

# STRESS ANALYSIS

Tower Tech model TTXL-08 & TTXR-08  
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 R. King*

DATE: *12/17/16*

REG. NO. 28201

# J.R. KING ENGINEERING

10890 NORTHMARK DRIVE  
EDEN PRAIRIE, MN 55344  
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## **Title:**

Fiberglass modular cooling tower – TTXL-08 & TTXR-08  
12' legs & 10' legs

## **Purpose:**

Analyze and design the components of the fiberglass cooling tower.

## **References:**

1. AISC, Steel Construction Manual, 8<sup>th</sup> edition
2. Structural Engineering Handbook, 2<sup>ND</sup> edition  
By Gaylord & Gaylord, 1973 McGraw-Hill
3. Aluminum Structures, 2<sup>nd</sup> 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:**

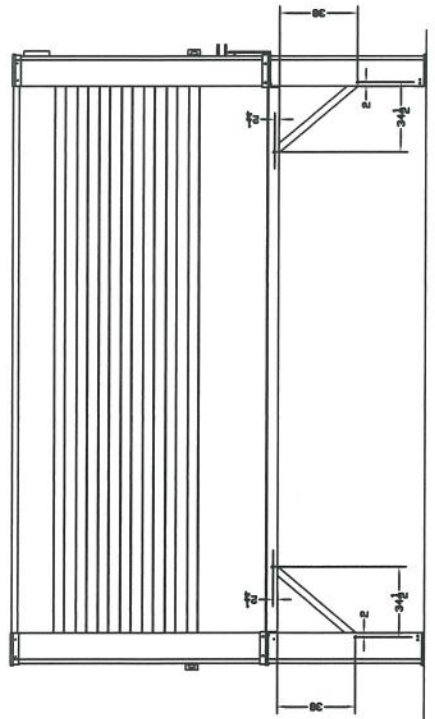
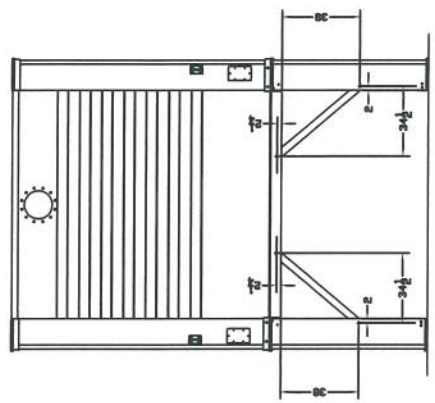
The design loads shall be in accordance with the IBC (International Building Code). Wind, seismic and gravity loadings are applied. The illustrated tower shell and substructure is designed to withstand a wind pressure of 91.6 psf. (ASCE7-10 200 mph wind, exposure C) and a seismic force factors: SDC E,  $S_s = 3$ ,  $S_1 = 2$ , soil class D.

## **Procedures:**

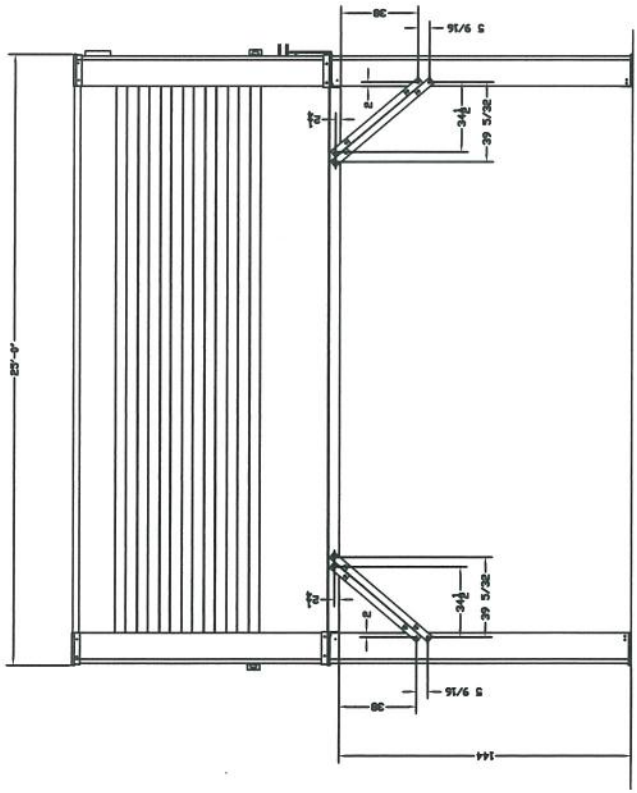
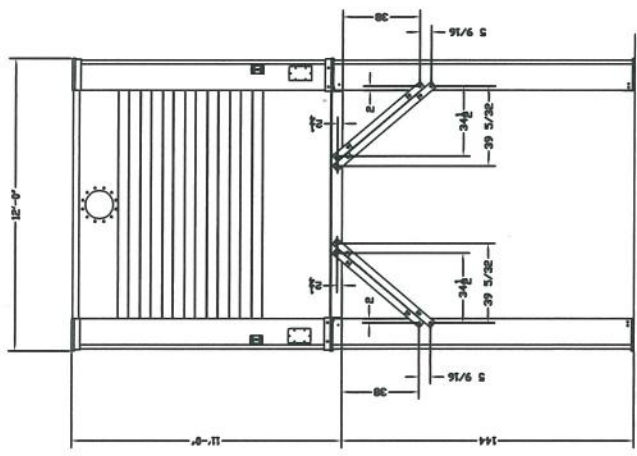
Procedures are the methodologies indicated in the listed references, as specifically presented within the calculations. To use the AISC equations and built-in sections within risa3d, the fiberglass properties have been put in place of the steel; the printouts that have "Steel" headings are calculated 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.



