Metallic Mirror:

A Parabolic Solar Trough

Sponsored by Arconic

Metallic Mirror: A Parabolic Solar Trough

The Team

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PITT | SWANSON ENGINEERING

ARCONIC
Innovation, engineered.

Objectives

A little bit about what we set out to do

Background

Current Technology and Issues

Silver-backed mirrors

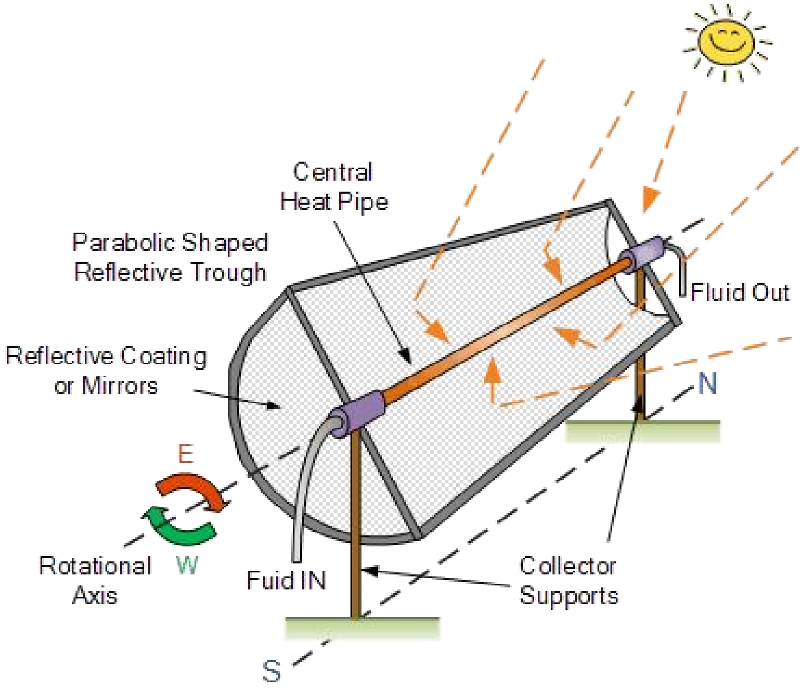
- Multiple panes with complex connections

Aluminum mounts w/ rubber absorbers

- Countless parts required for assembling
- Misplacing of parts common

Double-walled heating tube

Sun tracking technology



http://www.alternative-energy-tutorials.com/solar-hot-water/parabolic-trough-reflector.html

Current Trough Designs

Aluminum Space Frame

Length: 8 m

Aperture Width: 5 m

Aperture Area: 470 m^2 per SCA

Trough Weight: 23 kg/m^2

VS

Torque Tube (LS-2)

