Program

The UA Solar Decathlon entry is a modular, solar powered pavilion to raise awareness of emerging green technologies in the building industry. The south trombe wall serves as one platform for research in the project focused on the application of recycled plastic materials to architecture.

Transportation strategy

Although massive elements in buildings are often structural, the need to transport this house across the country prohibits traditional materials such as concrete or brick. The use of water allows the wall cavity to be emptied before transport and then re-filled on site in Washington DC. This reduces the energy it takes to ship the house across the country, and allows the benefits of thermal mass to temper the interior environment once the house is re-assembled.

Performance

The thermal performance of the wall system is paramount, but in order for this to be an effective envelope, physical and energy forces of both water and the system containing it must be carefully constrained. In addition to these critical factors, this system must integrate with others in the home.

Production

Design of production methods becomes critical to producing a high-quality, consistant product. Wherever possible existing industry methods have been adopted, but the paradigm shift from packaging technologies to Architecture produces new challenges and calls for innovation in both the design and construction methods.

Plastics and Architectural Ecologies_Polymer Trombe Wall

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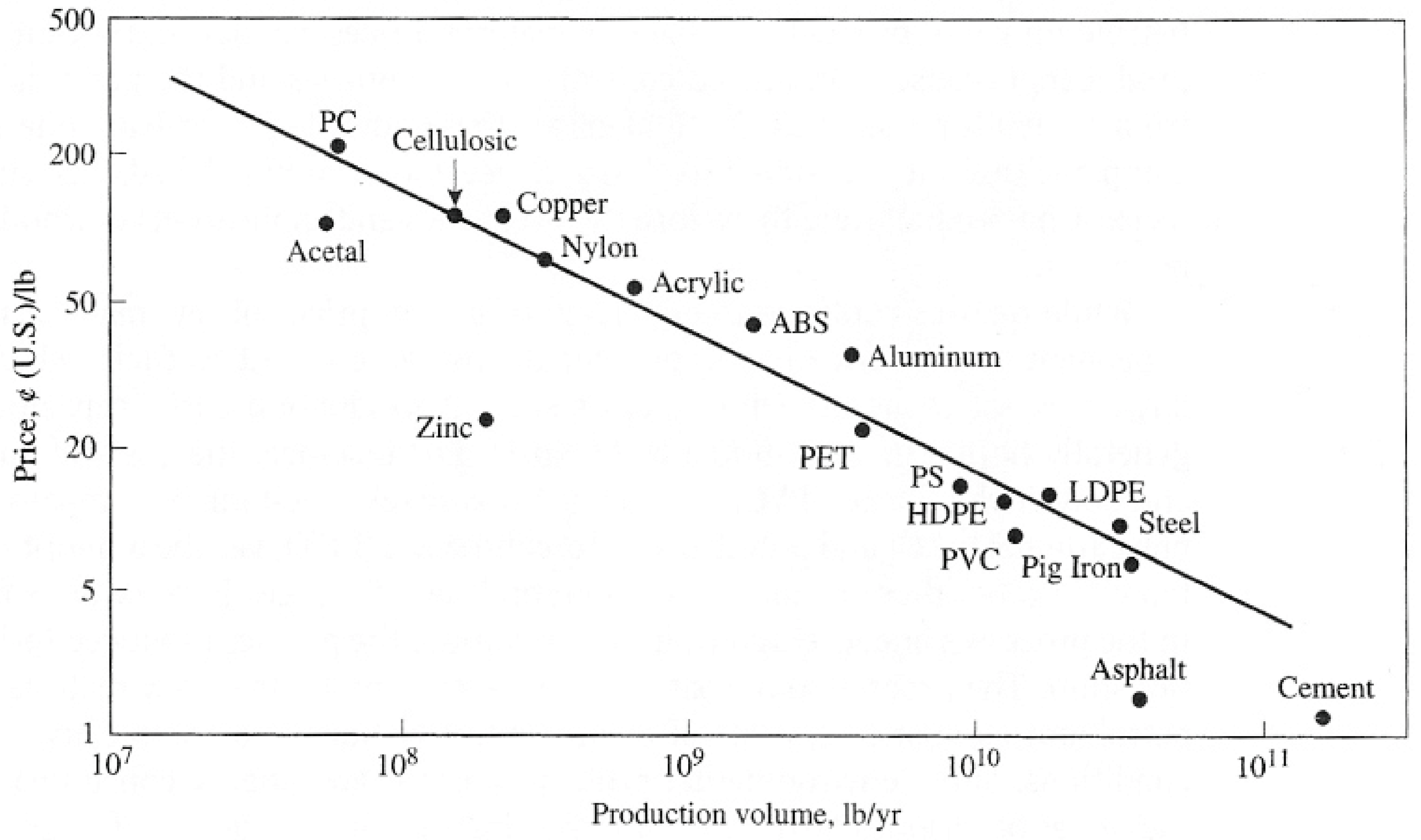
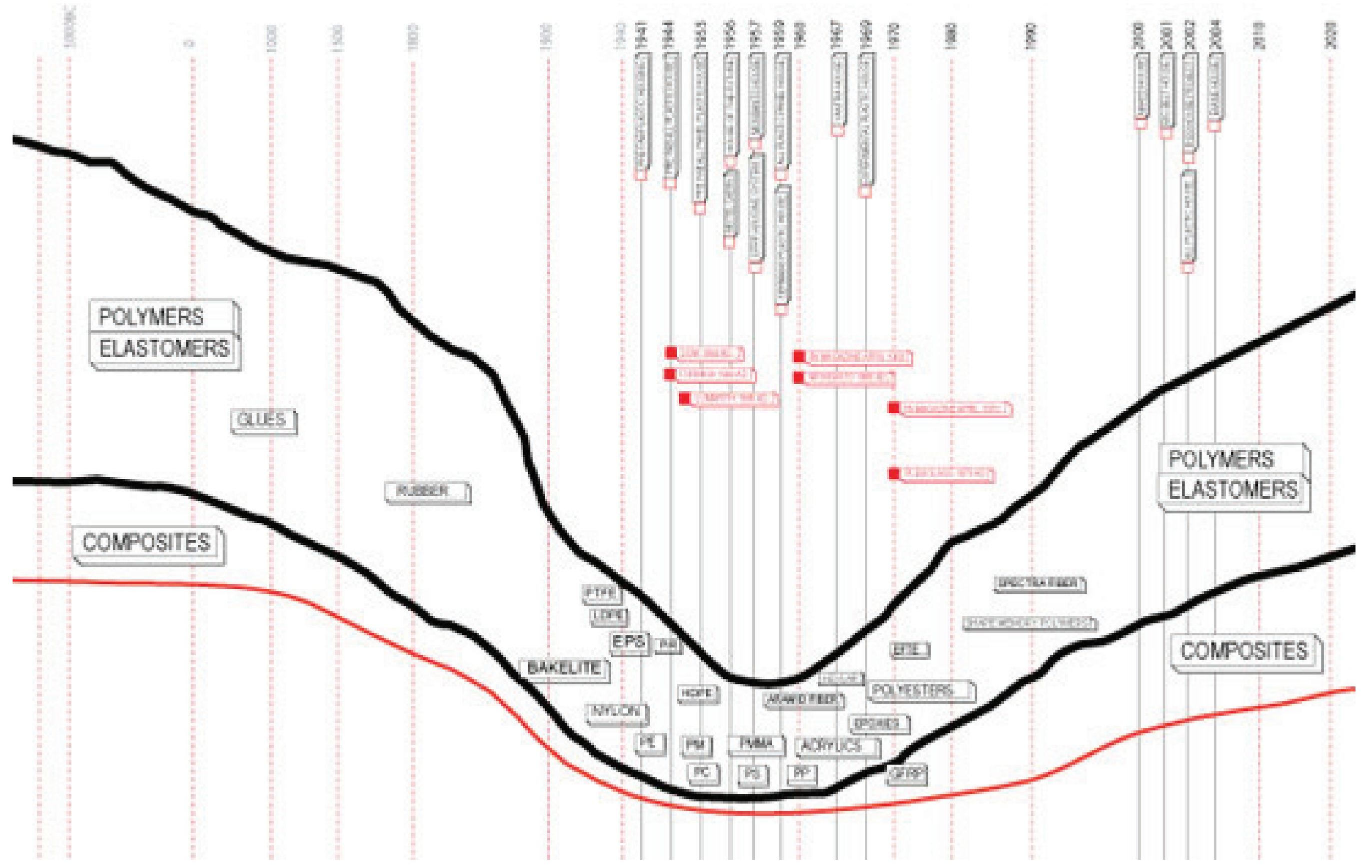
PET is one of the highest produced engineering grade thermoplastics in the world. Its recyclability index is very high, and can be re-used for many cycles with little mechanical degradation. Its low cost and high mechanical performance has been its attraction to the packaging industry, but with plastics pollution rates skyrocketing, environmental concerns point out an obvious flaw. Packaging disposable goods in non-disposable containers makes no sense. This inert, UV resistant, sterile, transparent material could be put to better use in something with a longer life cycle. 'Capturing' this material and putting it to use in buildings also reduces the pollution in landfills and oceans.

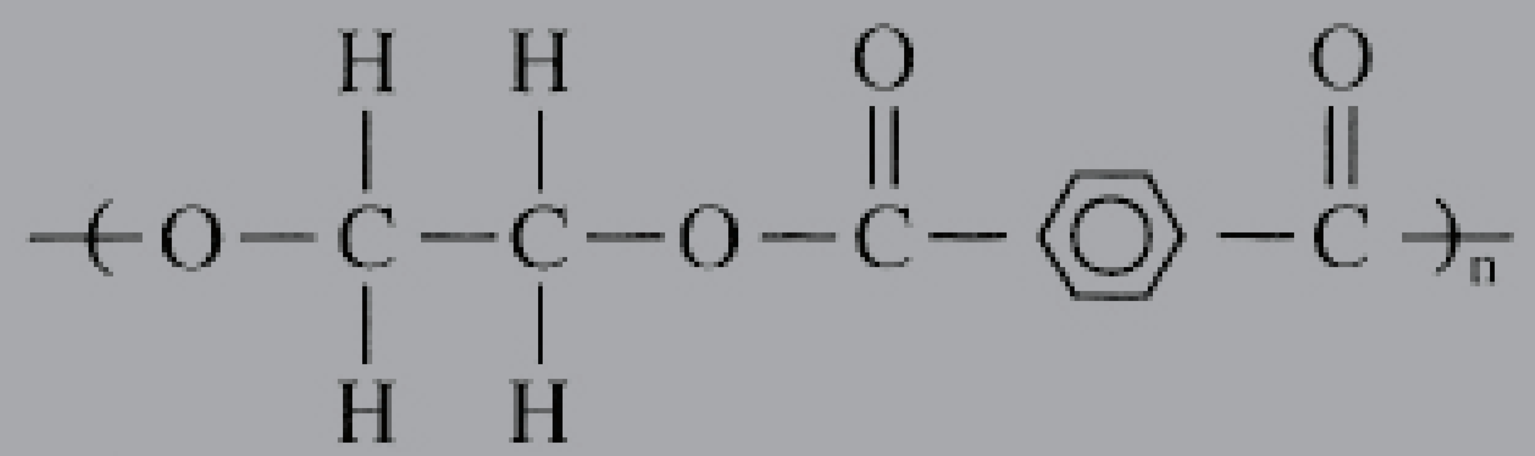




As advances in building technology couple with higher material costs, plastics are becoming more and more a viable option for construction materials with impressive performance characteristics of their own. By in large they offer lighter, more durable, and less expensive alternatives to the traditional building materials they replace. But in order to fully take advantage of the strengths plastics offer, their properties must be understood from the beginning of the design process.

- Soda bottles
- Film for cassettes and videos
- Automobile trim
- Fibers for carpets and clothes

- Kodar (Eastman)
- Rynite (DuPont)
- Ultradur (BASF)
- Hytrel (DuPont)
- Impet (Hoechst)
- Mylar (DuPont)
- Dacron (DuPont)



Polyethylene Teraphlate (PETE) Material Properties

Mechanical Properties

Coefficient of friction	0.2-0.4
Hardness – Rockwell	M94-101
Izod impact strength (J.m-1)	13-35
Poisson's ratio	0.37-0.44(oriented)
Tensile modulus (GPa)	2-4
Tensile strength (MPa)	80

Physical Properties

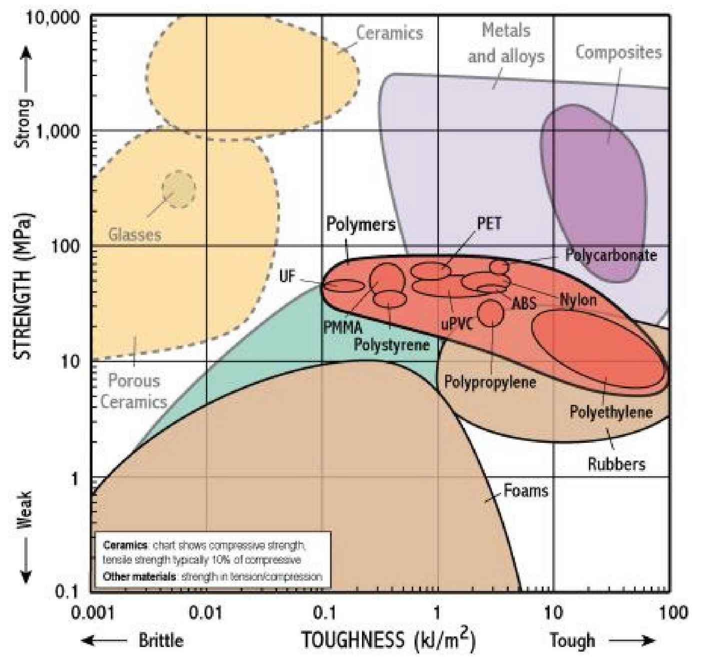
Density (g.cm-3)	1.3-1.4
Flammability	Self Extinguishing
Limiting oxygen index (%)	21
Refractive index	1.58-1.64
Resistance to Ultra-violet	Good
Water absorption - equilibrium (%)	<0.7
Water absorption - over 24 hours (%)	0.1

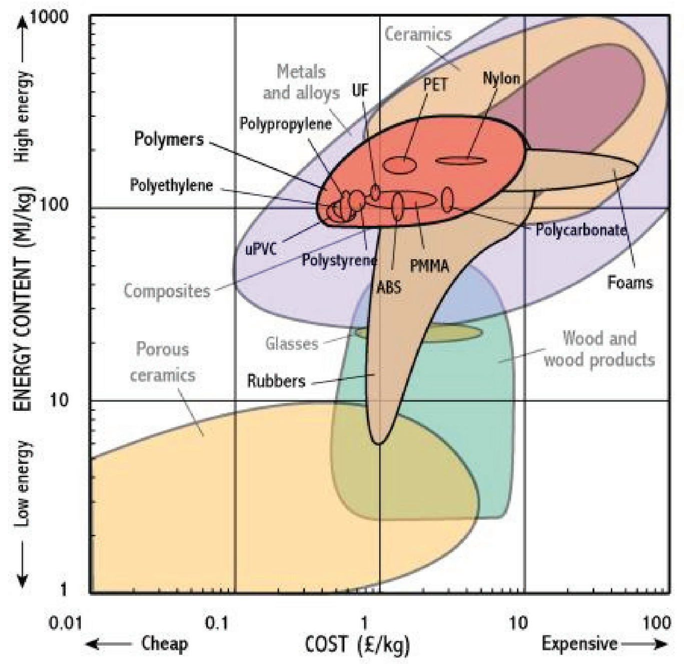
Thermal Properties

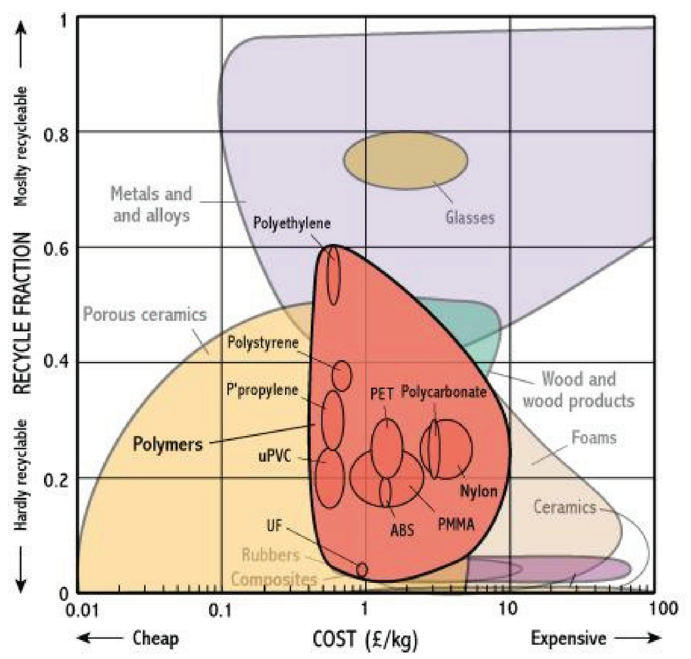
Coefficient of thermal expansion (x10-6 K-1)	20-80
Heat-deflection temperature - 0.45MPa (°C)	115
Heat-deflection temperature - 1.8MPa (°C)	80
Lower working temperature (°C)	-40 to -60
Upper working temperature (°C)	115-170
Processing temperature (°C)	227-350
Specific heat (J.K-1.kg-1)	1200 - 1350

Thermal conductivity (W.m-1.K-1) @23 Centigrade

PET	0.15-0.4
Glass	1.06
Steel	46
Water	.058







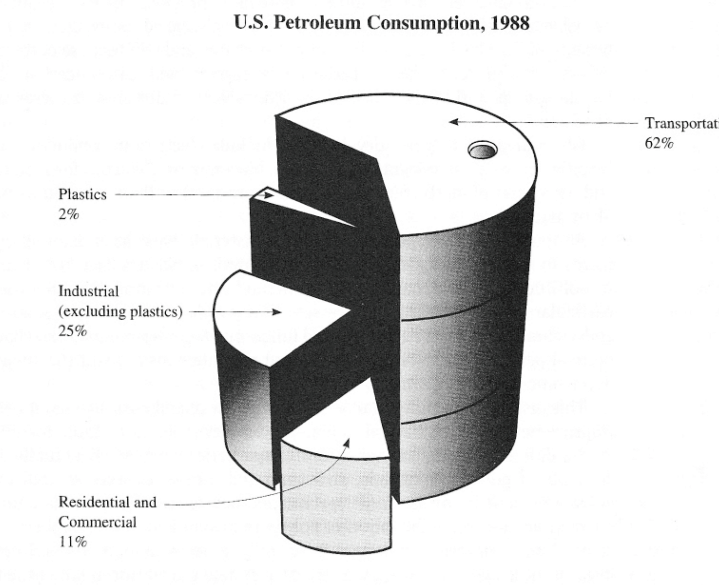


Figure 1.3 Plastics as a component of petroleum consumption in the United States.