STANDARD BRACING UP TO 120 INCH SUBSTRUCTURE



OPTIONAL BRACING UP TO 144 INCH SUBSTRUCTURE

## LATERAL FORCES

### Lateral Wind

200 mph, exposure "C" RISK III OR IV

$$qz = .00256(200)^2 \times 2 \times 9 \times 9 = 82.9$$

$$F_x = 82.9 \times 85.1 \times 1.3 \times A_f = 91.6 A_f$$

### Seismic Forces

Largest spectral response accelerations

$$S_s = 300\%g, S_1 = 200\%g \quad \text{Soil class "D", } F_a = 1.0, F_v = 1.5$$

$$S_{ms} = 1 \times 3.0 = 3.0 \quad S_{ds} = 2/3 \times S_{ms} = 2.0$$

$$S_{m1} = 1.5 \times 2 = 3.0 \quad S_{d1} = 2/3 \times S_{m1} = 2.0$$

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

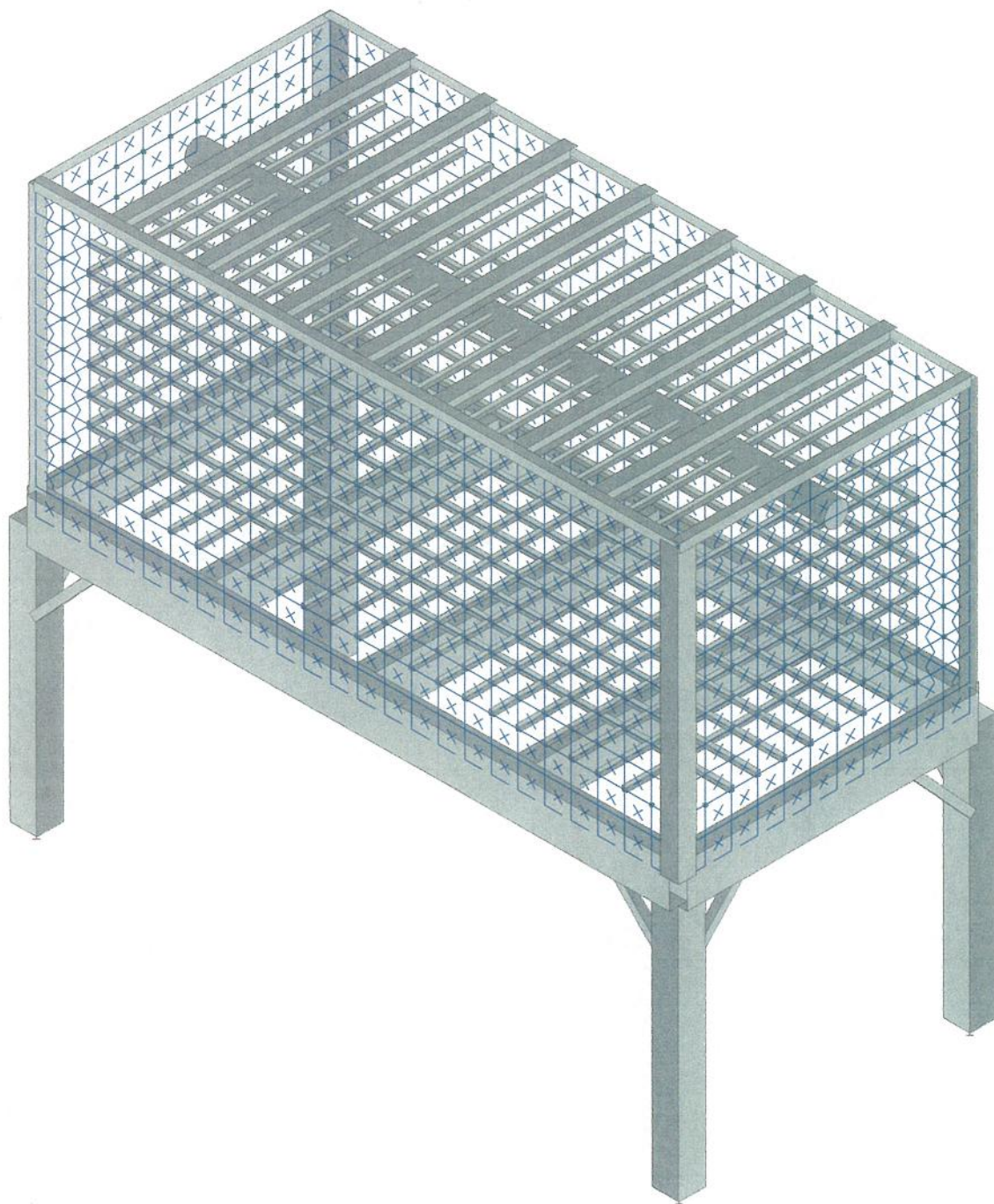
Seismic base shear:  $V = C_s \times W$

Operational weight,  $W = 25,695 \text{ lbs}$

$$C_s = S_{ds} / (R/I) = 2/3$$

$$V = C_s \times W = 17,130 \text{ lbs}$$





Envelope Only Solution

J.R. King Engineering

Jerry King

Tower Tech TTXL  
LEGS 10 FEET OR LESS

SK - 1

Dec 16, 2016 at 1:23 PM

TTXL-08.r3d





Company : J.R. King Engineering  
 Designer : Jerry King  
 Job Number :  
 Model Name : Tower Tech TTXL

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### Hot Rolled Steel Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (11... 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 Fa...	BLC Fa...	BLC Fa...	BLC Fa...	BLC Fa...	BLC Fa...	BLC Fa...	BLC Fa...	BLC Fa...	BLC Fa...	BLC Fa...	BLC Fa...