Length: 8 m

Aperture Width: 5 m

Aperture Area: 235 m^2 per SCA

Trough Weight: 29 kg/m^2

Notable Flaws

Parabolic glass mirrors require isolation through connectors

Numerous, silver-backed mirror panels per each trough

Missing surface area due to panel gaps

Prior Art Research

Notable Features

Parabolic metal-based mirrors not contributing to structure

Mirrors based on films + multilayer coatings

SkyFuel

Producer of ReflecTech

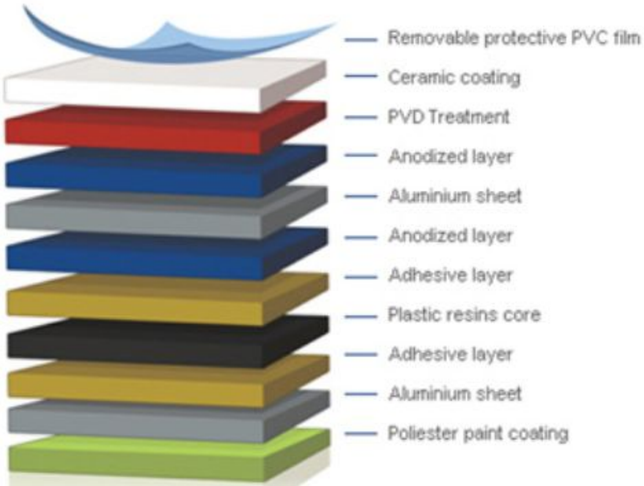
Highly-reflective film for aluminium

&

Alucoil

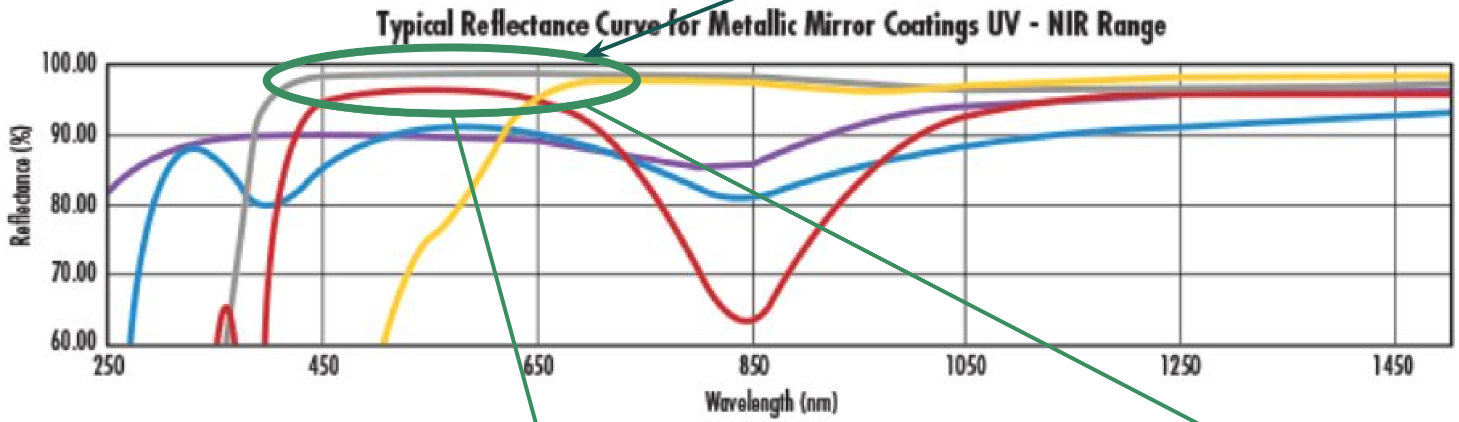
Producer of Almirr

Multilaminar mirrored aluminum technology



Material Research

Operating Range: 390 - 700 nm



Protected Aluminum		Enhanced Aluminum		UV Ehanced Aluminum		Protected Gold		Protected Silver	
Range (μm)	% Reflection	Range (μm)	% Reflection	Range (μm)	% Reflection	Range (μm)	% Reflection	Range (μm)	% Reflection
0.4 - 0.7	85	0.45 - 0.65	95	0.25 - 0.45	89	0.7 - 2.0	96	0.45 - 2.0	98
0.4 - 2.0	90	–	–	0.25 - 0.70	85	2.0 - 10.0	96	2.0 - 10.0	98

Requirements

Done is to have a complete functional design that

Has similar or improved effectiveness as current solution

- Less Deflection
- Greater Precision
- Larger Surface Area

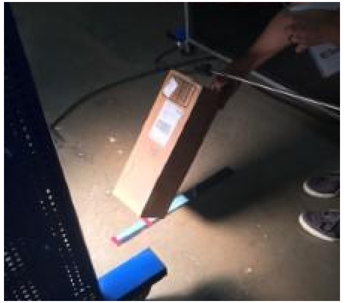
25% - 50% reduction in solar field costs:

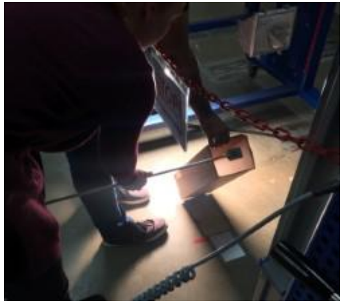
- Material Costs
- Amount of materials

Evolution

Our path through the design process

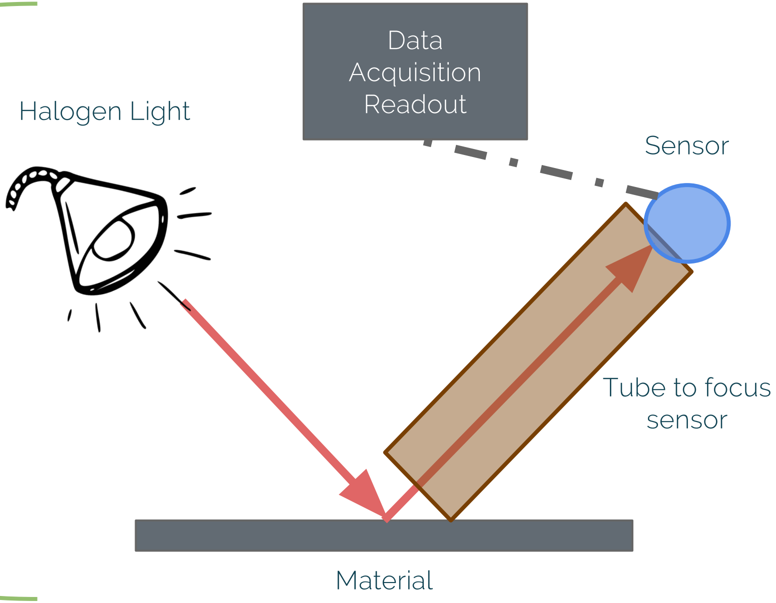
Material Testing Procedure





Procedure

1. Set 2" x 5" sample on the ground in front of halogen lamp
2. Cardboard tube lined up to eliminate ambient reflections
3. Solar thermal flat collected lined up at the end of the tube to measure solar radiance of each material
4. Mylar and mirrored aluminum tested 6 times. Silver anodized aluminum tested 3 times



Material Testing Results

Mirrored Aluminum
Mean: 3.0 kW/m^2
Std Dev: 0.175

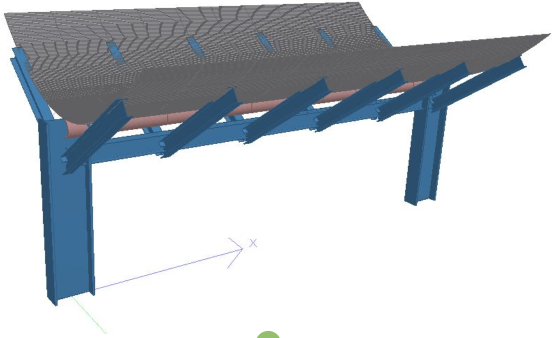
Mylar
Mean: 2.6 kW/m^2
Std Dev: 0.2

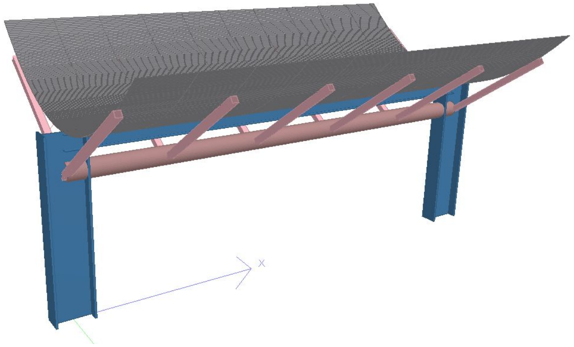
Aluminum Silver
Mean: 1.7 kW/m^2
Std Dev: 0.058