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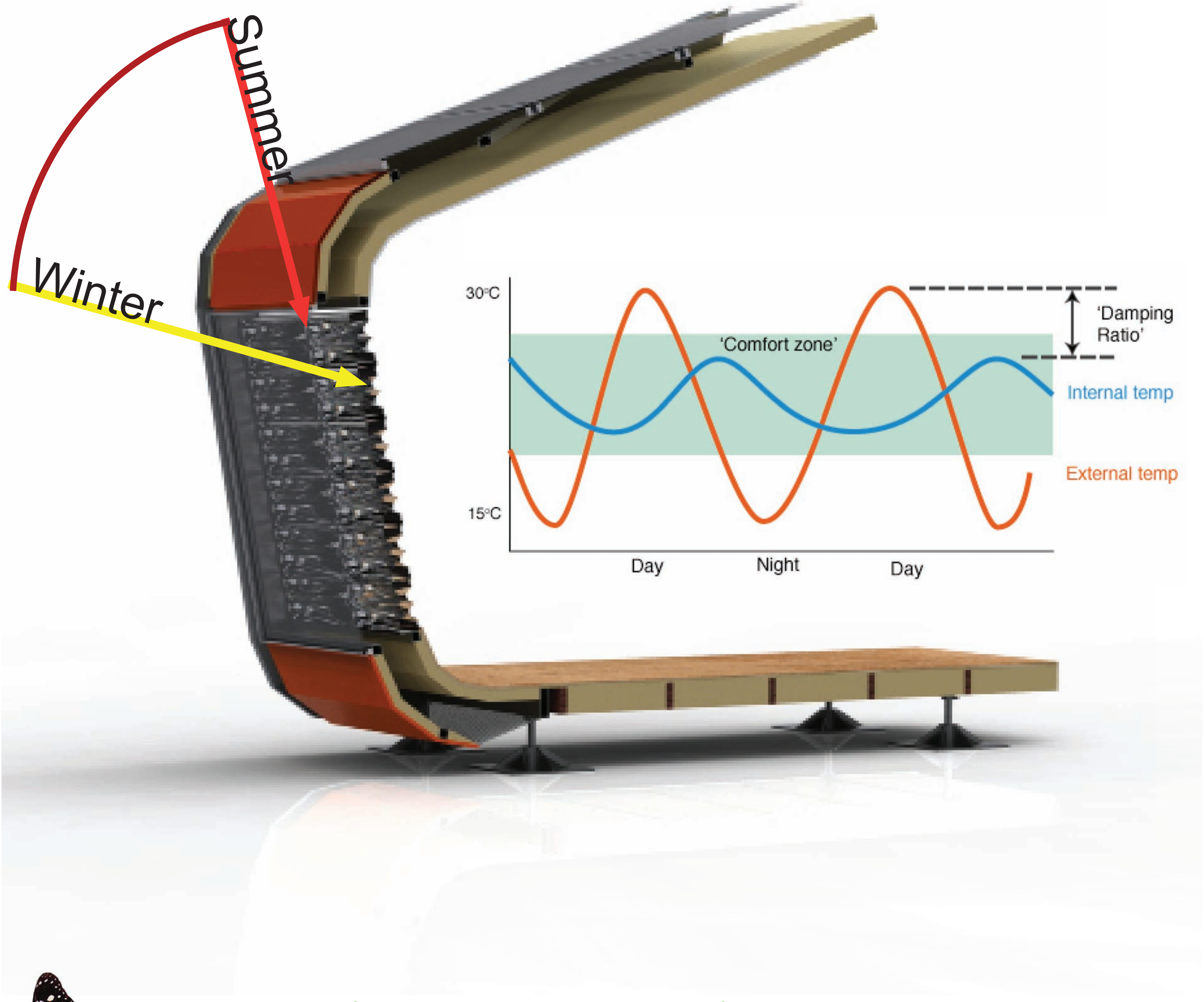
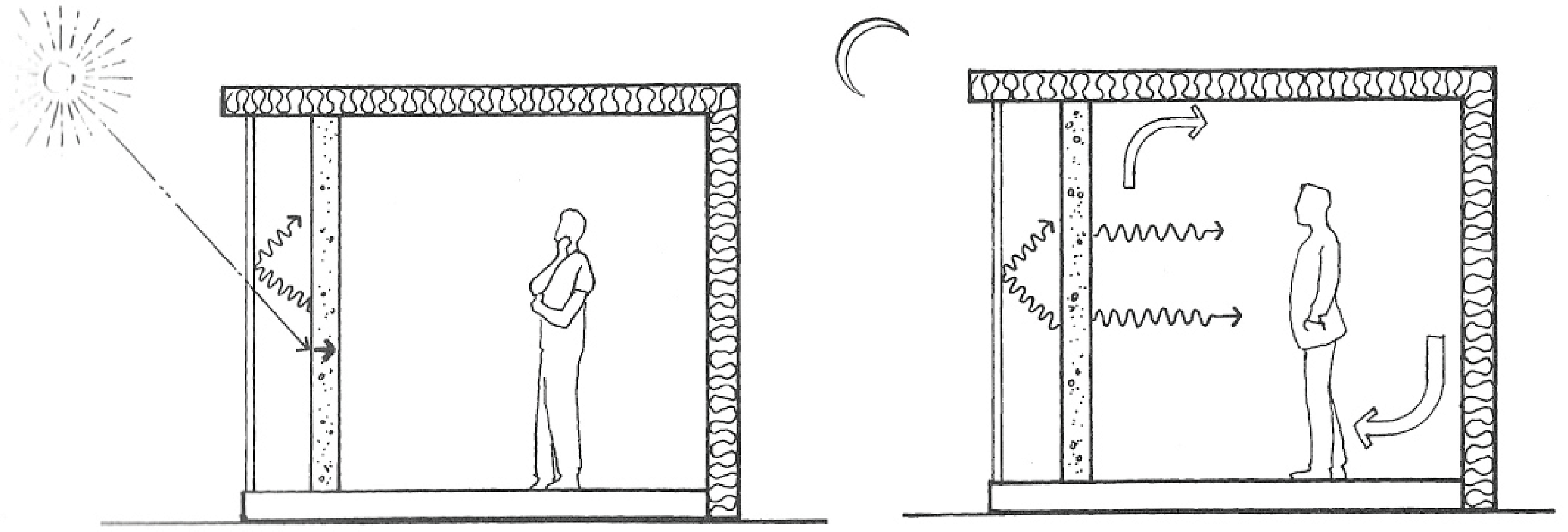
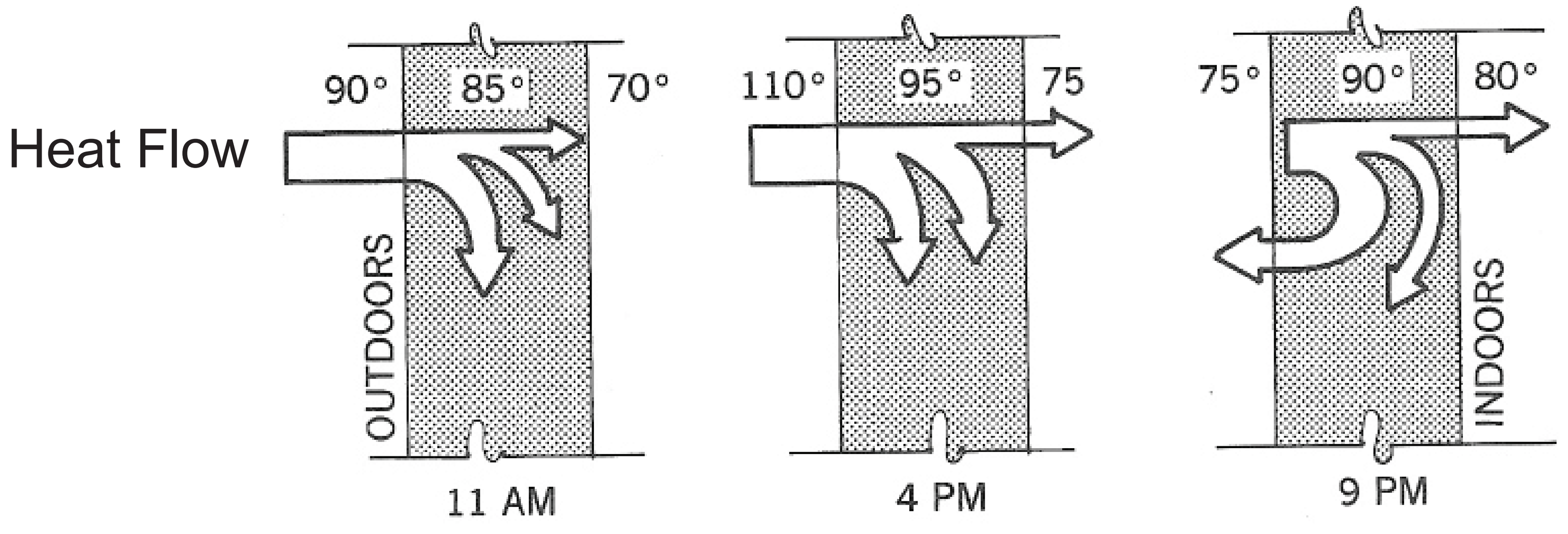
PETE

Material

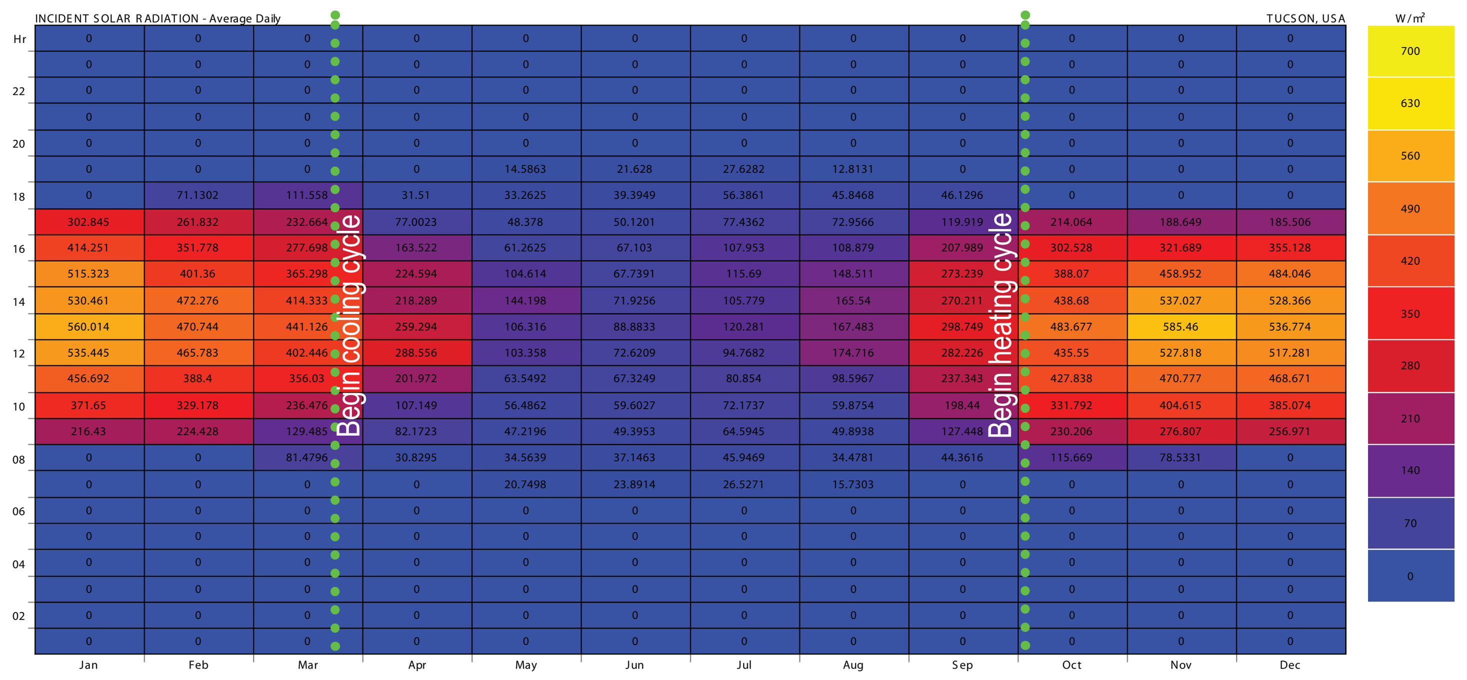




Traditional trombe-wall application using concrete as thermal mass. Water has nearly three times the heat capacity of concrete and can also serve as a day lighting source



As daylight penetrates the tanks, the thermal mass is "charged", and can be directed into the house over an extended period of time,=

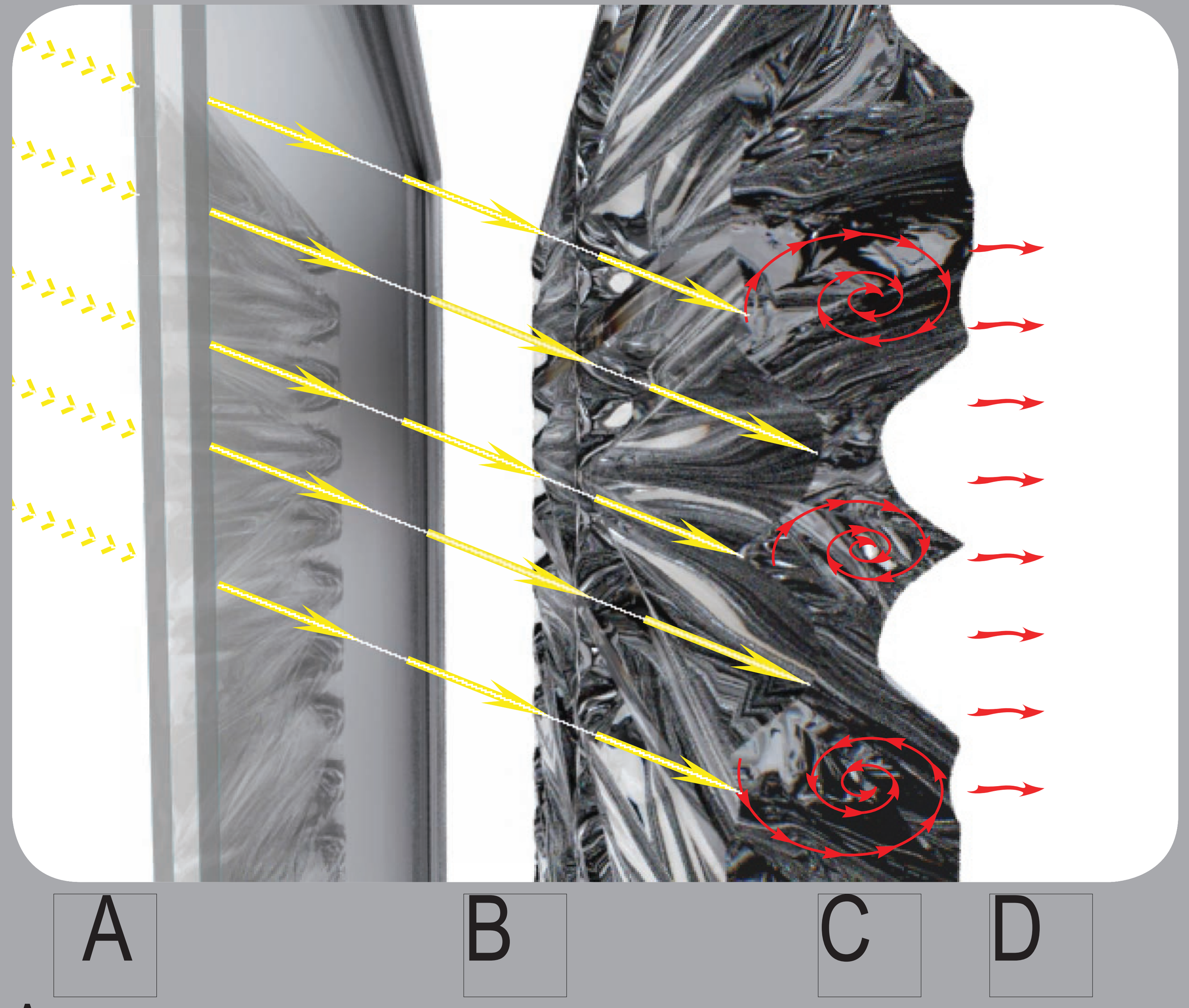


AVERAGE DAILY SOLAR EXPOSURE TUCSON, USA South Wall (320.00 ft2) (Azi: -180.0 deg, Alt: 0.0 deg)

	AVAIL. Btu/ft2	AVG SHADE		INCIDENT Btu/ft2	INCIDENT TOT.Btu	ABSORBED Btu/ft2	ABSORBED TOT.Btu		
Jan	2101.3	0%	0.0	1237.2	389743	1237.2	389743	0.0	0
Feb	2221.6	0%	0.0	1089.4	343191	1089.4	343191	0.0	0
Mar	2762.8	0%	0.0	966.3	304416	966.3	304416	0.0	0
Apr	3005.8	18%	0.0	534.1	168244	534.1	168244	0.0	0
May	3346.2	63%	0.0	265.8	83732	265.8	83732	0.0	0
Jun	3386.7	92%	0.0	227.2	71573	227.2	71573	0.0	0
Jul	2739.4	92%	0.0	315.7	99457	315.7	99457	0.0	0
Aug	2849.1	46%	0.0	366.2	115364	366.2	115364	0.0	0
Sep	2731.2	0%	0.0	667.5	210299	667.5	210299	0.0	0
Oct	2565.1	0%	0.0	1067.6	336317	1067.6	336317	0.0	0
Nov	2233.2	0%	0.0	1220.4	384473	1220.4	384473	0.0	0
Dec	1937.6	0%	0.0	1178.4	371241	1178.4	371241	0.0	0

Energy transfer is controlled through the envelope in four ways.