1	SIEMIC			SX*... 1	SZ*SF 1															
2	IBC 16-9	Yes		DL 1	LL 1															
3	IBC 16-12 (a) ...	Yes		DL 1	WLX .6															
4	IBC 16-12 (a) ...	Yes		DL 1	WLZ .6															
5	IBC 16-13 (a) ...	Yes		DL 1	WLX .45	LL .75														
6	IBC 16-13 (a) ...	Yes		DL 1	WLZ .45	LL .75														
7	IBC 16-13 (c) ...	Yes		DL 1	WLX .45	LL .75														
8	IBC 16-13 (c) ...	Yes		DL 1	WLZ .45	LL .75														
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 16-12 (b) ...	Yes		DL 1	Sds*DL .14	SX*SF .7	SZ*... -.21													
12	IBC 16-12 (b) ...	Yes		DL 1	Sds*DL .14	SZ*SF .7	SX*... -.21													
13	IBC 16-14 (a) ...	Yes		DL 1	Sds*DL .105	SX*SF .525	SZ*... 158	LL .75												
14	IBC 16-14 (a) ...	Yes		DL 1	Sds*DL .105	SZ*SF .525	SX*... 158	LL .75												
15	IBC 16-14 (a) ...	Yes		DL 1	Sds*DL .105	SX*SF .525	SZ*... -1...	LL .75												
16	IBC 16-14 (a) ...	Yes		DL 1	Sds*DL .105	SZ*SF .525	SX*... -1...	LL .75												
17	IBC 16-16 (a) Yes			DL .6	Sds*DL -.14	SX*SF .7	SZ*... .21													
18	IBC 16-16 (b) Yes			DL .6	Sds*DL -.14	SZ*SF .7	SX*... .21													
19	IBC 16-16 (c) Yes			DL .6	Sds*DL -.14	SX*SF .7	SZ*... -.21													
20	IBC 16-16 (d) Yes			DL .6	Sds*DL -.14	SZ*SF .7	SX*... -.21													





### Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distribu..	Area(Me...)	Surface...
1	DEAD	DL		-1						
2	FILL	DL						2		
3	WATER	LL						2		
4	WIND-Z	WLZ								264
5	WIND-X	WLX								121
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	2.749	9	7.013	5	3.598	4	0	2	0	2	0	2
2		min	-.77	20	-7.067	4	-.833	11	0	2	0	2	0	2
3	N2	max	2.643	17	13.387	4	3.657	4	0	2	0	2	0	2
4		min	-.876	12	.476	19	-.787	19	0	2	0	2	0	2
5	N1	max	2.749	11	13.387	4	3.657	4	0	2	0	2	0	2
6		min	-.785	20	1.25	19	-.791	19	0	2	0	2	0	2
7	N4	max	2.643	19	6.155	2	3.598	4	0	2	0	2	0	2
8		min	-.891	12	-7.067	4	-.837	11	0	2	0	2	0	2
9	Totals:	max	10.648	17	24.64	2	14.509	4						
10		min	-3.194	12	4.045	19	-3.193	11						

### 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	M30	HSS3.5x3...	.938	2.211	4	.008	0 y	3 6.146	12	13.2	13.2	1	.6	1	H1-1
2	M32A	HSS3.5x3...	.938	2.211	4	.009	0 y	3 6.146	12	13.2	13.2	1	.6	1	H1-1
3	M29A	HSS3.5x3...	.468	2.302	4	.008	0 y	3 6.146	12	13.2	13.2	1	.6	1	H2-1
4	M31	HSS3.5x3...	.468	2.302	4	.009	4.4...	y 3 6.146	12	13.2	13.2	1	.6	1	H2-1
5	M3	HSS12x12x6	.452	6.735	4	.114	6.8...	z 4 9.006	12	13.2	13.2	1	.6	.6	H1-2
6	M4	HSS12x12x6	.452	6.735	4	.114	6.8...	y 4 9.006	12	13.2	13.2	1	.6	.6	H1-2
7	M32	HSS3.5x3...	.441	2.121	3	.019	0 y	4 6.146	12	13.2	13.2	1	.6	1	H1-1
8	M29	HSS3.5x3...	.440	2.121	3	.019	0 y	4 6.146	12	13.2	13.2	1	.6	1	H1-1
9	M2	HSS12x12x6	.415	6.735	4	.112	6.8...	y 4 9.006	12	13.2	13.2	1	.6	.6	H2-1
10	M1	HSS12x12x6	.415	6.735	4	.112	6.8...	z 4 9.006	12	13.2	13.2	1	.6	.6	H2-1
11	M24	PIPE 10.0	.314	12	4	.037	0	4 1.63	12	13.2	13.2	1	1	.85	H1-2
12	M31A	HSS3.5x3...	.208	2.302	3	.019	4.4...	y 4 6.146	12	13.2	13.2	1	.6	1	H2-1
13	M30A	HSS3.5x3...	.208	2.302	3	.019	0 y	4 6.146	12	13.2	13.2	1	.6	1	H2-1
14	M7	L8x8x14	.203	0	5	.096	0 z	4 1.457	12	- Code check b...					H1-1
15	M8	L8x8x14	.203	0	5	.114	0 y	4 1.457	12	- Code check b...					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	.018	12	.009	4	.02	19	4.043e-04	4	3.733e-06	9	1.553e-06	12
2		min	-1.118	3	-.073	2	-13.185	4	-8.664e-05	11	-6.223e-06	3	-3.65e-05	3
3	N2026	max	.019	12	-.006	4	.02	19	5.092e-05	15	9.142e-03	3	2.711e-06	12
4		min	-2.658	3	-.071	2	-13.173	4	-6.579e-04	4	-5.773e-06	20	-6.371e-05	3
5	N1984	max	.019	12	-.01	18	.02	19	3.879e-05	15	3.45e-03	3	2.341e-06	12
6		min	-2.78	3	-.071	2	-13.168	4	-6.644e-04	4	-3.668e-06	20	-5.75e-05	3
7	N1942	max	.019	12	-.011	18	.02	19	2.536e-05	15	1.772e-03	3	2.081e-06	12
8		min	-2.839	3	-.071	2	-13.163	4	-6.716e-04	4	-2.422e-06	20	-5.241e-05	3
9	N1900	max	.019	20	-.011	18	.02	19	1.122e-05	15	5.924e-04	3	1.96e-06	12
10		min	-2.867	3	-.07	2	-13.159	4	-6.789e-04	4	-8.646e-07	20	-4.967e-05	3
11	N1858	max	.019	20	-.011	19	.02	19	4.901e-06	19	1.143e-06	12	1.963e-06	20





Company : J.R. King Engineering  
 Designer : Jerry King  
 Job Number :  
 Model Name : Tower Tech TTXL

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**Envelope Joint Displacements (Continued)**

Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [rad]	LC	Y Rotatio...	LC	Z Rotatio...	LC	
12		min	-2.867	3	-.07	2	-13.156	4	-6.86e-04	4	-5.865e-04	3	-4.965e-05	3
13	N1816	max	.019	20	-.011	19	.02	19	2.799e-06	19	2.864e-06	12	2.092e-06	20
14		min	-2.839	3	-.071	6	-13.153	4	-6.926e-04	4	-1.778e-03	3	-5.233e-05	3

**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	1.057	3	.051	3	3.158	4	1.416	3	6.623	4
2		min		-.576	4	-6.892	4	.025	20	.037	4	.044	20
3		max	B	6.902	4	.473	4	3.215	4	1.586	4	6.678	4
4		min		-.162	3	-1.126	3	.027	20	.138	3	.047	20
5	P393	max	T	.107	16	-.015	19	3.158	4	2.257	12	6.623	4
6		min		-.576	4	-6.892	4	.01	19	-.785	20	.018	19
7		max	B	6.902	4	.473	4	3.215	4	2.234	16	6.678	4
8		min		.004	19	-.189	16	.01	19	1.555	4	.018	19
9	P207	max	T	1.124	3	.093	3	3.153	4	1.446	3	6.6	4
10		min		-.552	4	-6.859	4	.024	20	-.013	4	.043	20
11		max	B	6.882	4	.46	4	3.211	4	1.539	4	6.664	4
12		min		-.174	3	-1.195	3	.026	20	.126	3	.045	20
13	P394	max	T	.103	16	-.013	19	3.153	4	2.293	20	6.6	4
14		min		-.552	4	-6.859	4	.009	19	-.751	18	.016	19
15		max	B	6.882	4	.46	4	3.211	4	2.293	20	6.664	4
16		min		.005	19	-.17	16	.009	19	1.566	3	.016	19
17	P196	max	T	6.729	4	.466	4	3.132	4	2.275	19	6.509	4
18		min		.013	20	-.193	15	.016	20	1.554	4	.028	20
19		max	B	.107	15	-.023	20	3.122	4	2.303	18	6.52	4
20		min		-.52	4	-6.765	4	.01	20	-.249	5	.022	20





Envelope Only Solution

J.R. King Engineering

Jerry King

Tower Tech TTXL

12 FEET LEGS

SK - 1

Dec 16, 2016 at 1:45 PM

TTXL-08 - 12.r3d





Company : J.R. King Engineering  
 Designer : Jerry King  
 Job Number :  
 Model Name : Tower Tech TTXL

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### Hot Rolled Steel Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (11... Density[k/ft^3]	Yield[ksi]	Ry	Fu[ksi]	Rt	
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### 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]
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5	B-3	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
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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	BR-2	HSS7x4x4	VBrace	Tube	fiberglass	Typical	4.77	12.8	30.5	29.3
12	COLLECTOR	C8x11.5	Beam	Channel	fiberglass	Typical	3.37	1.31	32.5	.13

### General Section Sets

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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	Fa...	BLC	Fa...	BLC	Fa...	BLC	Fa...	
1	SIEMIC			SX*	1	SZ*SF	1															
2	IBC 16-9	Yes		DL	1	LL	1															
3	IBC 16-12 (a) ...	Yes		DL	1	WLX	.6															
4	IBC 16-12 (a) ...	Yes		DL	1	WLZ	.6															
5	IBC 16-13 (a) ...	Yes		DL	1	WLX	.45	LL	.75													
6	IBC 16-13 (a) ...	Yes		DL	1	WLZ	.45	LL	.75													
7	IBC 16-13 (c) ...	Yes		DL	1	WLX	.45	LL	.75													
8	IBC 16-13 (c) ...	Yes		DL	1	WLZ	.45	LL	.75													
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 16-12 (b) ...	Yes		DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	-.21											
12	IBC 16-12 (b) ...	Yes		DL	1	Sds*DL	.14	SZ*SF	.7	SX*...	-.21											
13	IBC 16-14 (a) ...	Yes		DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	.158	LL	.75									
14	IBC 16-14 (a) ...	Yes		DL	1	Sds*DL	.105	SZ*SF	.525	SX*...	.158	LL	.75									
15	IBC 16-14 (a) ...	Yes		DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	-.1...	LL	.75									
16	IBC 16-14 (a) ...	Yes		DL	1	Sds*DL	.105	SZ*SF	.525	SX*...	-.1...	LL	.75									
17	IBC 16-16 (a) Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	.21											
18	IBC 16-16 (b) Yes			DL	.6	Sds*DL	-.14	SZ*SF	.7	SX*...	.21											
19	IBC 16-16 (c) Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	-.21											