Mirrored Aluminum statistically more reflective to a 99% confidence level

Final Design Concept

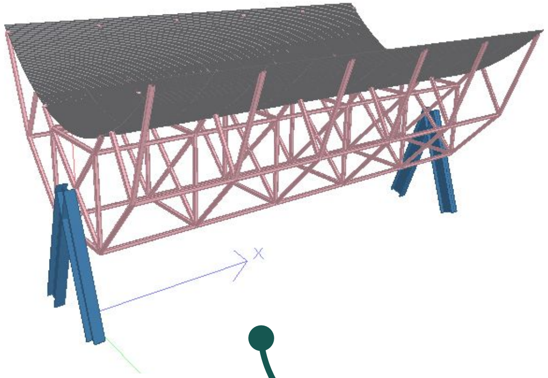
Design 1





Design 2

Design 3



Final Design Concept for Virtual Prototype

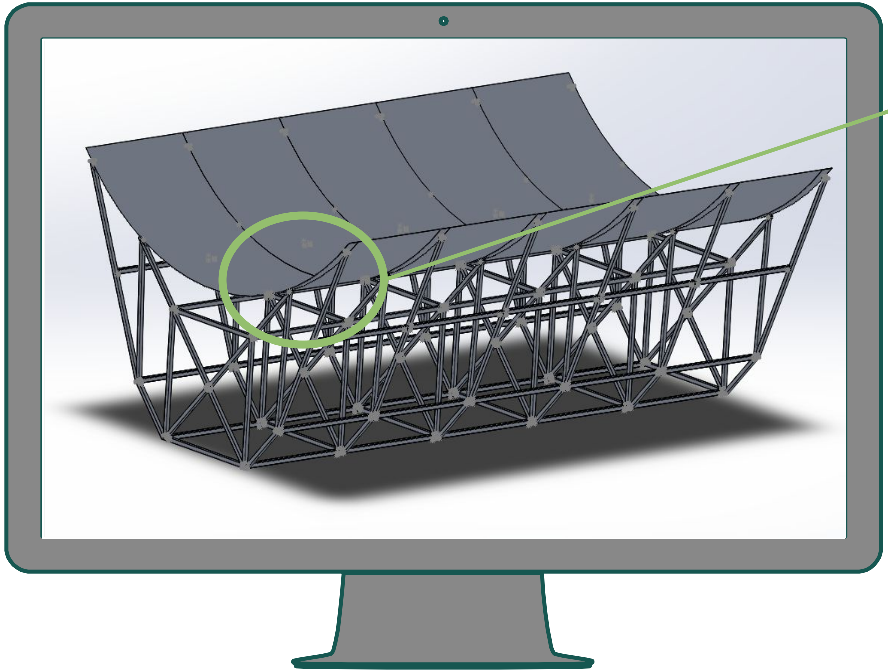
Analysis of Design

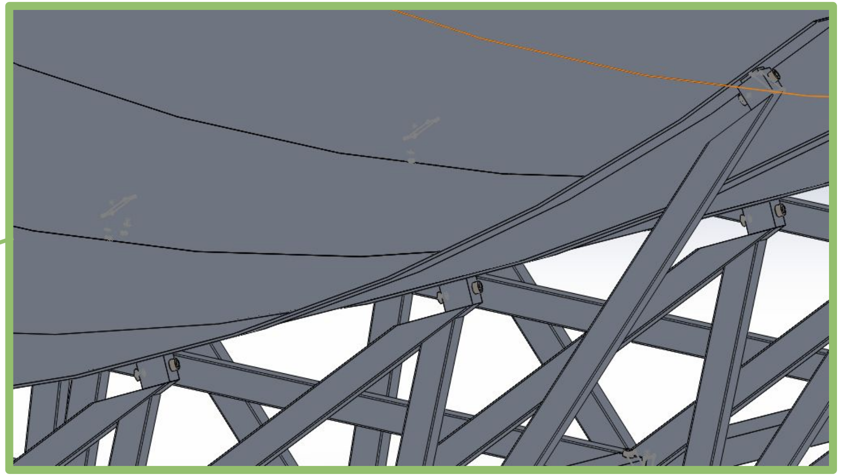
	Design 1	Design 2	Design 3
Trough Thickness (inches)	0.75	0.375	0.10
Substructure Material	Steel/Aluminum	Steel/Aluminum	Aluminum
FEA - Max. Deflection (inches)	0.51	0.45	0.68

Prototype

Breathing digital life into our design

Virtual Prototype





All aspects modeled to create an accurate bill of materials (BoM)

Prototype Testing

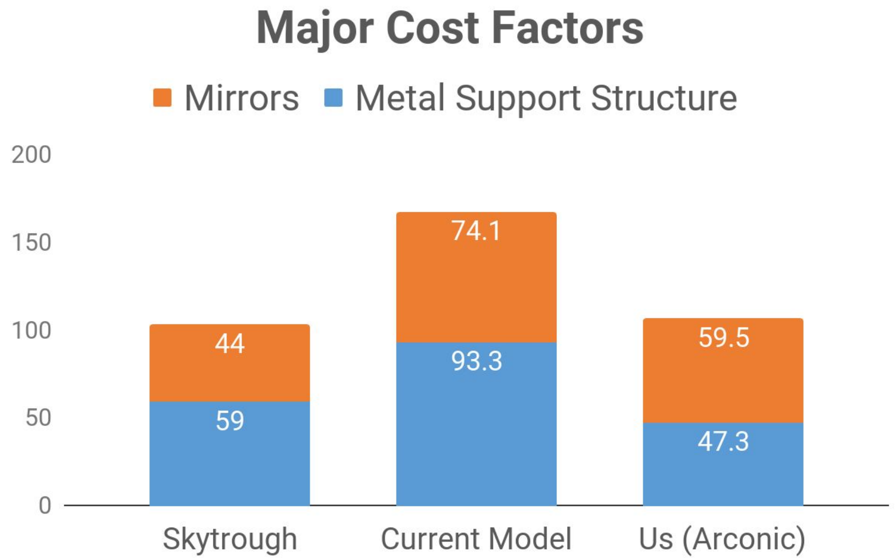
	Prototype
Trough Thickness (inches)	0.075
Substructure Al Square Tube Size (inches)	1.5 x 1.5
FEA - Max. Deflection (inches)	0.69