1. Glazing converts short wave radiation to long wave
2. Plastic skin provides resists conduction, controlling the rate of heat transfer
3. Water provides medium to absorb and hold energy
4. Air movement through cavity expels unwanted heat



A short wave radiation
B Long wave radiation
C Convective cycle
D Heat emission

Mass calculations per tank

Each tank = [60"x10"x3"= 1800 in3 = 1.04ft3 = 7.78 gallons
5 tanks per bay = 5.2 ft3 = 38.9 gallons = 324 lbs
6 bays total = 31.2 ft3 = 233.4 gallons = 1945 lbs total
Total heat storage capacity = [62.4 BTU / ft3] x 31.2 ft3 = 1946 BTU
Area of south wall 5' x 30' = 150 ft2 =12.97 BTU/ft2

Results

June: 227 BTU^{ft2} x .23* = 52 BTU^{ft2} / 12.97 = 4.0 degree ▲T

January: 1237 BTU^{ft2} x .23* = 285 BTU^{ft2} / 12.97 = 12.9 degree ▲T

(* = solar energy transmission of glazing)

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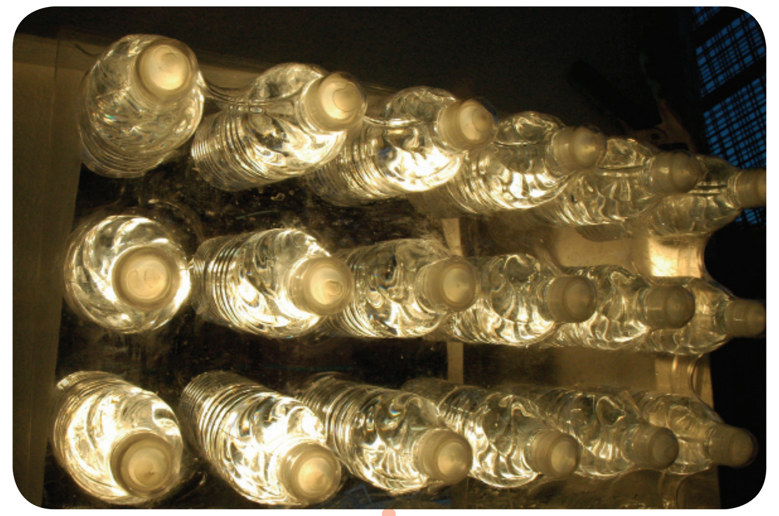
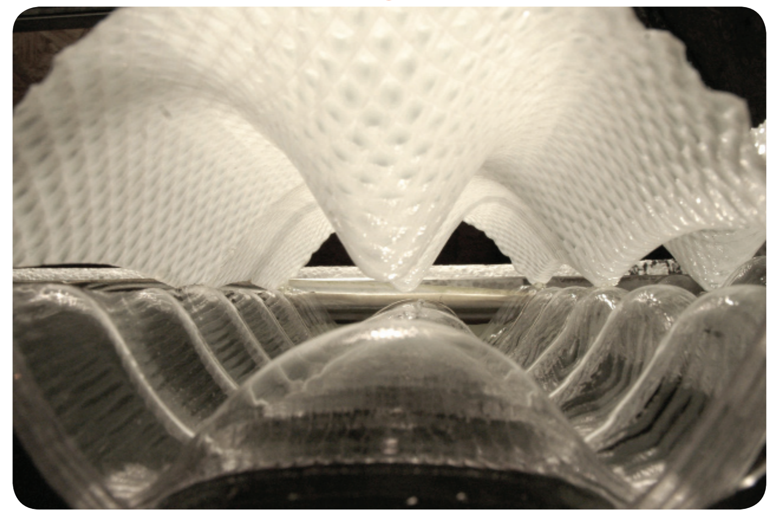
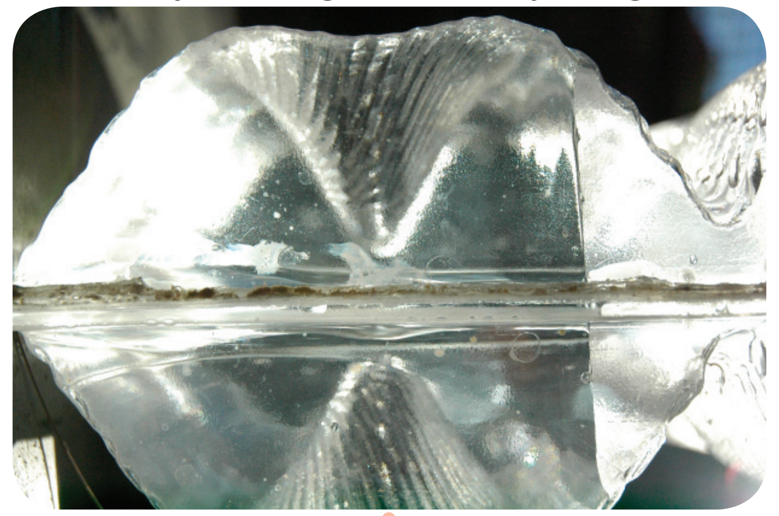
Energy System Design



Water bottle wall panel exploring the direct use of packaging in architectural applications. Exploration of water and its container as optical and performative phenomenon

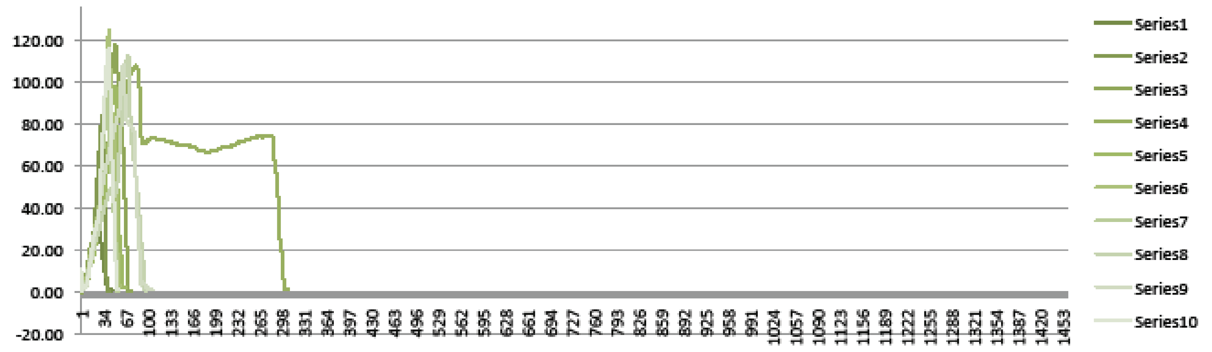


Vacuum formed skin geometries assembled with epoxy. Exploration of assembly strategies and layering.

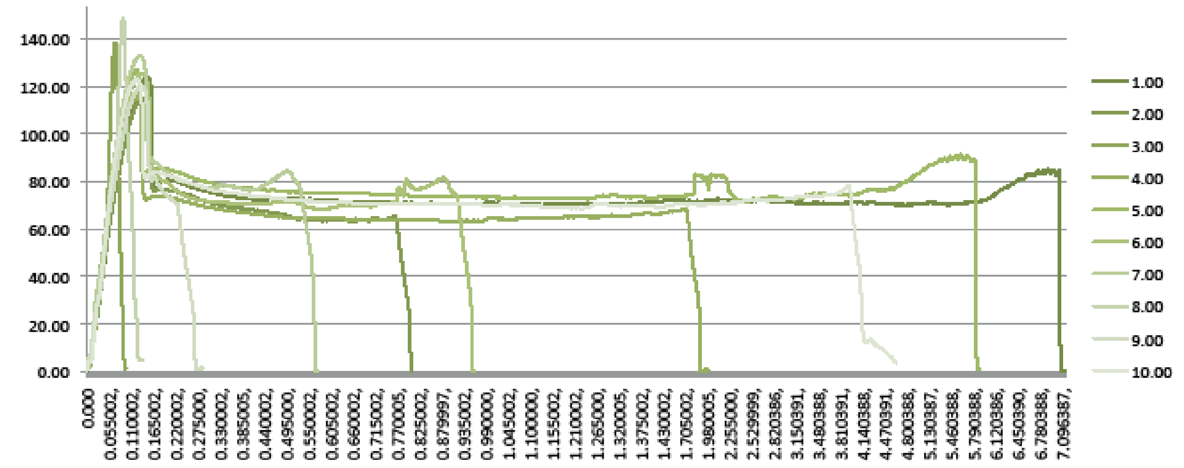


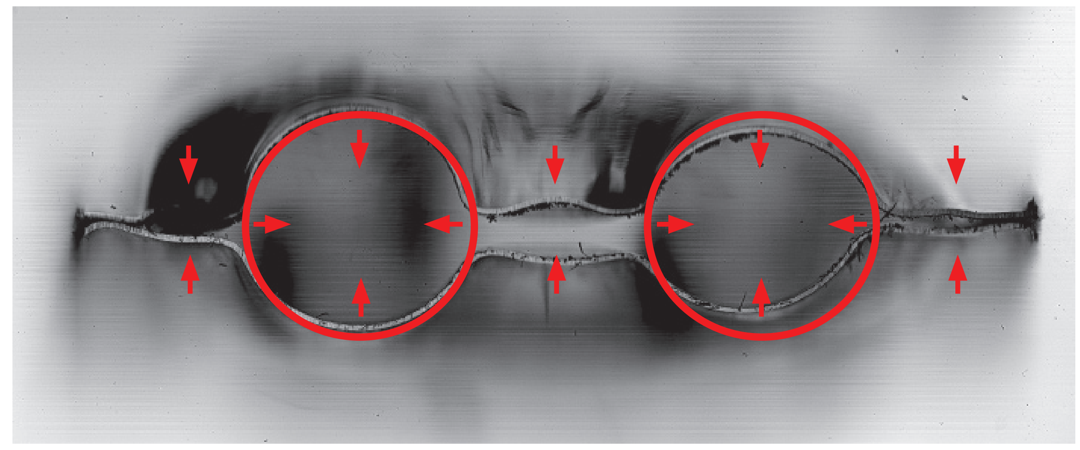
Geometries joined to form sealed component using thermal processes. Exploration of containment and sealing strategies.

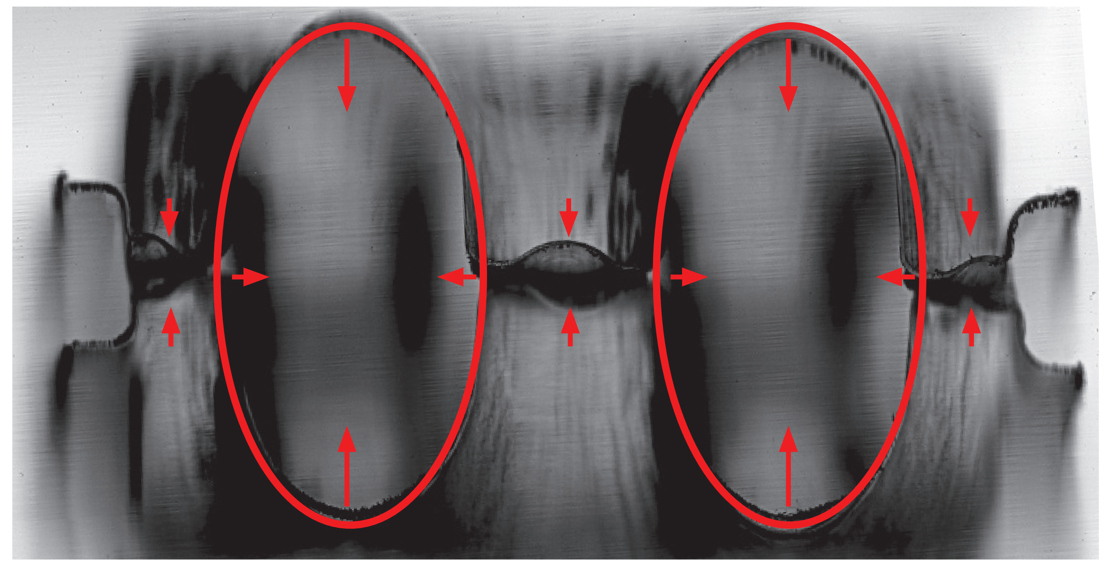
Panel system using vacuum pump and hydraulic connection lines. Exploration in filling and evacuation strategies.



The effect of polymer chain alignment on structural behavior of PET-G is significant. Heating, stretching, then rapidly cooling the plastic skin strategically results in higher stress/strain resistance for the tanks.





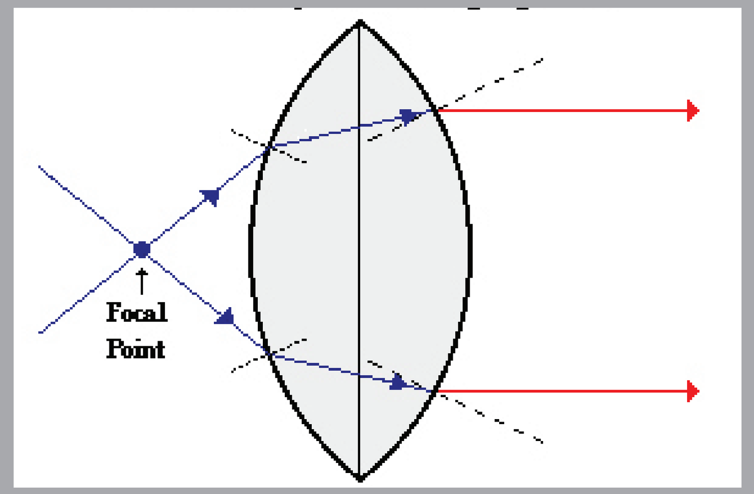


Forces

Structural resistance to Gravity, Vacuum forces, Hydrostatic pressure, Thermal expansion

Phenomenology

Light refraction, reflection, distortion,



In addition to providing structural integrity, the geometry of the tank surfaces produces a converging lens effect for daylight passing through the wall.

Refined geometric system using chemical sealing process. Exploration of re-enforcement strategies and optical qualities.

