9.207	6	.746	6	4.235	2	1.763	3	8.86	2
18		min		-.065	8	-.402	10	.037	11	-.328	14	.093	11
19		max	B	.395	16	.012	16	4.339	6	1.812	14	8.976	6
20		min		-.579	2	-9.249	2	.029	13	-.42	13	.072	13

Properties

	ASTM TEST METHOD	UNITS/ VALUE	SERIES 500/525 SHAPES	SERIES 625 SHAPES	SERIES 500/525 PLATE ⑤ 1/8" 3.175mm	3/16" - 1/4" 4.76-6.35mm	3/8" - 1" 9.5-25.4mm	SERIES 625 PLATE ⑤ 1/8" 3.175mm	3/16" - 1/4" 4.76-6.35mm	3/8" - 1" 9.5-25.4mm
MECHANICAL										
Tensile Stress, LW	D638	psi	30,000	30,000	20,000	20,000	20,000	20,000	20,000	20,000
		N/mm²	207	207	138	138	138	138	138	138
Tensile Stress, CW	D638	psi	7,000	7,000	7,500	10,000	10,000	7,500	10,000	10,000
		N/mm²	48.3	48.3	51.7	68.9	68.9	51.7	68.9	68.9
Tensile Modulus, LW	D638	10^6 psi	2.5	2.6	1.8	1.8	1.8	1.8	1.8	1.8
		10^3N/mm²	17.2	17.9	12.4	12.4	12.4	12.4	12.4	12.4
Tensile Modulus, CW	D638	10^6 psi	0.8	0.8	0.7	0.9	1.4	1.0	1.0	1.4
		10^3N/mm²	5.52	5.52	4.83	6.21	9.65	6.89	6.89	9.65
Compressive Stress, LW	D695	psi	30,000	30,000	24,000	24,000	24,000	24,000	24,000	24,000
		N/mm²	207	207	165	165	165	165	165	165
Compressive Stress, CW	D695	psi	15,000	16,000	15,500	16,500	20,000	16,500	17,500	17,500
		N/mm²	103	110	107	114	138	114	121	121
Compressive Modulus, LW	D695	10^6 psi	2.5	2.6	1.8	1.8	1.8	1.8	1.8	1.8
		10^3N/mm²	17.2	17.9	12.4	12.4	12.4	12.4	12.4	12.4
Compressive Modulus CW	D695	10^6 psi	0.8	0.8	0.7	0.9	1.4	1.0	1.0	1.4
		10^3N/mm²	6.89	6.89	6.89	6.89	6.89	6.89	6.89	6.89
Flexural Stress, LW	D790	psi	30,000	30,000	35,000	35,000	30,000	35,000	35,000	30,000
		N/mm²	207	207	241	241	207	241	241	207
Flexural Stress, CW	D790	psi	10,000	10,000	13,000	15,000	18,000	13,000	15,000	18,000
		N/mm²	68.9	68.9	89.6	103	124	89.6	103	124
Flexural Modulus, LW	D790	10^6 psi	1.6	1.6	1.8	2	2	1.8	2	2
		10^3N/mm²	11.0	11.0	12.4	13.8	13.8	12.4	13.8	13.8
Flexural Modulus, CW	D790	10^6 psi	0.8	0.8	0.9	1.1	1.4	1.0	1.1	1.4
		10^3N/mm²	5.52	5.52	6.21	7.58	9.65	6.89	7.58	9.65
Modulus of Elasticity ①	full section	10^6 psi	2.6	2.8						
		10^3N/mm²	17.9	19.3						
Modulus of Elasticity: W & I shapes > 4" / W & I shapes > 102mm	full section	10^6 psi	2.5	2.5						
		10^3N/mm²	17.2	17.2						
Parallel Compressive Shear Stress, LW ②⑨	D3846	psi	3,000	3,000						
		N/mm²	20.7	20.7						
Shear Modulus, LW ③⑨	—	10^6 psi	0.425	0.425						
		10^3N/mm²	2.93	2.93						
Short Beam Shear, LW ⑧⑨	D2344	psi	4,500	4,500						
		N/mm²	31.0	31.0						
Bearing Stress, LW	D953	psi	30,000	30,000	32,000	32,000	32,000	32,000	32,000	32,000
		N/mm²	207	207	220.6	221	221	221	221	221
Poisson's Ratio, LW ⑨	D3039	in/in	0.33	0.33	0.31	0.31	0.31	0.32	0.32	0.32
		mm/mm	.330	.330	.310	.310	.310	.320	.320	.320
Notched Izod Impact, LW	D256	ft-lbs/in	25	25	15	10	10	15	10	10
		J/mm	1.33	1.33	.801	.533	.533	.801	.533	.533
Notched Izod Impact, CW	D256	ft-lbs/in	4	4	5	5	5	5	5	5
		J/mm	.214	.214	.267	.267	.267	.267	.267	.267
PHYSICAL										
Barcol Hardness	D2583	—	45 ④	45 ④	40	40	40	40	40	40
24 hr Water Absorption ⑦	D570	% Max	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Density	D792	lbs/in³	.062-.070	.062-.070	.060-.068	.060-.068	.060-.068	.060-.068	.060-.068	.060-.068
		10^{-3}g/mm³	1.72-1.94	1.72-1.94	1.66-1.88	1.66-1.88	1.66-1.88	1.66-1.88	1.66-1.88	1.66-1.88
Coefficient of Thermal Expansion, LW ⑨	D696	10^{-6} in/in/°F	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
		10^{-6} mm/mm/°C	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Thermal Conductivity ⑨	C177	BTU-in/ft²Hr/°F	4	4						
		w(m⁻°K)	.58	.58						