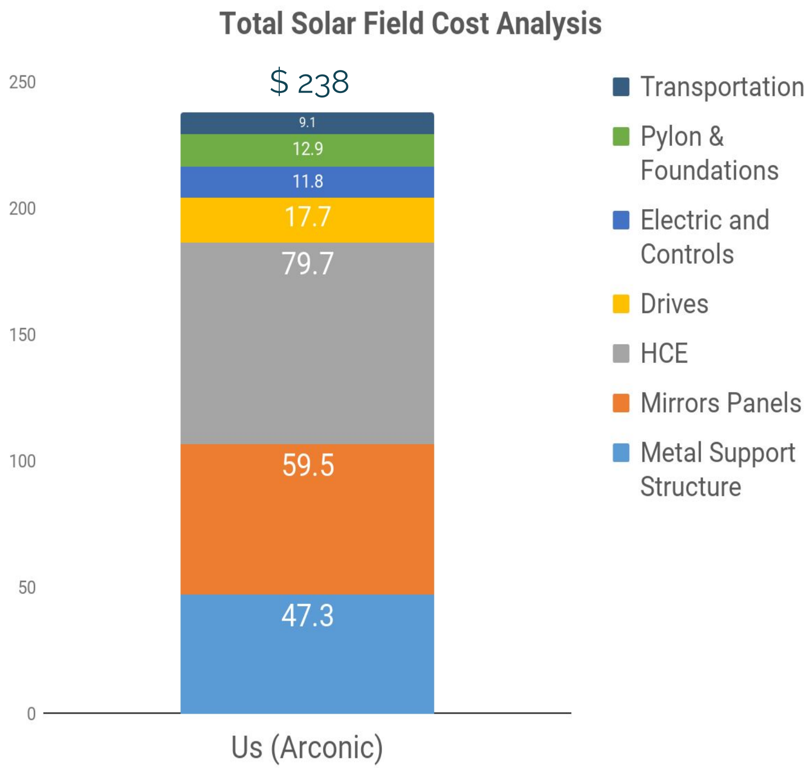
Mirror sections (5) will be joined by formed strips of 6" x 0.25" aluminium with an adhesive, effectively restoring the structural integrity of a single sheet, while also using the added stiffness to enforce the desired parabola.

The strips will be mounted to the truss structure with slip-fit joints secured with a bolt and nylock nut.

The remainder of the truss structure will be welded with slip-fit joints (secured by bolt and nylock nut) for the horizontal linkages to achieve the final structure.

Cost Analysis





Cost per unit area ($\$/m^2$)

Results

What we learned from our prototype

Results

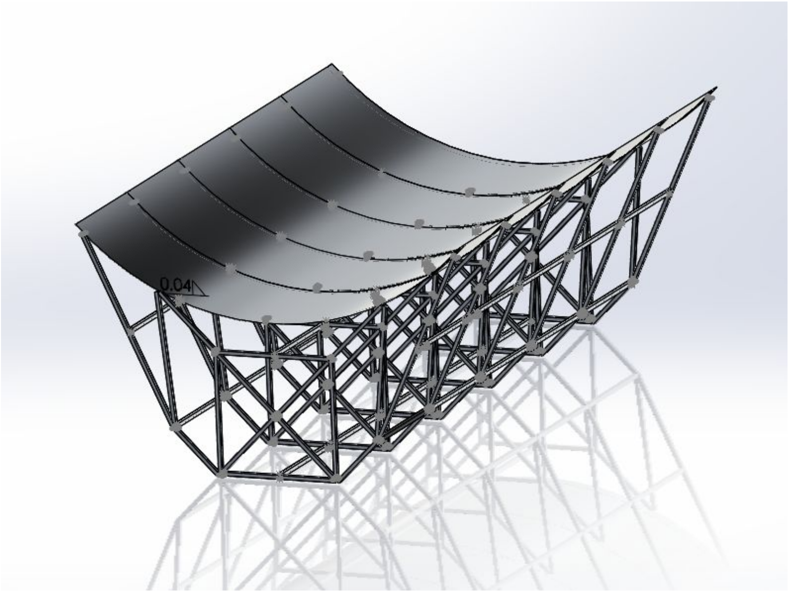
We were able to create a complete functional design that