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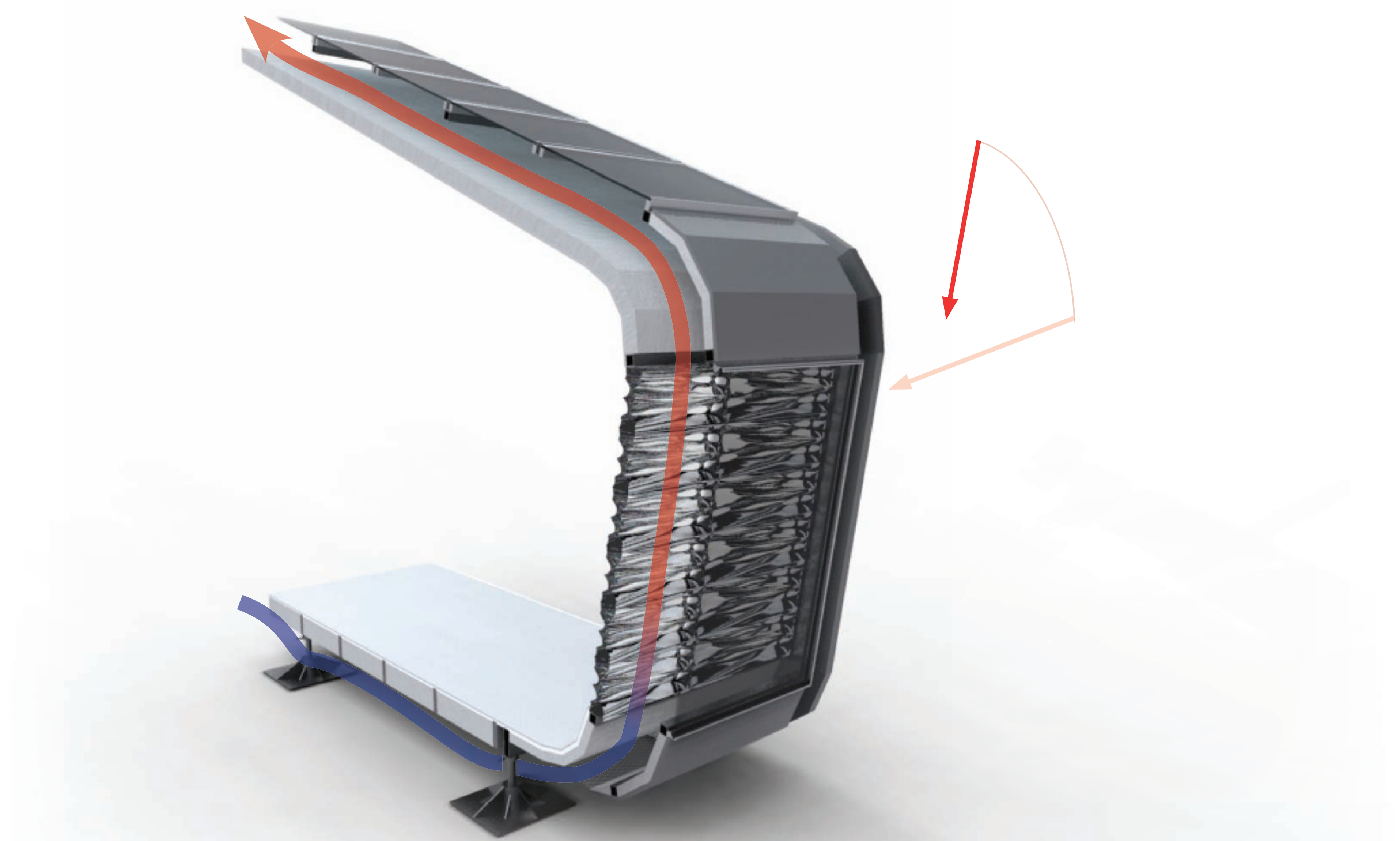
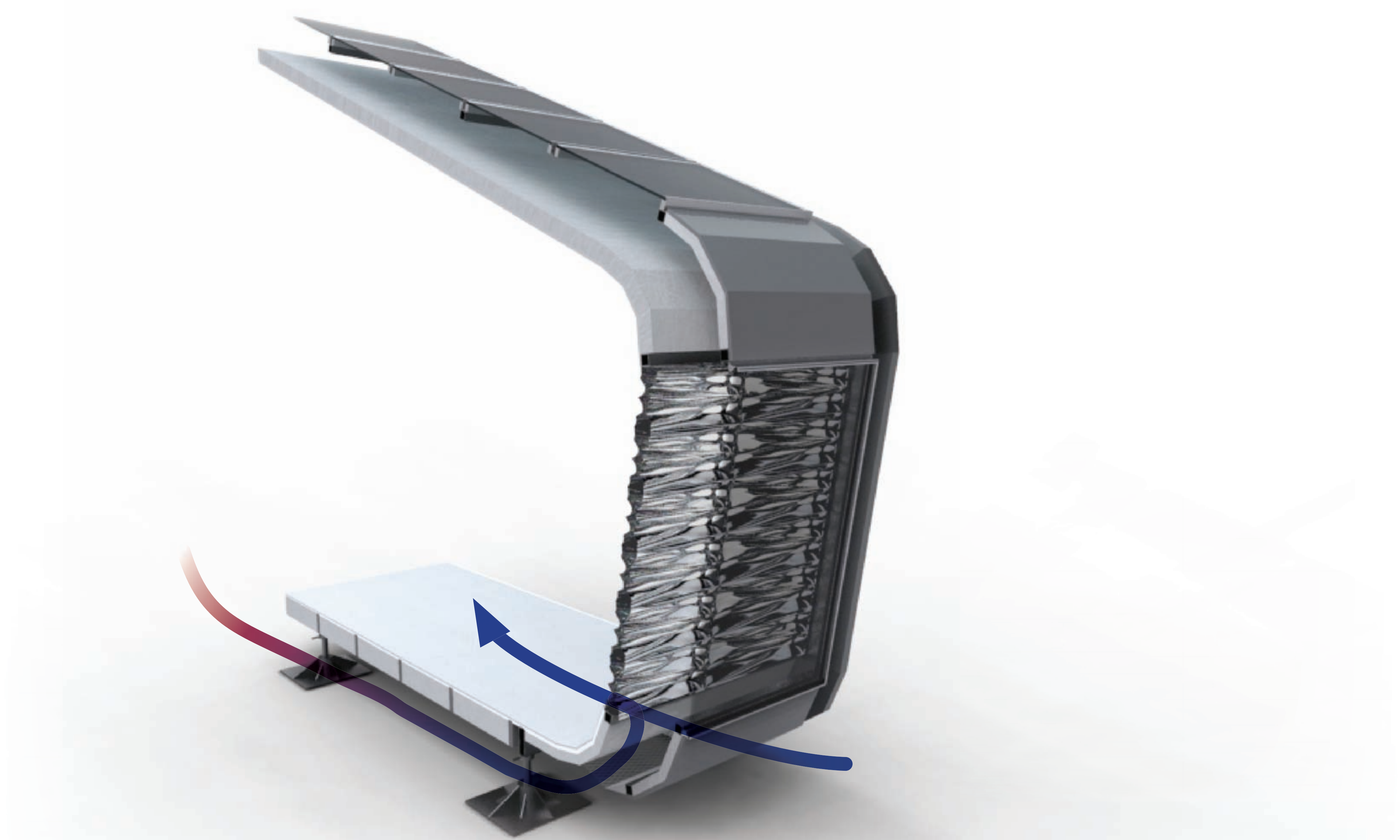
Geometry Developent



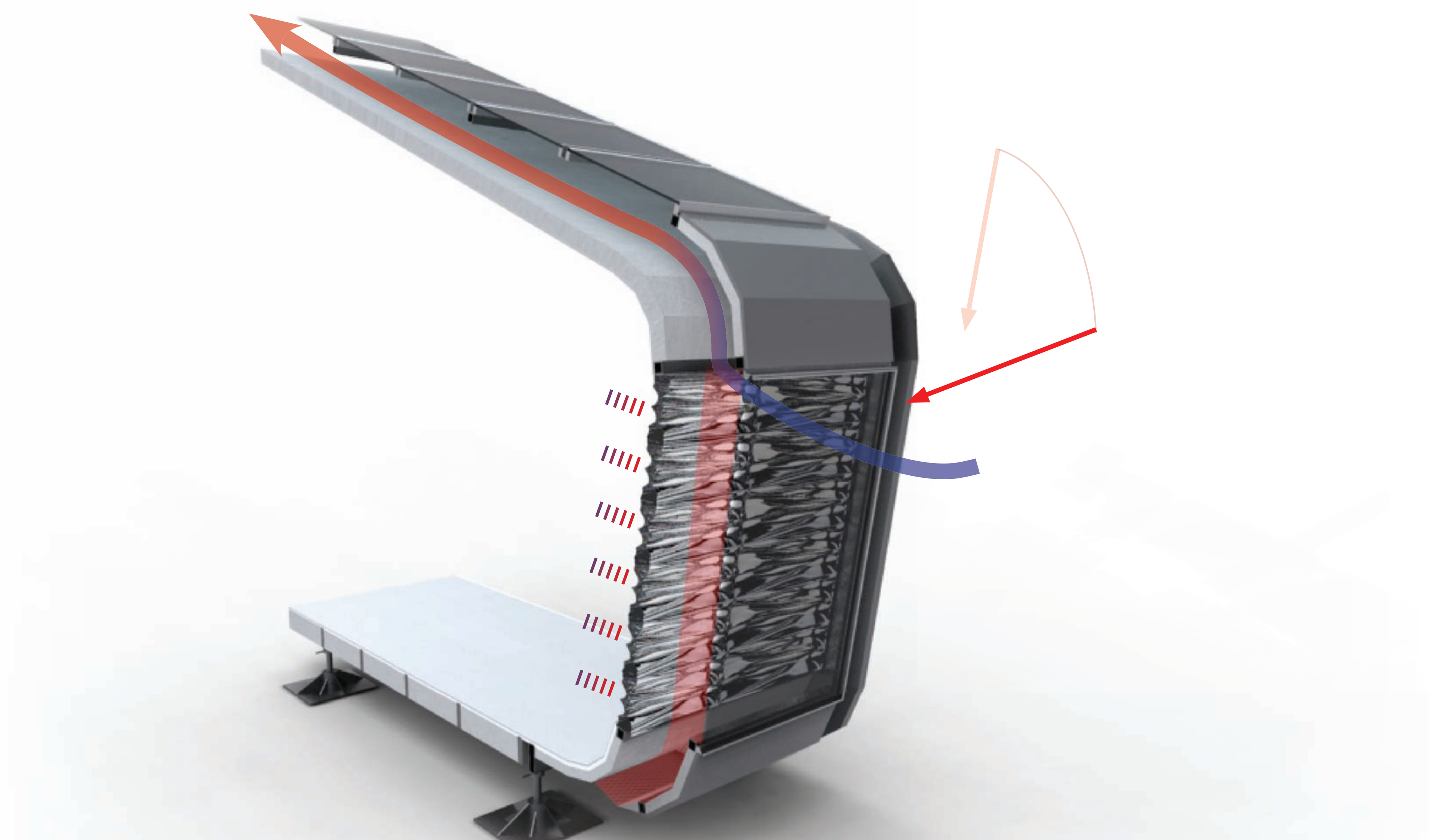
Summer Day Time

Thermal mass is shaded and air is drawn across surface to evacuate heat via conduction. This air flow also cools the solar panels from beneath.



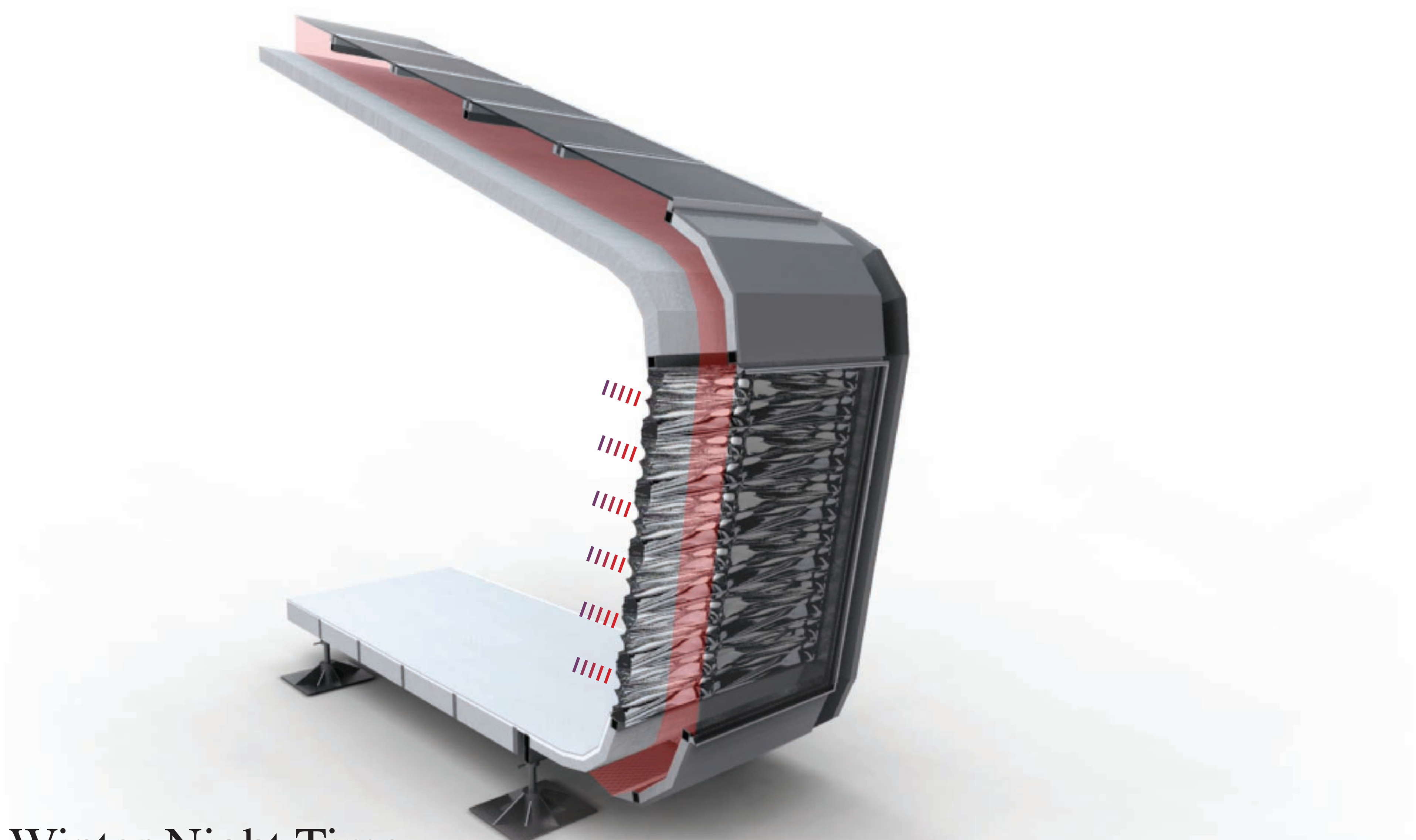
Summer Night Time

Air can be brought in from below the home and through the south wall to provide natural ventilation to the interior space.



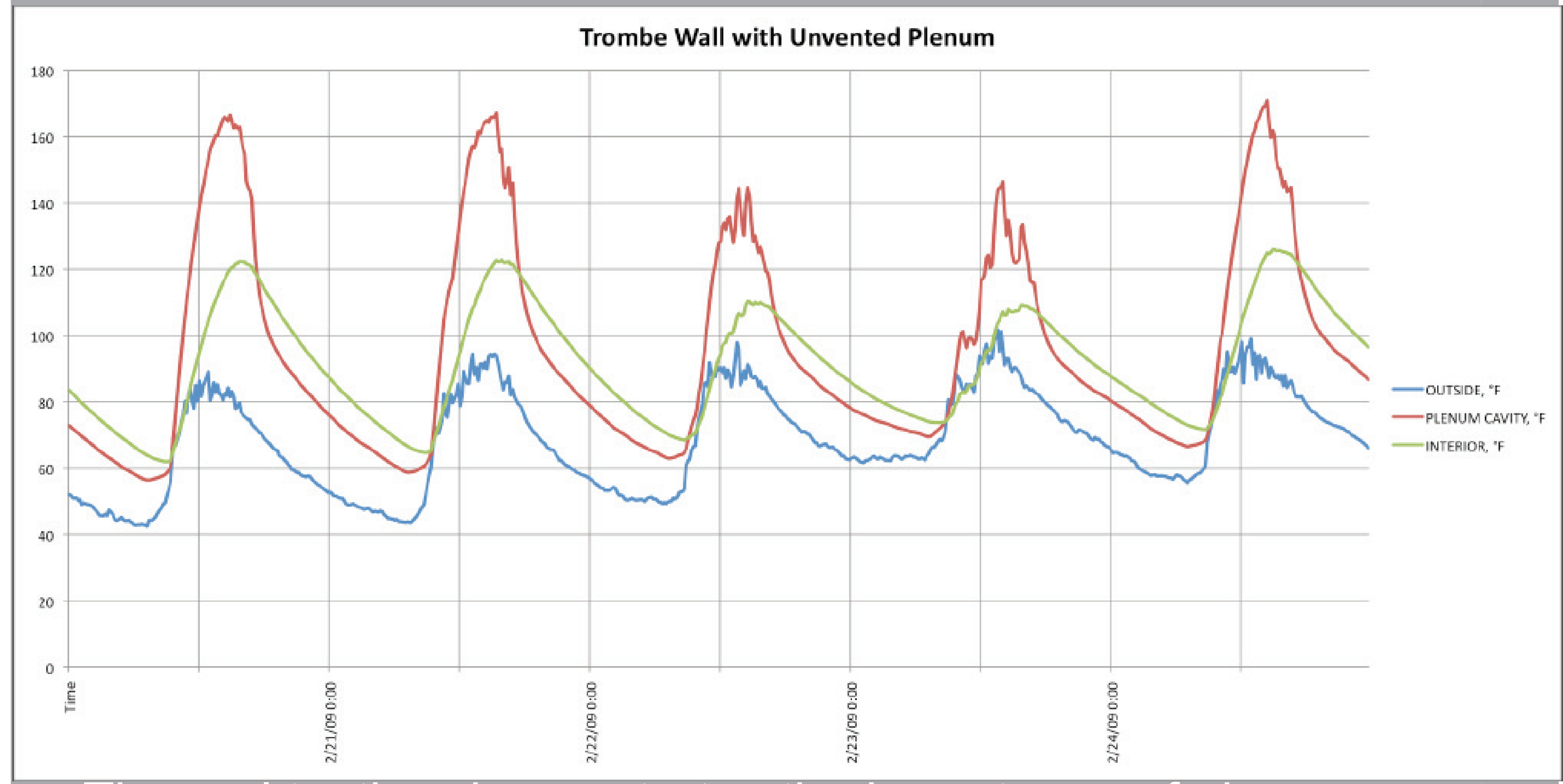
Winter Day Time

Air is trapped around the trombe wall and thermal mass is exposed to sun, absorbing heat energy. The solar panel portion of the plenum cavity is vented to prevent overheating.