Company : J.R. King Engineering  
 Designer : Jerry King  
 Job Number :  
 Model Name : Tower Tech TTXL

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### Load Combinations (Continued)

Description	Sol...P	Delta	SRSS	BLC Fa...	BLC	Factor	BLC	Fac...	BLC Fa...	BLC Fa...	BLCFa.....	BLC Fact.	BLC Fact...
20	IBC 16-16 (d)	Yes		DL	.6	Sds*DL	-.14	SZ*SF	.7	SX*..	-.21		

### Basic Load Cases

BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distribu..	Area(Me...	Surface...
1 DEAD	DL			-1					
2 FILL	DL						2		
3 WATER	LL						2		
4 WIND-Z	WLZ								264
5 WIND-X	WLX								121
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 3.084	9	7.252	5	3.605	4	0	2	0	2	0	2
2	min -889	20	-8.356	4	-931	11	0	2	0	2	0	2
3 N2	max 3.012	17	14.737	4	3.65	4	0	2	0	2	0	2
4	min -961	12	.666	19	-896	19	0	2	0	2	0	2
5 N1	max 3.084	11	14.737	4	3.65	4	0	2	0	2	0	2
6	min -897	20	1.183	19	-898	19	0	2	0	2	0	2
7 N4	max 3.012	19	6.186	2	3.605	4	0	2	0	2	0	2
8	min -969	12	-8.356	4	-933	11	0	2	0	2	0	2
9 Totals:	max 12.101	17	24.763	2	14.509	4						
10	min -3.63	12	4.084	19	-3.616	11						

### 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	M3	HSS12x12x6	.566	8.694	4	.147	8.8...	z 4 8.118	12	13.2	13.2	1	.6	.6	H1-2
2	M4	HSS12x12x6	.566	8.694	4	.147	8.8...	y 4 8.118	12	13.2	13.2	1	.6	.6	H1-2
3	M30	HSS7x4x4	.537	1.986	4	.014	0	y 3 7.761	12	13.2	13.2	1	.6	1	H1-1
4	M32A	HSS7x4x4	.537	1.986	4	.015	4.4...	y 3 7.761	12	13.2	13.2	1	.6	1	H1-1
5	M2	HSS12x12x6	.530	8.694	4	.145	8.8...	y 4 8.118	12	13.2	13.2	1	.6	.6	H2-1
6	M1	HSS12x12x6	.530	8.694	4	.145	8.8...	z 4 8.118	12	13.2	13.2	1	.6	.6	H2-1
7	M32	HSS3.5x3....	.520	2.121	3	.020	0	y 4 6.146	12	13.2	13.2	1	.6	1	H1-1
8	M29	HSS3.5x3....	.520	2.121	3	.020	4.4...	y 4 6.146	12	13.2	13.2	1	.6	1	H1-1
9	M29A	HSS7x4x4	.343	2.392	4	.014	0	y 3 7.761	12	13.2	13.2	1	.6	1	H2-1
10	M31	HSS7x4x4	.343	2.392	4	.015	0	y 3 7.761	12	13.2	13.2	1	.6	1	H2-1
11	M24	PIPE_10.0	.314	12	4	.037	0	4 1.63	12	13.2	13.2	1	1	.85	H1-2
12	M31A	HSS3.5x3....	.252	2.302	3	.020	4.4...	y 4 6.146	12	13.2	13.2	1	.6	1	H2-1
13	M30A	HSS3.5x3....	.252	2.302	3	.020	4.4...	y 4 6.146	12	13.2	13.2	1	.6	1	H2-1
14	M7	L8x8x14	.222	0	5	.098	0	z 4 1.457	12	- Code check b...					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 .016	12	.02	4	.017	19	2.161e-04	4	1.826e-06	9	9.795e-07	12
2	min -1.972	3	-.078	2	-14.697	4	-4.612e-05	11	-5.981e-06	3	-3.97e-05	3
3 N2026	max .017	12	0	4	.017	19	4.967e-05	15	9.143e-03	3	1.71e-06	12
4	min -3.513	3	-.077	2	-14.685	4	-8.54e-04	4	-3.12e-06	20	-6.93e-05	3
5 N1984	max .017	12	-.011	4	.017	19	3.761e-05	15	3.45e-03	3	1.42e-06	12
6	min -3.635	3	-.076	2	-14.679	4	-8.606e-04	4	-2.201e-06	20	-6.192e-05	3
7 N1942	max .017	12	-.012	18	.017	19	2.422e-05	15	1.772e-03	3	1.217e-06	12
8	min -3.693	3	-.076	2	-14.674	4	-8.679e-04	4	-1.485e-06	20	-5.59e-05	3