Has improved effectiveness over current solution with

- Less Deflection - more than 1" less than the deflection given by NREL
- Greater Precision - more accurate during assembly time in the field
- Larger Surface Area - little to no gaps over entire reflective surface area

Has reduced overall cost

- Cost per m^2 for materials is down ~34%
- Less parts for transportation and assembly



Results vs. Objectives

	Our Design	Technical Requirements
Precision Error (mrad)	8.0-	< 8.00
Intercept Factor	0.96+	> 0.96
Surface Area (m^2)	45.92	> 45.0
Deflection (inches)	0.68	< 2.00
Cost per square meter ($\$/m^2$)	238.40	< 265

Conclusions

How we did and what more can be done

Measures of Success

Done

- Similar or Improved Effectiveness
- Cost Reduction of 25-50%

Suggestions for Follow-On

- Further research can be done on the concept of layering grades or finishes of aluminium to reduce cost and increase torsional stiffness.
- Research into alloys, coatings, and films to increase reflectivity while still use a metal-based mirror for structural support.
- Other cost factors like receivers, heat transfer fluid, and transportation can be reduced to achieve greater overall reduction in solar field cost.
- Calculating the reduction in transportation and assembly costs using our design would further give supporting evidence for our cost reduction.

THANKS!

Any questions?

Appendix

BoM

Name	Material	Length	Width	Height	Wall thickness	Thread	Area	Volume	Density (lb/inch3)	Weight(lb)	Material Cost	Price (1 pc)	Qty	Total Cost	Cost /m2
Mirror	Mirrored Aluminum	220	63	0.075			4.725	1039.5	0.1051	109.25	365.99	475.79	5	2378.95	59.47
Parabolic Sling	Aluminum	220	6	0.25			1.5	330	0.098	32.34	53.36	69.37	6	416.22	
Square Tube	Aluminum	38	1.5	1.5	0.12		0.6624	25.1712	0.098	2.47	4.07	5.29	12	63.49	
Square Tube	Aluminum	39.5	1.5	1.5	0.12		0.6624	26.1648	0.098	2.56	4.23	5.50	12	66.00	
Square Tube	Aluminum	81	1.5	1.5	0.12		0.6624	53.6544	0.098	5.26	8.68	11.28	6	67.67	
Square Tube	Aluminum	101.3	1.5	1.5	0.12		0.6624	67.10112	0.098	6.58	10.85	14.11	12	169.26	
Square Tube	Aluminum	31.5	1.5	1.5	0.12		0.6624	20.8656	0.098	2.04	3.37	4.39	12	52.63	
Square Tube	Aluminum	63.7	1.5	1.5	0.12		0.6624	42.19488	0.098	4.14	6.82	8.87	12	106.44	
Square Tube	Aluminum	59	1.5	1.5	0.12		0.6624	39.0816	0.098	3.83	6.32	8.22	24	197.17	47.69
Inner Connect Tube	Aluminum	1.5	1.49	1.49			2.2201	3.33015	0.098	0.33	0.54	0.70	80	56.00	
Square Tube	Aluminum	60.5	1.5	1.5	0.25		1.25	75.625	0.098	7.41	12.23	15.90	40	635.89	
Screw	Black Oxide Steel	2.5				(1/2)-13 (UNC)						0.45	104	46.80	
Nut	Steel					(1/2)-13 (UNC)						0.09	104	9.36	
Square Tube	Aluminum	1.8	1.4	1.4	0.25		1.15	2.07	0.098	0.20	0.33	0.44	12	5.22	
Square Tube	Aluminum	1.75	1.5	1.5	0.25		1.25	2.1875	0.098	0.21	0.35	0.46	24	11.04	
Square Tube	Aluminum	1.55	1.4	1.4	0.25		1.15	1.7825	0.098	0.17	0.29	0.37	12	4.50	