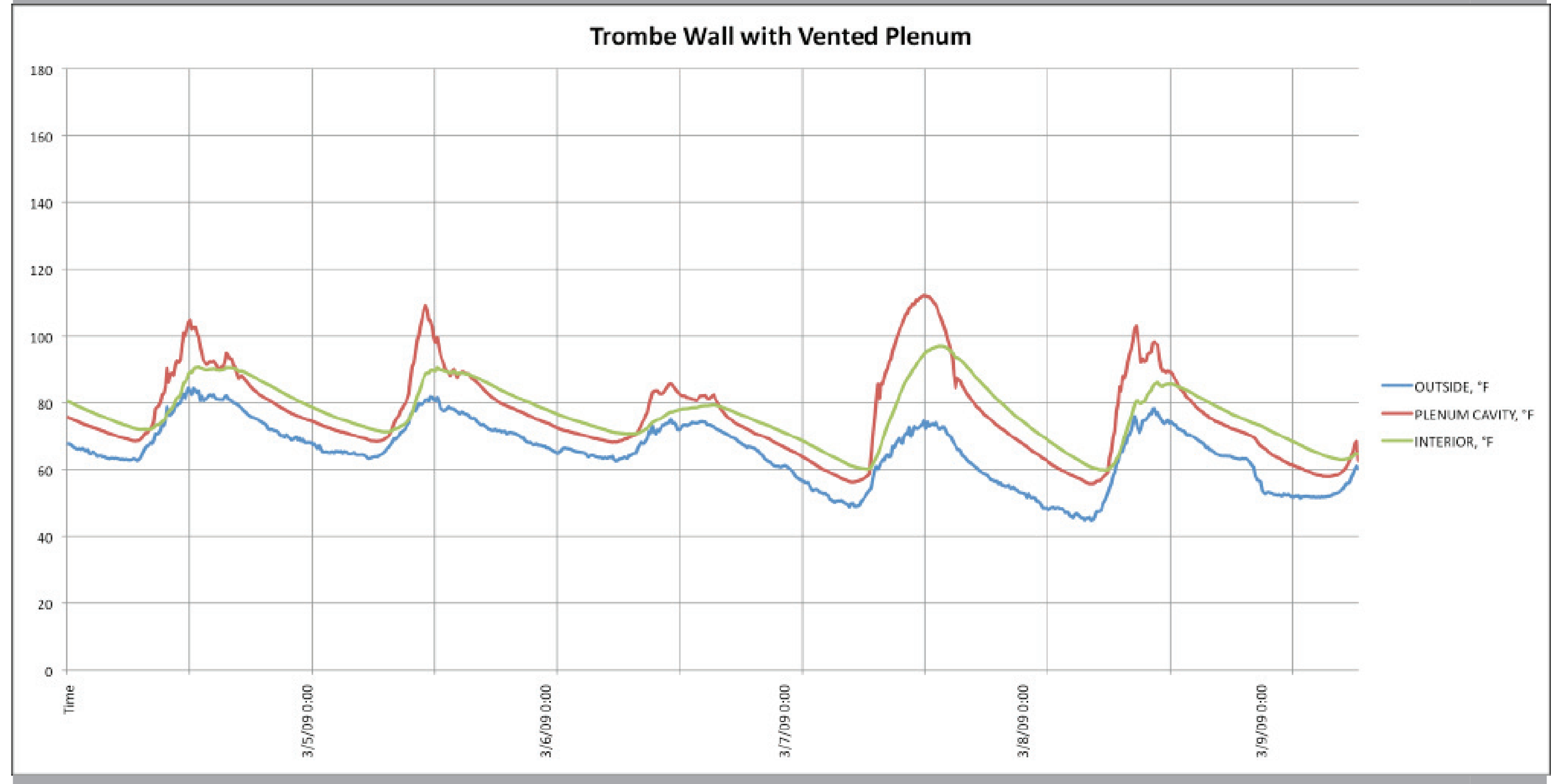


Winter Night Time

The entire plenum cavity is sealed off and the thermal mass creates lag time and reduces the temperature changes inside the home.



Thermal testing demonstrates the importance of air movement in the cavity. Even in the winter cycle, solar gain in the trombe space can produce temperatures in excess of 165 degrees farenheight.



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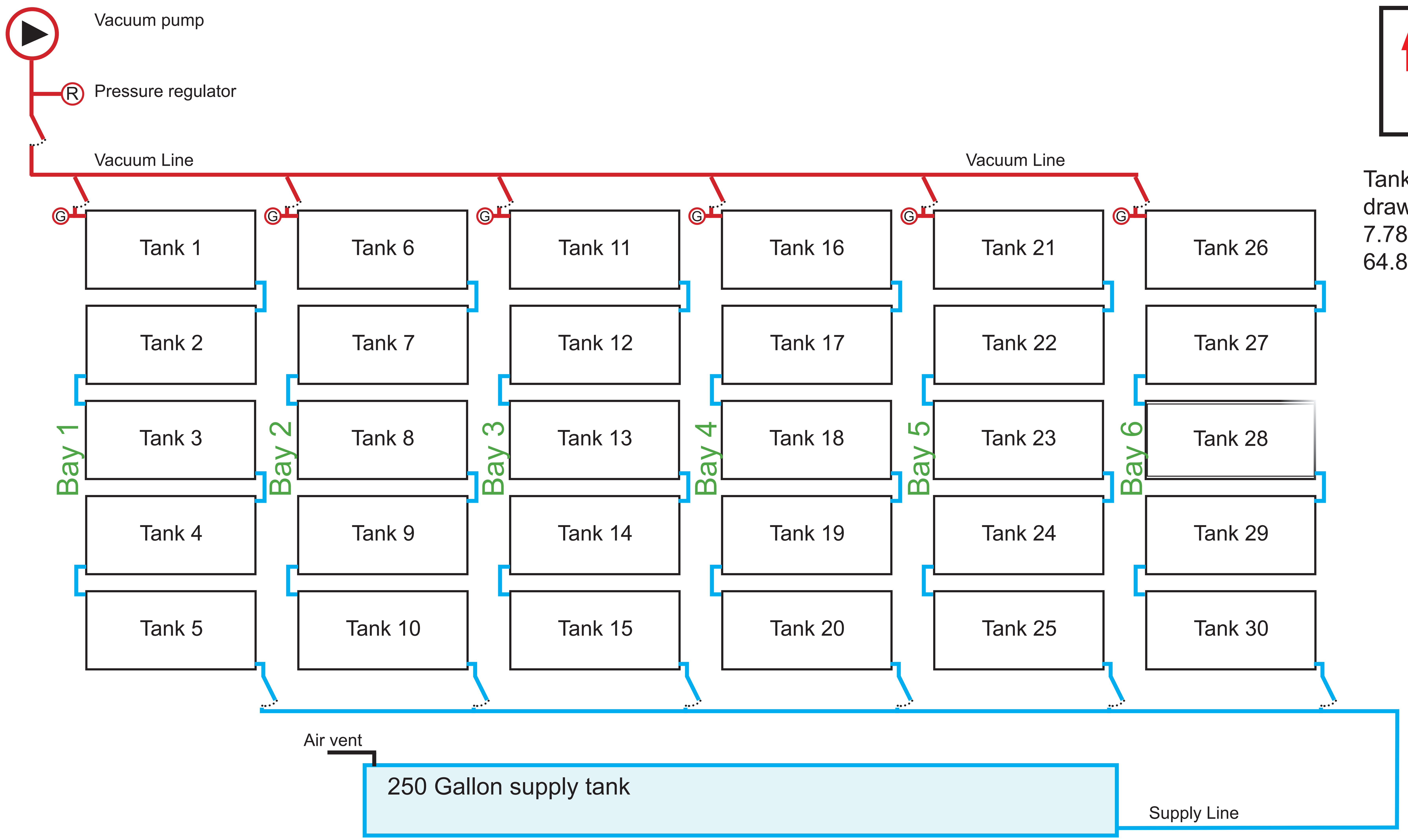
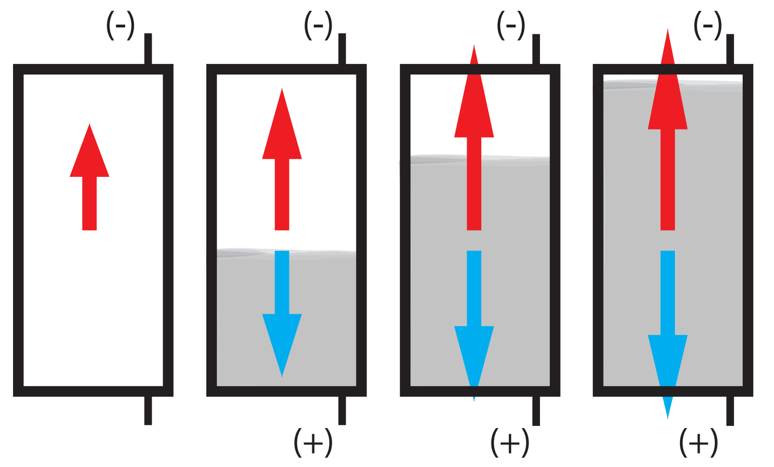
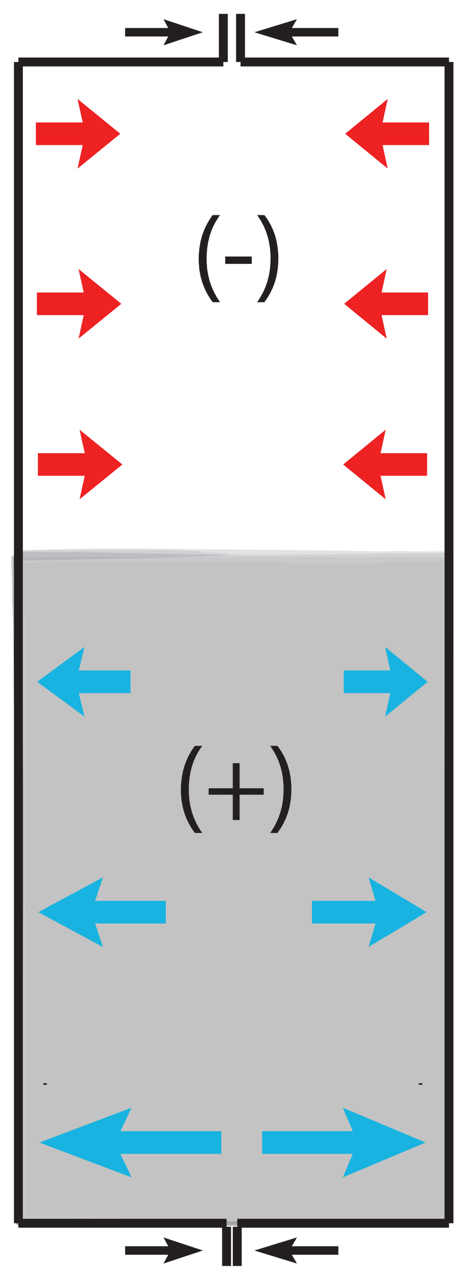
Skin System Modes

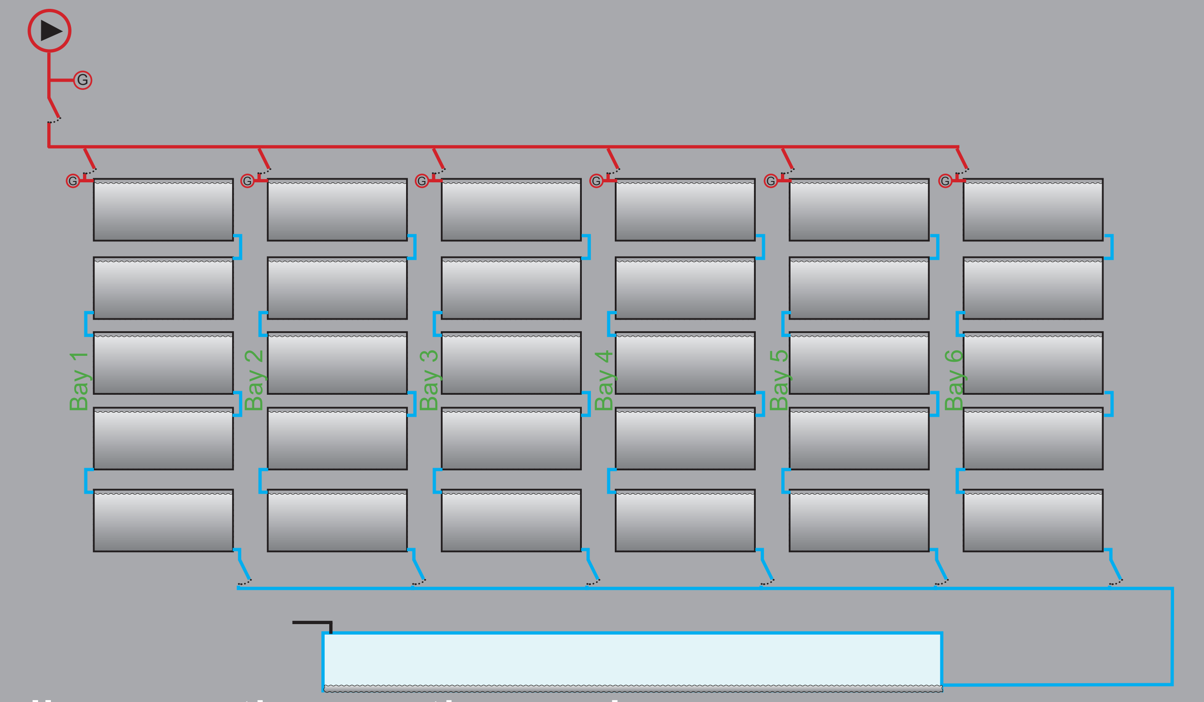




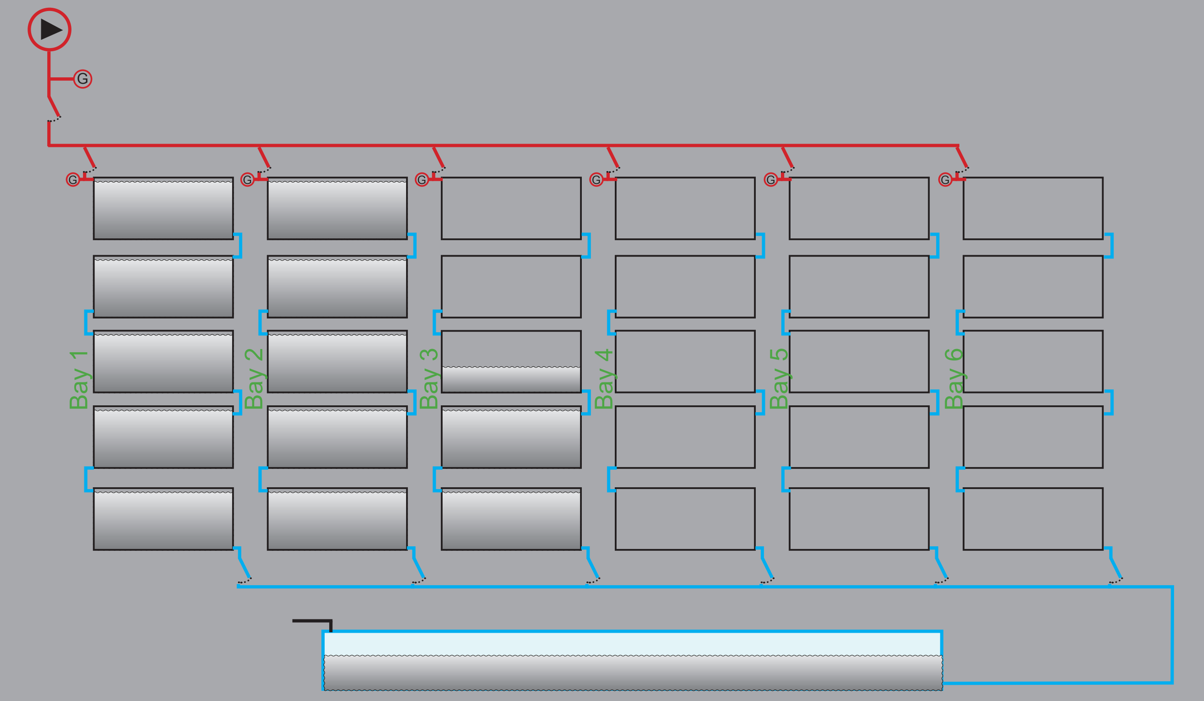
Tank Pressure increases as water is drawn in. Proportional to its weight.
7.78 Gallon capacity = 64.8 pounds
64.8 / 4.16^{ft2} = 15.57 PSF = .216 PSI



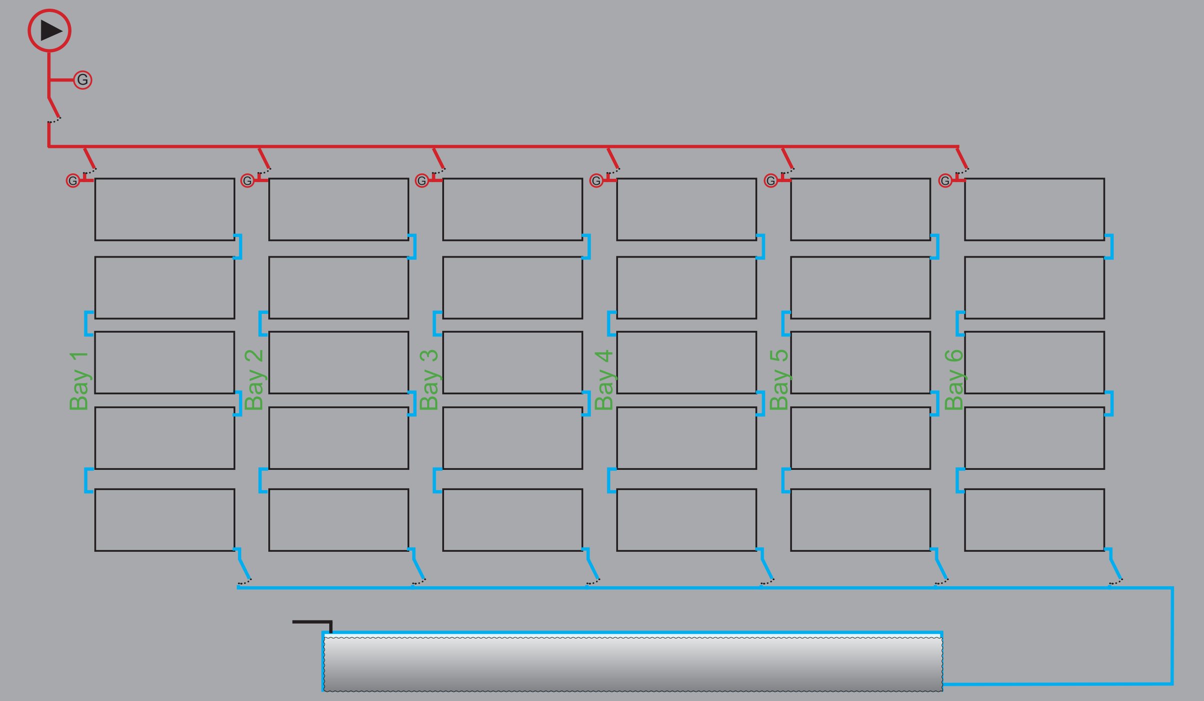
The columnar effect dictates that pressure is greater at the bottom of the tank than the top, therefore wider tanks make more sense than tall ones.