Company : J.R. King Engineering  
 Designer : Jerry King  
 Job Number :  
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**Envelope Joint Displacements (Continued)**

	Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [rad]	LC	Y Rotatio...	LC	Z Rotatio...	LC
9	N1900	max	.017	12	-.012	18	.017	19	1.008e-05	15	5.924e-04	3	1.122e-06	12
10		min	-3.722	3	-.076	2	-14.67	4	-8.754e-04	4	-5.593e-07	20	-5.267e-05	3
11	N1858	max	.017	20	-.012	19	.017	19	3.425e-06	19	5.972e-07	12	1.124e-06	20
12		min	-3.722	3	-.076	2	-14.667	4	-8.825e-04	4	-5.865e-04	3	-5.264e-05	3
13	N1816	max	.017	20	-.012	19	.017	19	1.281e-06	19	1.617e-06	12	1.225e-06	20
14		min	-3.693	3	-.078	6	-14.665	4	-8.889e-04	4	-1.778e-03	3	-5.582e-05	3
15	N1774	max	.017	20	-.012	19	.017	19	-6.535e-07	19	2.409e-06	12	1.435e-06	20
16		min	-3.635	3	-.086	6	-14.663	4	-8.947e-04	4	-3.449e-03	3	-6.178e-05	3

**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	1.061	3	.04	3	3.162	4	1.397	3	6.627	4
2		min		-.569	4	-6.893	4	.025	20	.038	4	.043	20
3		max	B	6.901	4	.48	4	3.211	4	1.586	4	6.675	4
4		min		-.16	3	-1.134	3	.025	20	.159	3	.043	20
5	P393	max	T	.106	16	-.02	19	3.162	4	2.269	20	6.627	4
6		min		-.569	4	-6.893	4	.013	19	-.139	5	.024	19
7		max	B	6.901	4	.48	4	3.211	4	2.269	20	6.675	4
8		min		.007	19	-.191	2	.013	19	1.529	3	.024	19
9	P207	max	T	1.127	3	.085	3	3.156	4	1.431	3	6.602	4
10		min		-.547	4	-6.859	4	.024	20	-.013	4	.041	20
11		max	B	6.882	4	.465	4	3.209	4	1.539	4	6.662	4
12		min		-.173	3	-1.201	3	.024	20	.142	3	.041	20
13	P394	max	T	.103	16	-.017	19	3.156	4	2.284	20	6.602	4
14		min		-.547	4	-6.859	4	.012	19	-.13	5	.021	19
15		max	B	6.882	4	.465	4	3.209	4	2.284	20	6.662	4
16		min		.007	19	-.17	16	.012	19	1.543	3	.021	19
17	P196	max	T	6.729	4	.458	4	3.136	4	2.267	19	6.512	4
18		min		.007	20	-.193	15	.015	20	1.553	4	.027	20
19		max	B	.107	15	-.023	20	3.118	4	2.267	19	6.516	4
20		min		-.528	4	-6.764	4	.015	20	-.269	5	.027	20