All values are minimum ultimate properties from coupon tests except as noted.

① This value is determined from full section simple beam bending of EXTREN® structural shapes.

② The shear stress test results will change radically if the notched orientation is altered. The value in this chart represents the test configuration where the notches are machined parallel to the reinforcing mat. For notches machined perpendicular to the reinforcing mat, this value would be two to three times larger.

③ The Shear Modulus value has been determined from tests with full sections of EXTREN® structural shapes. (See Strongwell's Strongwell *Design Manual* for further information.)

④ Value would be 50 if the surfacing veil were not there.

⑤ Plate compressive stress/modulus measured edgewise and flexural stress/modulus measured flatwise.

⑥ Values apply to Series 525 and 625.

⑦ Measured as a percentage maximum by weight.

⑧ Span to depth ratio of 3:1; EXTREN® angles will have a minimum value of 4000 psi and the I/W shapes are tested in the web.

⑨ Typical values because these are shape and composite dependent tests.

LW — Lengthwise
CW — Crosswise
PF — Perpendicular to laminate face
N.T. — Not Tested

Specifications for Wall Sections of Tower Tech, Inc. ("Buyer")

1. Definition of "Products": The terms "Products," as used hereinafter, shall mean finished "Perimeter Basin Wall," finished "Center Basin," finished "Mid Wall," and finished "Top Wall," all manufactured by the pultrusion process.

2. Material Technical Properties: Products to, at a minimum, conform to the following typical properties of pultruded materials:

Mechanical Properties (Coupon Sample, u.n.o.)	ASTM Test Method	Polyester
Properties at 100% at 77°F (90% at or below 100°F, 80% at 100-125°F, 70% at 125-150°F)		
Specific Gravity	ASTM D792	1.75
Density, lb/in cubed	ASTM D792	0.07
Tensile Strength, LW, psi	ASTM D638	33,000
Tensile Strength, CW, psi	ASTM D638	7,500
Tensile Modulus of Elasticity, LW, ksi	ASTM D638	3,000
Tensile Modulus of Elasticity, CW, ksi	ASTM D638	1,000
Compressive Strength, LW, psi	ASTM D695	33,000
Compressive Strength, CW, psi	ASTM D695	17,000
Comp. Modulus of Elasticity, LW, ksi	ASTM D695	3,000
Comp. Modulus of Elasticity, CW, ksi	ASTM D695	1,000
Flexural Strength, LW, psi	ASTM D790	33,000
Flexural Strength, CW, psi	ASTM D790	10,000
Flexural Modulus, LW, ksi	ASTM D790	2,000
Flexural Modulus, CW, ksi	ASTM D790	1,000
Modulus of Elasticity, ksi	Perimeter Basin & Center Basin, Full Section	3,200
Modulus of Elasticity, ksi	Mid Wall & Top Wall, Full Section	2,200
Shear Modulus, ksi	Full Section	420
Shear Strength by Punch, PF, psi	ASTM D732	6,000
Bearing Stress, LW, psi	ASTM D953	30,000
Bearing Stress, CW, psi	ASTM D953	18,000
Izod Impact, Notched, LW, ft-lb/in	ASTM D256	30
Izod Impact, Notched, CW, ft-lb/in	ASTM D256	5
Barcol Hardness	ASTM D2583	45
Possion's Ratio, LW, in/in	ASTM D3039	0.35
Possion's Ratio, CW, in/in	ASTM D3039	0.1+E105

(LW = Lengthwise; CW = Crosswise; PF = Perpendicular to Laminate Face)

Thermal Properties	ASTM Test Method	Polyester
Coef. Of Linear Expansion in/in/F	ASTM D696	?
Thermal Conductivity, BTU/hr/sq ft/F/in	ASTM D C177	?

Flammability	ASTM Test Method	Polyester
Flammability Classification	UL94	94V-O
Flammability Extinguishing	ASTM D635	Self-exinguish.
NBS Smoke Chamber	ASTM E662	650
Flame Resistance (Ignition/Burn), sec	FTMS 406-2023	55/30

Other Properties	ASTM Test Method	Polyester
Water Absorption, % 24 hr.	**ASTM D570**	**0.5 Max**
Customer Standard Color	----------	Specific Beige
NSF Potable Water Approved	----------	----------