System full, operating as thermal mass



Filling system with vacuum pump



System empty, holding tank full.

Filling and evacuating the system is critical to its operation and performance. As the water is transported into the wall, pressure and gravitational forces increase. By using a vacuum pump the system outward pressure is converted to inward, and each tank half is forced together. With the vacuum relieved, gravity empties the entire system back to the storage tank.

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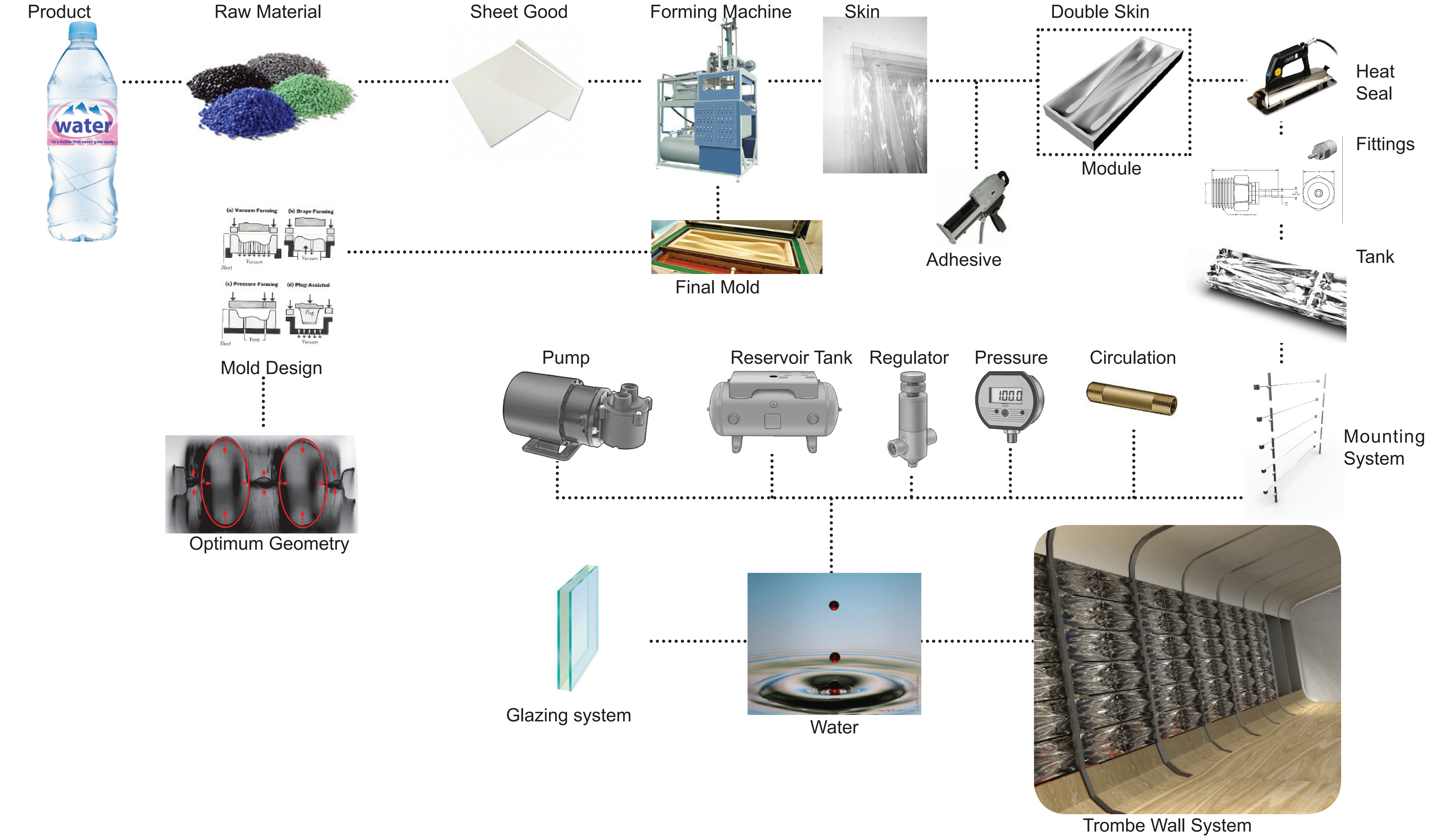
Distribution System Design



Using design methods adopted from the automotive and aeronautic industries, individual building components can be configured for specific applications within a larger system. Here multiple systems come together to form the final assembly, including circulation, pressure regulation, water storage, and energy distribution.

Design opportunities are available throughout the production sequence, and include material, geometry, performance, and durability factors.

Production Design

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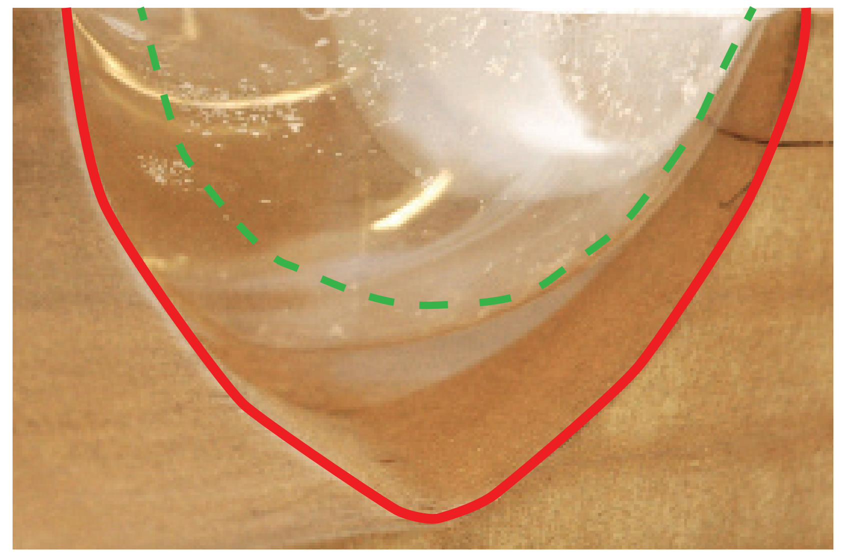
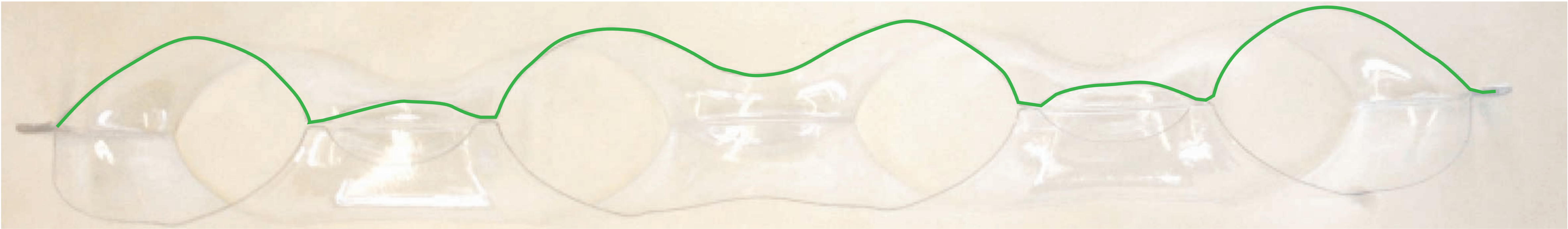
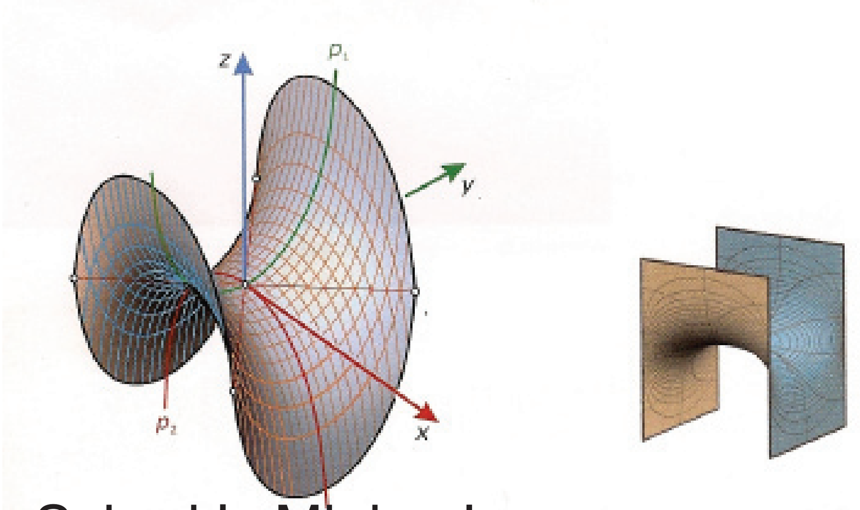


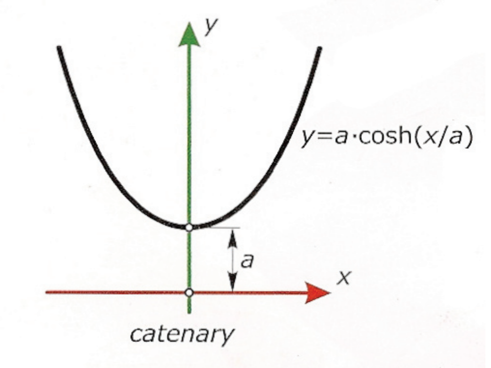
Variations between tank mold and pulled plastic parts show resistance to applied geometry. Although ‘full’ pulls are possible with additional heat, they yield weaker tanks. The ‘failed’ pulls provide more efficient resistance to vacuum pressure, but do not provide the detail needed at connection points in the mold. This need to achieve detail leads to geometry optimization.



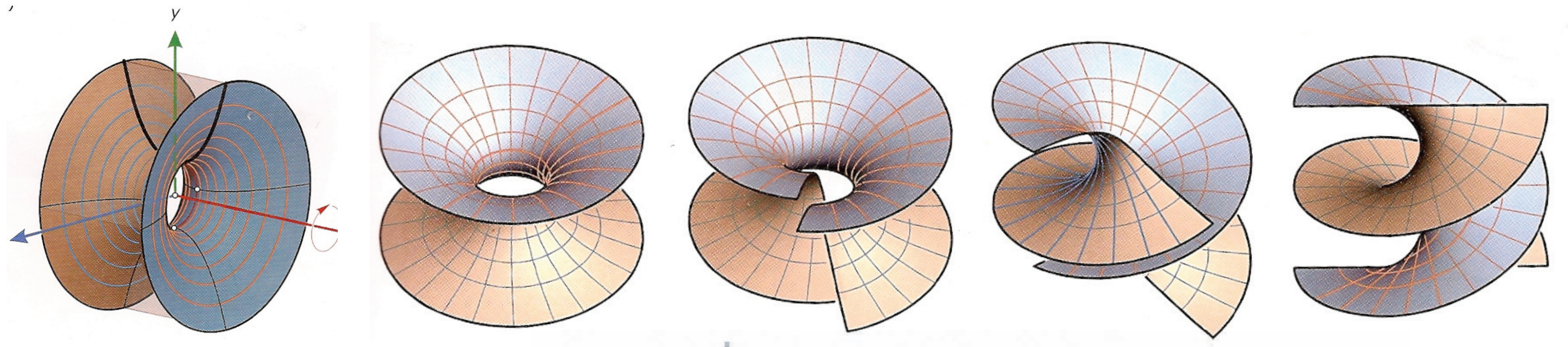


Scherk’s Minimal Surface

The analysis of formed plastic geometry has lead to the investigation of minimal surface geometries, where a given set of parameters yields the most efficient surface possible.

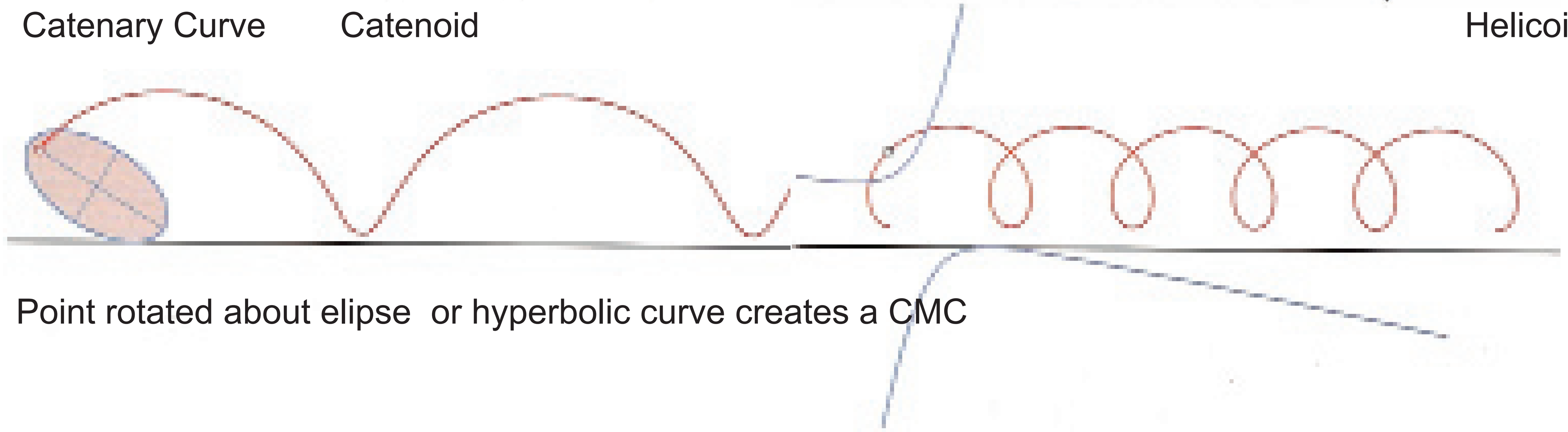


Catenary Curve



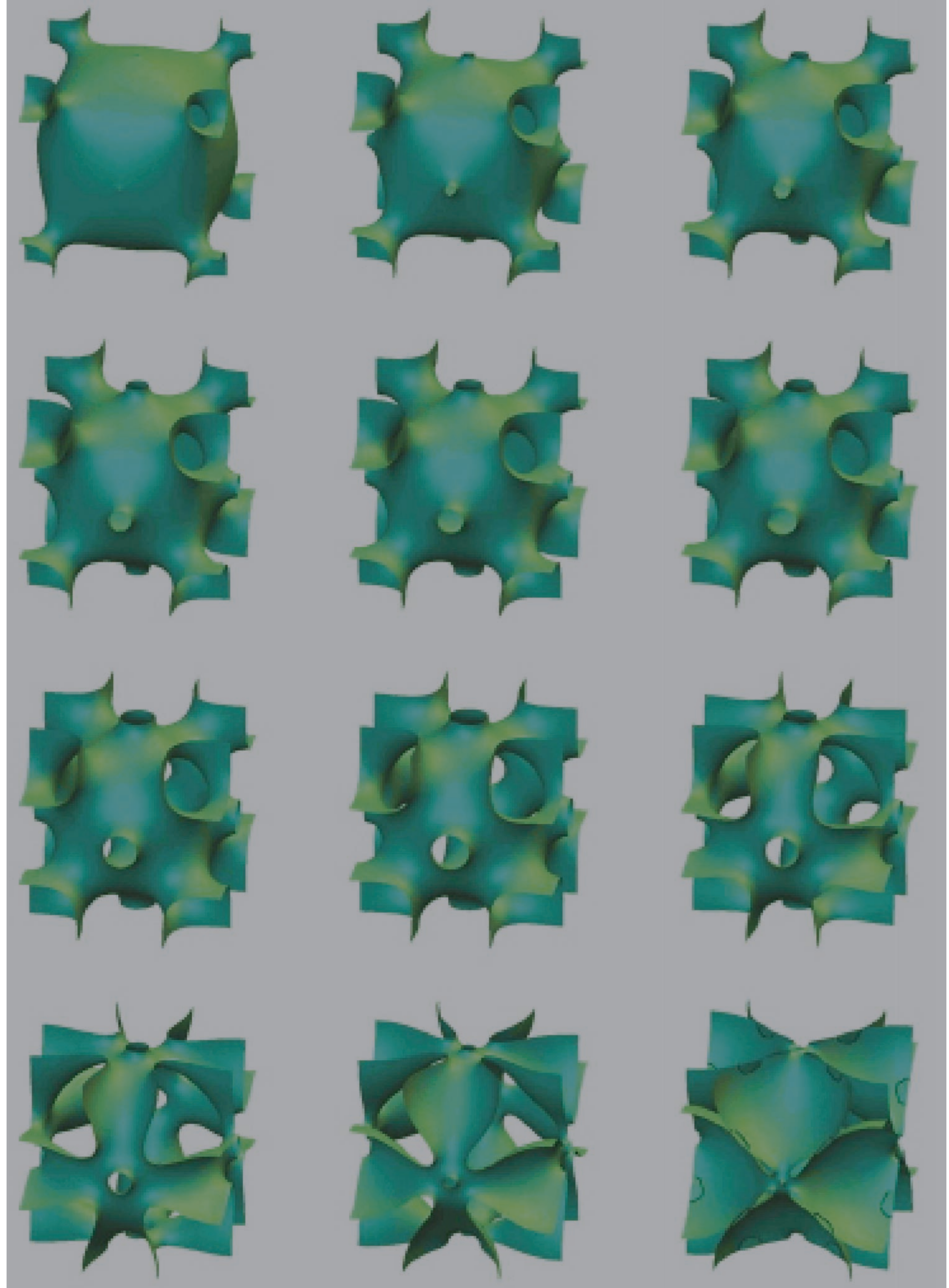
Catenoid

Helicoid



Point rotated about elipse or hyperbolic curve creates a CMC

Constant Mean Curvature (CMC) surfaces are present in the cellular boundaries in foams and soap bubble. CMC profiles are created by rotating a hyperbolic curvature along a straight line.