# Properties

	ASTM TEST METHOD	UNITS/VALUE	SERIES 500/S25 SHAPES	SERIES 625 SHAPES	SERIES 500/S25 PLATE ⑤			SERIES 625 PLATE ⑤		
					1/8" 3.175mm	3/16" - 1/4" 4.76-6.35mm	3/8" - 1" 9.5-25.4mm	1/8" 3.175mm	3/16" - 1/4" 4.76-6.35mm	3/8" - 1" 9.5-25.4mm
<b>MECHANICAL</b>										
Tensile Stress, LW	D638	psi N/mm <sup>2</sup>	30,000 207	30,000 207	20,000 138	20,000 138	20,000 138	20,000 138	20,000 138	20,000 138
Tensile Stress, CW	D638	psi N/mm <sup>2</sup>	7,000 48.3	7,000 48.3	7,500 51.7	10,000 68.9	10,000 68.9	7,500 51.7	10,000 68.9	10,000 68.9
Tensile Modulus, LW	D638	10 <sup>4</sup> psi 10 <sup>3</sup> N/mm <sup>2</sup>	2.5 17.2	2.6 17.9	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4
Tensile Modulus, CW	D638	10 <sup>4</sup> psi 10 <sup>3</sup> N/mm <sup>2</sup>	0.8 5.52	0.8 5.52	0.7 4.83	0.9 6.21	1.4 9.65	1.0 6.89	1.0 6.89	1.4 9.65
Compressive Stress, LW	D695	psi N/mm <sup>2</sup>	30,000 207	30,000 207	24,000 165	24,000 165	24,000 165	24,000 165	24,000 165	24,000 165
Compressive Stress, CW	D695	psi N/mm <sup>2</sup>	15,000 103	16,000 110	15,500 107	16,500 114	20,000 138	16,500 114	17,500 121	17,500 121
Compressive Modulus, LW	D695	10 <sup>4</sup> psi 10 <sup>3</sup> N/mm <sup>2</sup>	2.5 17.2	2.6 17.9	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4
Compressive Modulus CW	D695	10 <sup>4</sup> psi 10 <sup>3</sup> N/mm <sup>2</sup>	0.8 6.89	0.8 6.89	0.7 6.89	0.9 6.89	1.4 6.89	1.0 6.89	1.0 6.89	1.4 6.89
Flexural Stress, LW	D790	psi N/mm <sup>2</sup>	30,000 207	30,000 207	35,000 241	35,000 241	30,000 207	35,000 241	35,000 241	30,000 207
Flexural Stress, CW	D790	psi N/mm <sup>2</sup>	10,000 68.9	10,000 68.9	13,000 89.6	15,000 103	18,000 124	13,000 89.6	15,000 103	18,000 124
Flexural Modulus, LW	D790	10 <sup>4</sup> psi 10 <sup>3</sup> N/mm <sup>2</sup>	1.6 11.0	1.6 11.0	1.8 12.4	2 13.8	2 13.8	1.8 12.4	2 13.8	2 13.8
Flexural Modulus, CW	D790	10 <sup>4</sup> psi 10 <sup>3</sup> N/mm <sup>2</sup>	0.8 5.52	0.8 5.52	0.9 6.21	1.1 7.58	1.4 9.65	1.0 6.89	1.1 7.58	1.4 9.65
Modulus of Elasticity ①	full section	10 <sup>4</sup> psi 10 <sup>3</sup> N/mm <sup>2</sup>	2.6 17.9	2.8 19.3						
Modulus of Elasticity: W & I shapes > 4" W & I shapes > 102mm	full section	10 <sup>4</sup> psi 10 <sup>3</sup> N/mm <sup>2</sup>	2.5 17.2	2.5 17.2						
Parallel Compressive Shear Stress, LW ② ③	D3846	psi N/mm <sup>2</sup>	3,000 20.7	3,000 20.7						
Shear Modulus, LW ③ ④	—	10 <sup>4</sup> psi 10 <sup>3</sup> N/mm <sup>2</sup>	0.425 2.93	0.425 2.93						
Short Beam Shear, LW ⑤ ⑥	D2344	psi N/mm <sup>2</sup>	4,500 31.0	4,500 31.0						
Bearing Stress, LW	D953	psi N/mm <sup>2</sup>	30,000 207	30,000 207	32,000 220.6	32,000 221	32,000 221	32,000 221	32,000 221	32,000 221
Poisson's Ratio, LW ⑦	D3039	in/in mm/mm	0.33 .330	0.33 .330	0.31 .310	0.31 .310	0.31 .310	0.32 .320	0.32 .320	0.32 .320
Notched Izod Impact, LW	D256	ft-lbs/in J/mm	25 1.33	25 1.33	15 .801	10 .533	10 .533	15 .801	10 .533	10 .533
Notched Izod Impact, CW	D256	ft-lbs/in J/mm	4 .214	4 .214	5 .267	5 .267	5 .267	5 .267	5 .267	5 .267
<b>PHYSICAL</b>										
Barcol Hardness	D2583	—	45 ⑧	45 ⑧	40	40	40	40	40	40
24 hr Water Absorption ⑨	D570	% Max	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Density	D792	lbs/in <sup>3</sup> 10 <sup>3</sup> g/mm <sup>3</sup>	.062-.070 1.72-1.94	.062-.070 1.72-1.94	.060-.068 1.66-1.88	.060-.068 1.66-1.88	.060-.068 1.66-1.88	.060-.068 1.66-1.88	.060-.068 1.66-1.88	.060-.068 1.66-1.88
Coefficient of Thermal Expansion, LW ⑩	D696	10 <sup>-4</sup> in/in/°F 10 <sup>-4</sup> mm/mm/°C	4.4 8.0	4.4 8.0	4.4 8.0	4.4 8.0	4.4 8.0	4.4 8.0	4.4 8.0	4.4 8.0
Thermal Conductivity ⑪	C177	BTU-in/ft <sup>2</sup> Hr°F w/(m <sup>2</sup> *K)	4 .58	4 .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      PF — Perpendicular to laminate face  
 CW — Crosswise      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-extinguish.
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	-----	-----