Iterative series of Schoen’s gyroids - a triply periodic CMC surface found in foams and other film matrices.

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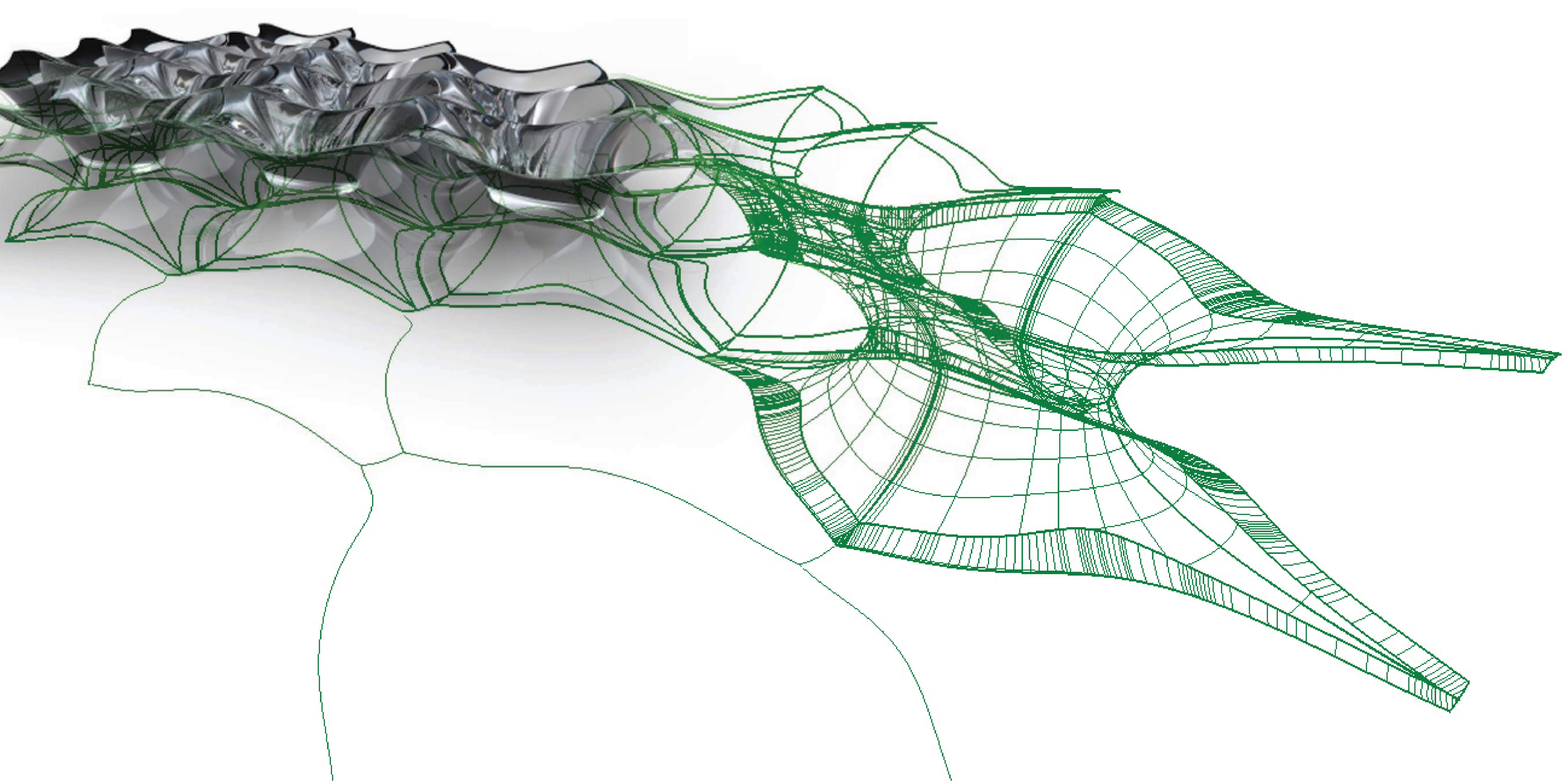
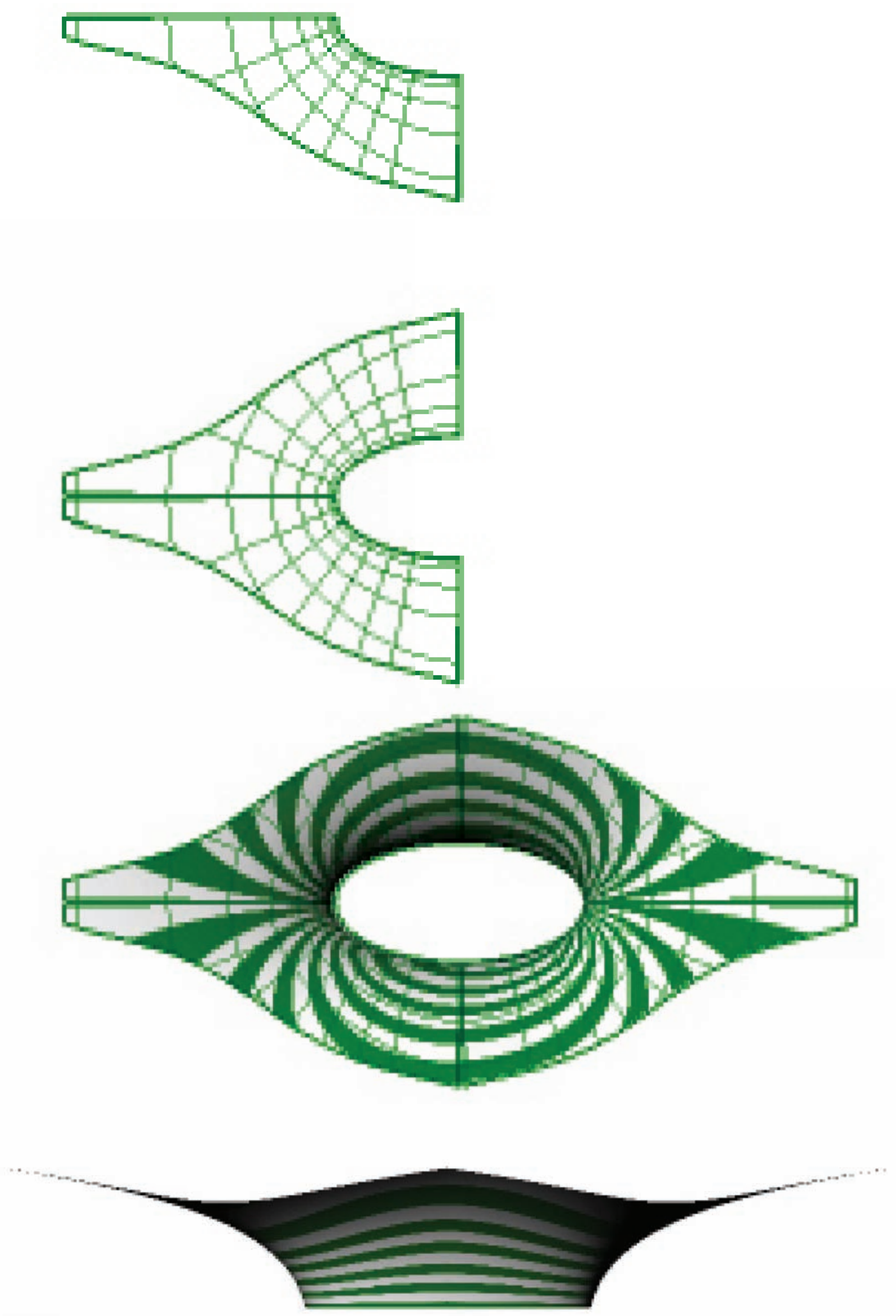
Geometric Development





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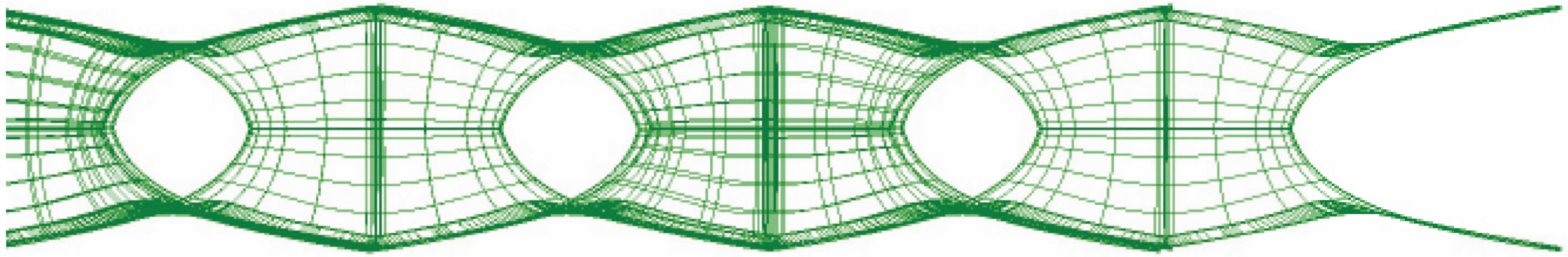

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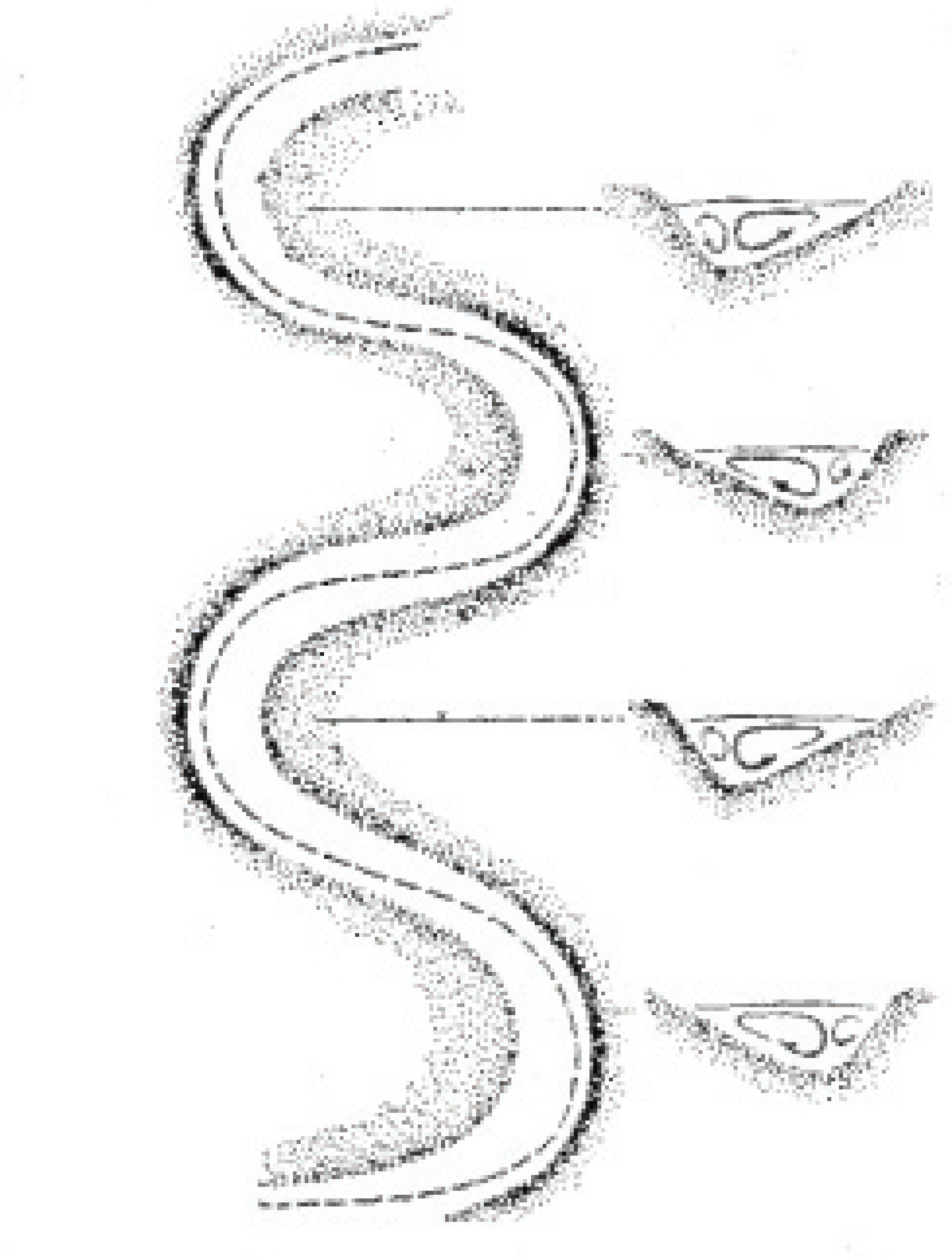
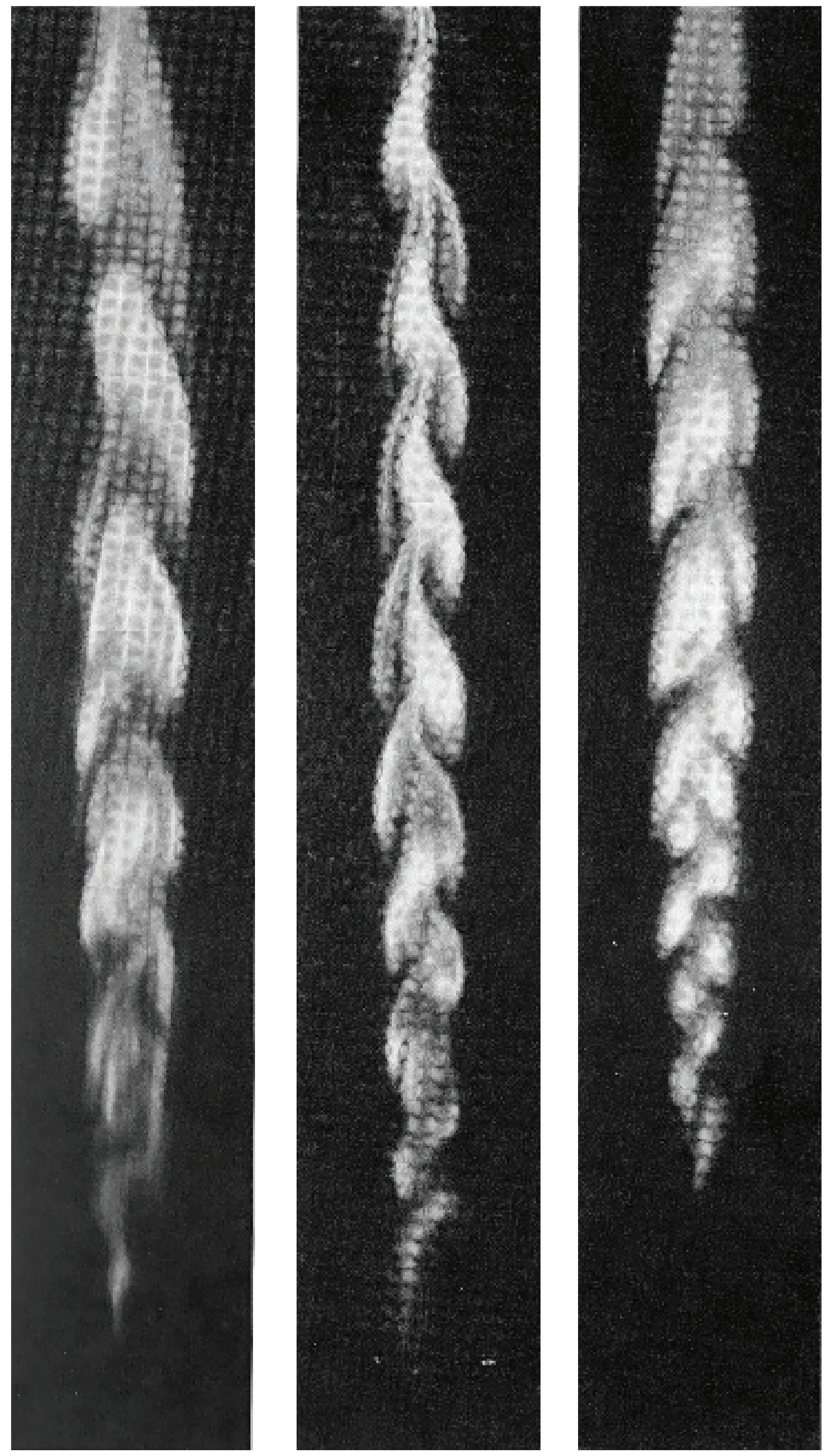
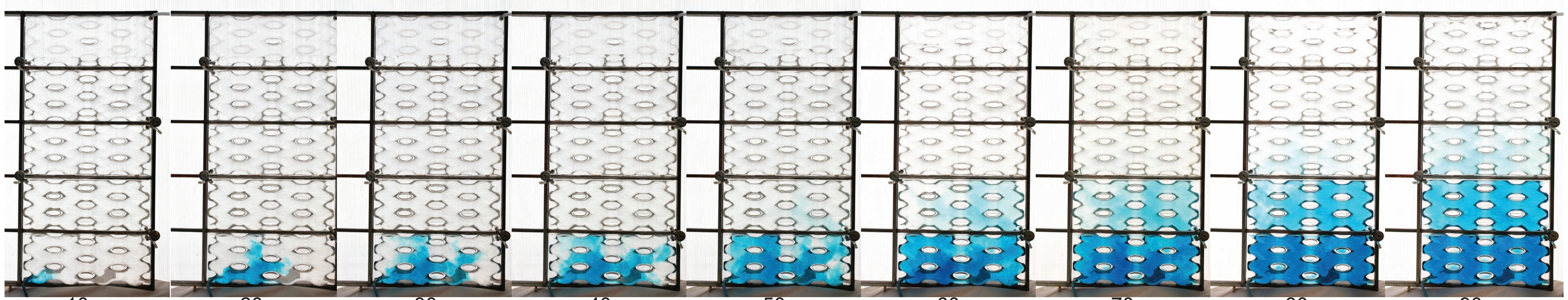
Optimized Geometry



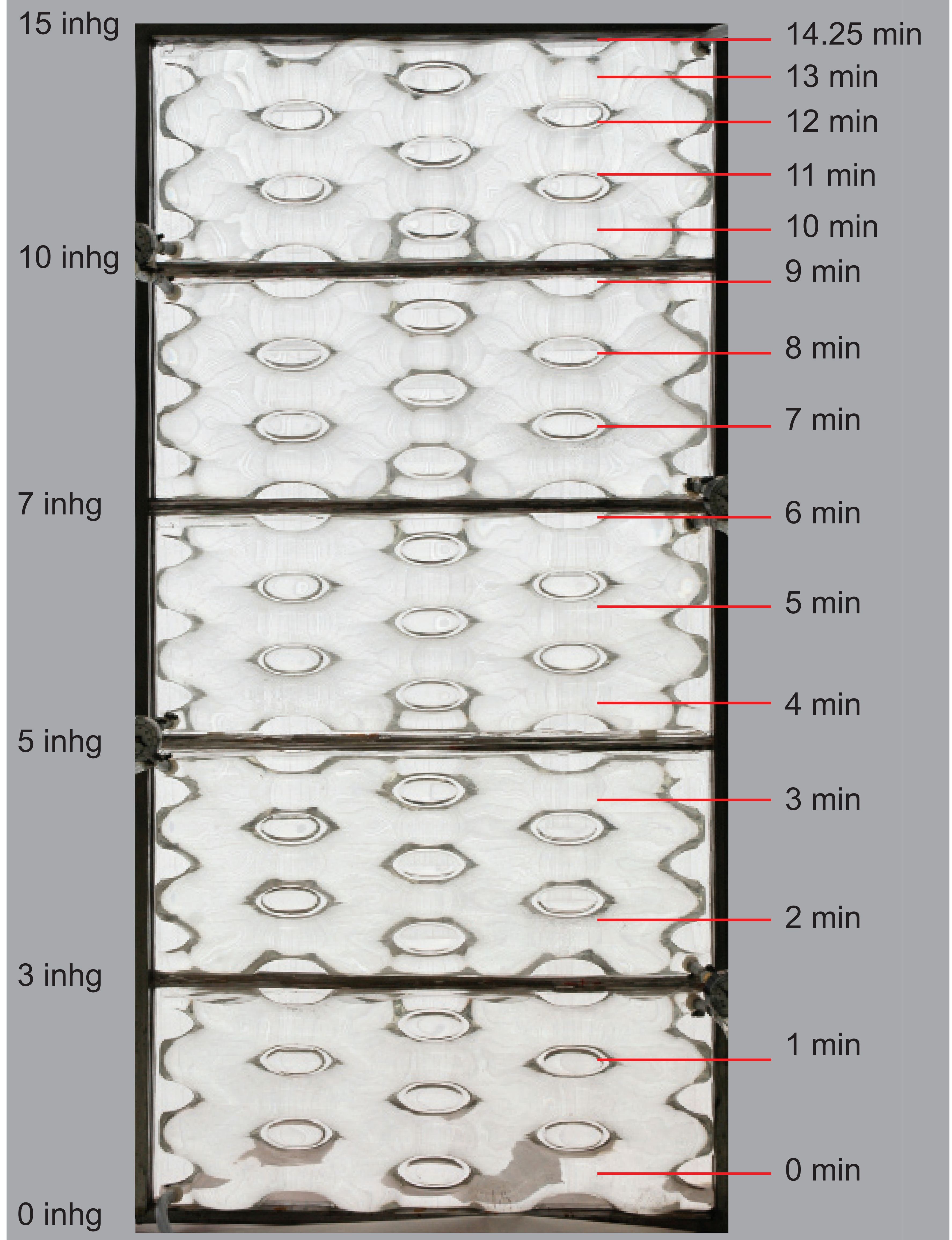


Violin Flute French Horn



10 s 20 s 30 s 40 s 50 s 60 s 70 s 80 s 90 s

Dye test to visualize flow patterns in a full scale prototype. Gradient indicates relative mixing of water between tanks.



	capacity	weight	head pressure	height (in)
Tank 1	2.4 gal	29.9 lbs	15 inhg	60
Tank 2	2.4 gal	29.9 lbs	10 inhg	48
Tank 3	2.4 gal	29.9 lbs	7 inhg	36
Tank 4	2.4 gal	29.9 lbs	5 inhg	24
Tank 5	2.4 gal	29.9 lbs	3 inhg	12
Total	**12 gallons**	**149.5 lbs**		

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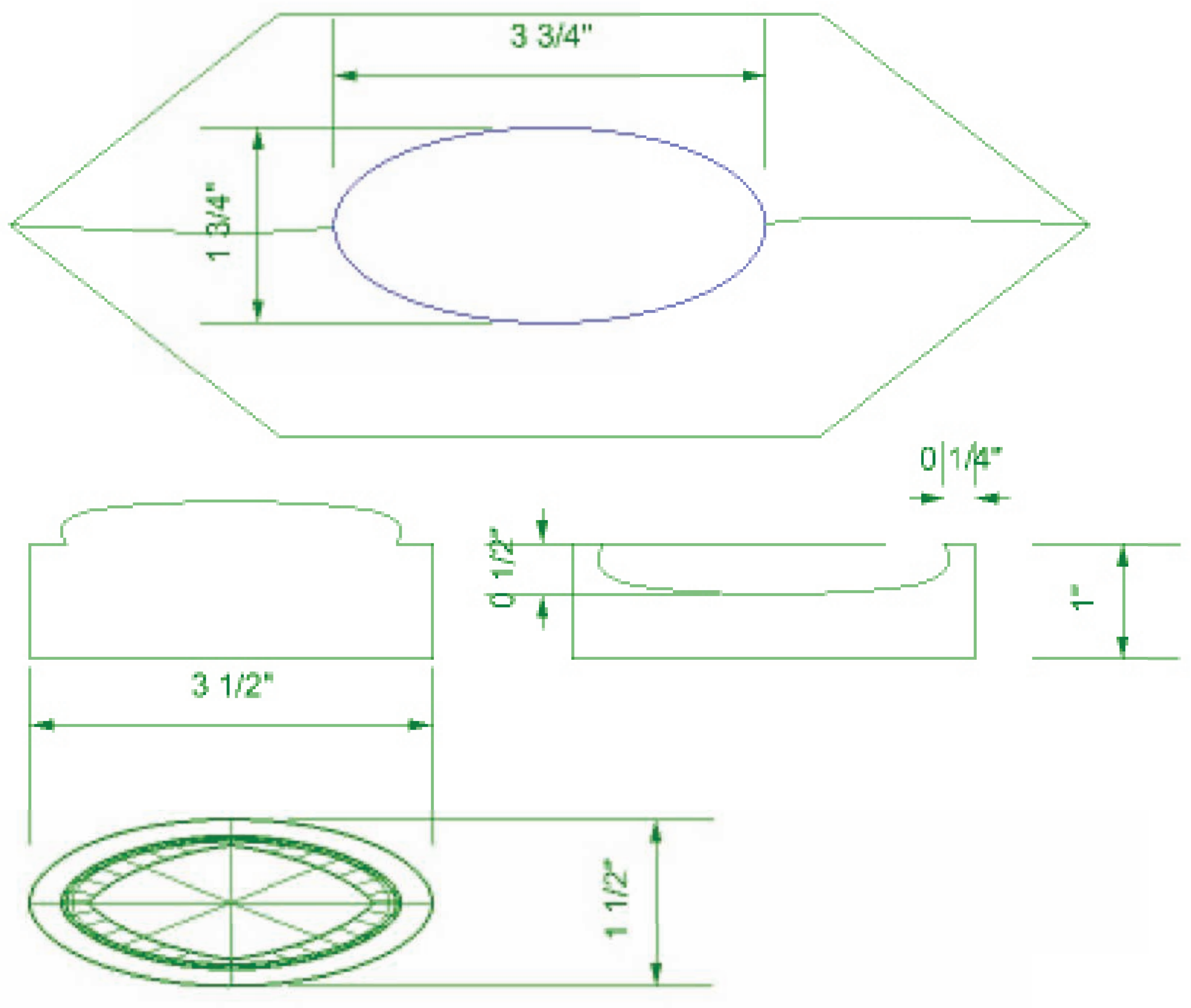
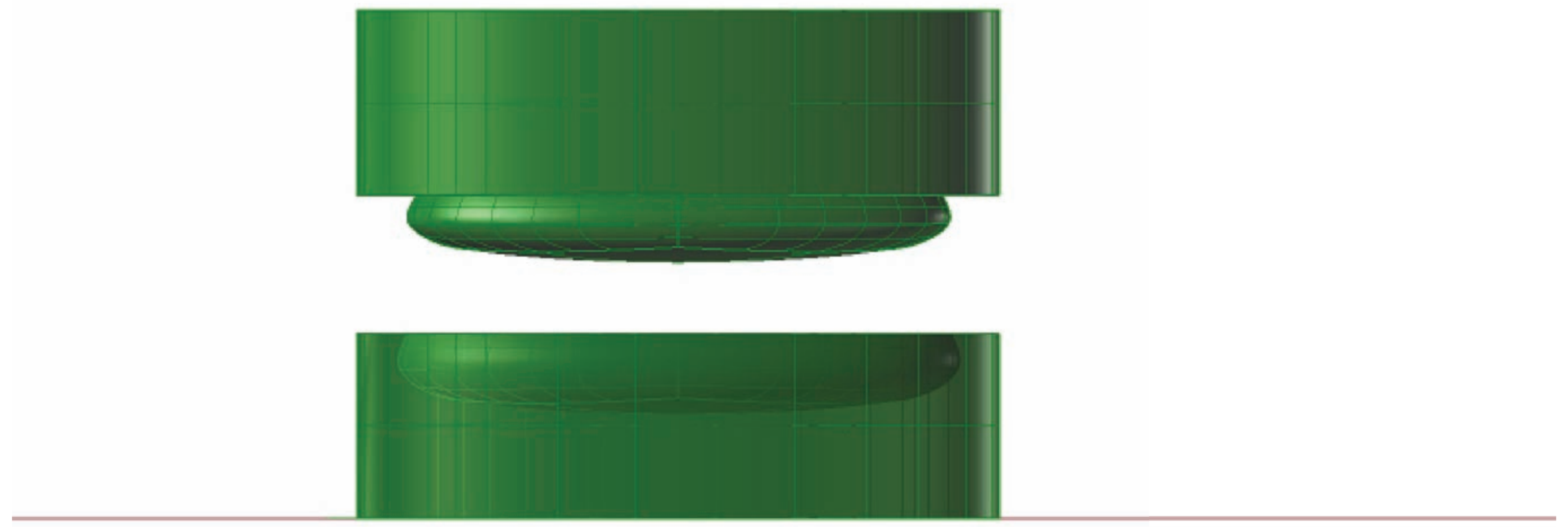
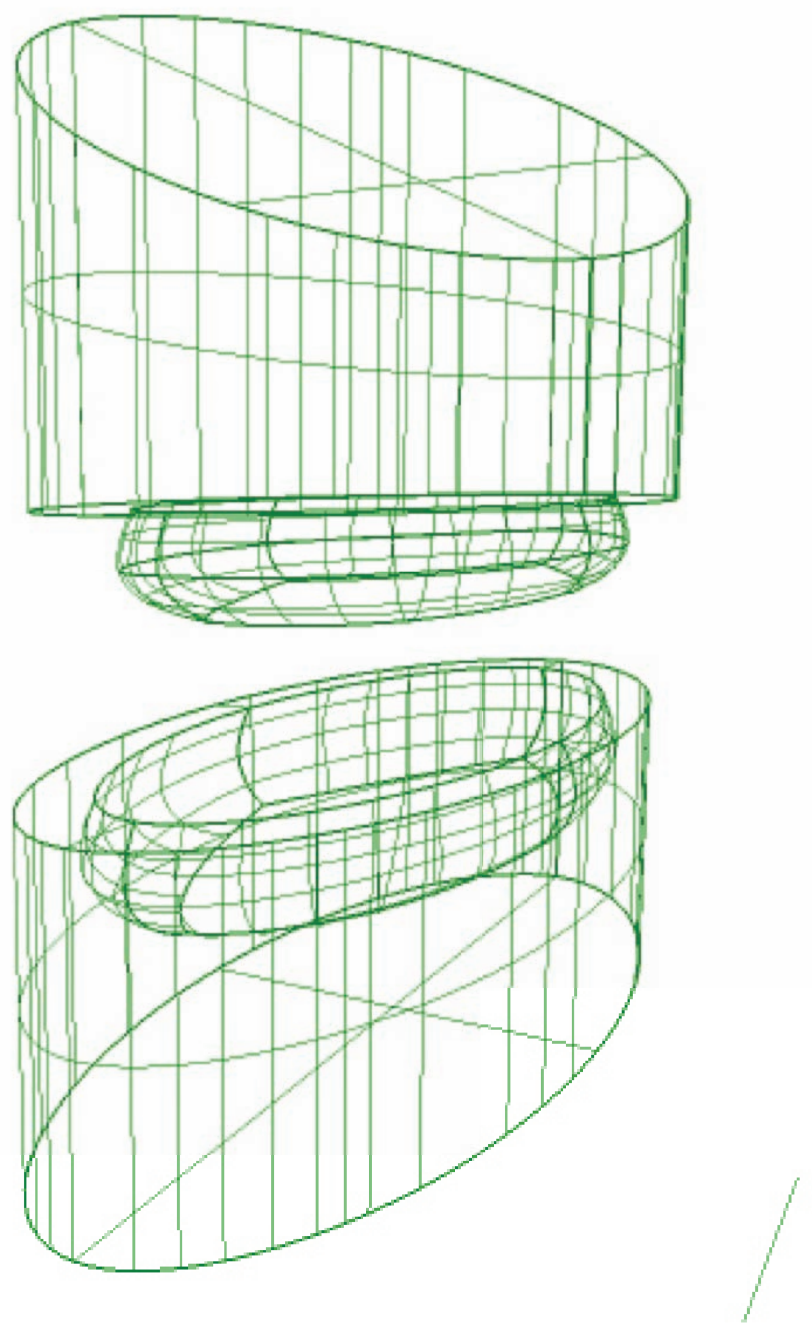
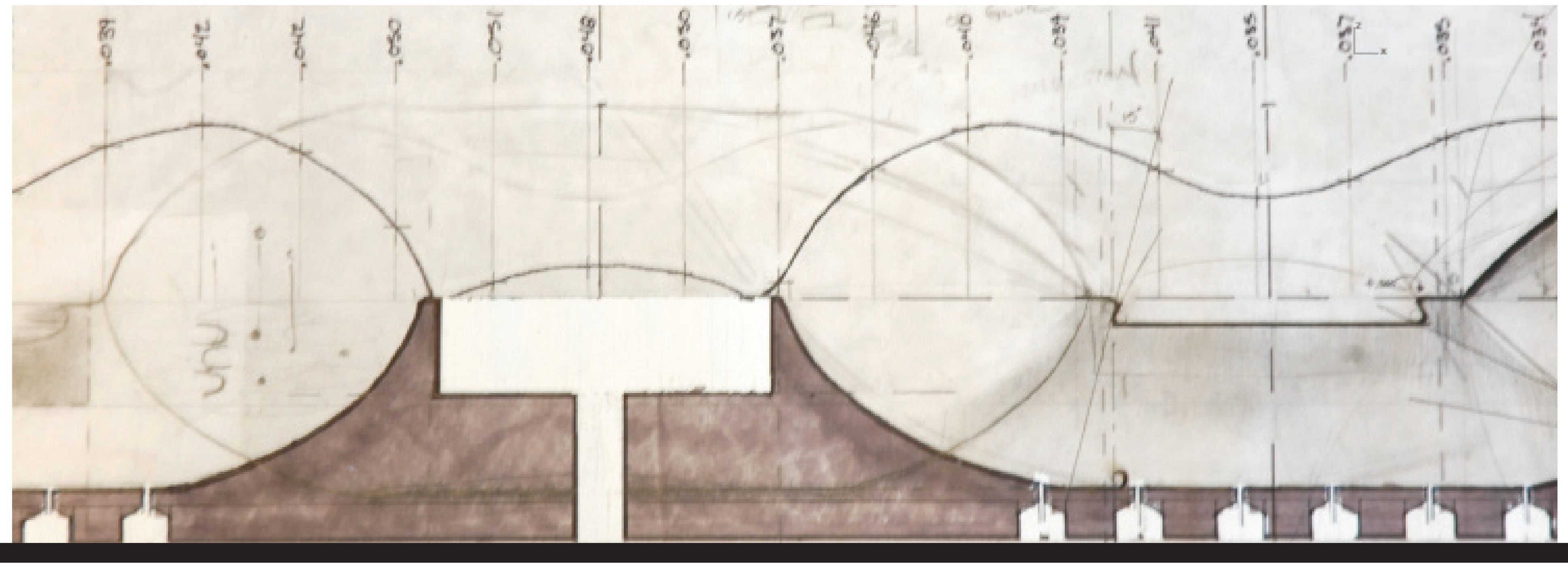
Flow









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<u>Snap Connections</u>