Desalination Buoy

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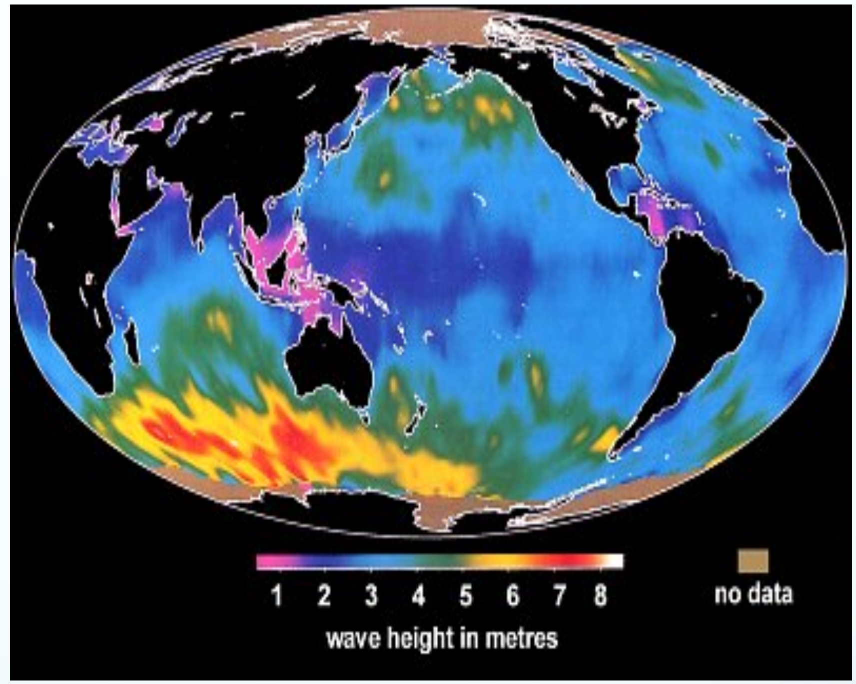
Project Goals

- Concept: Create a buoy system that can desalinate ocean water
  - Use a piston to create pressure for reverse osmosis
  - Target coastal developing areas
- Target output: 1000 gal per day per device
  - Human drinking, sanitation & hygiene needs: 50 liters/day (13.21 gal/day)*
- Goal: Generate an appropriately scaled pressure with a prototype
  - Use a smaller device with a proportional flow rate

*http://www.waterencyclopedia.com/St-Ts/Survival-Needs.html

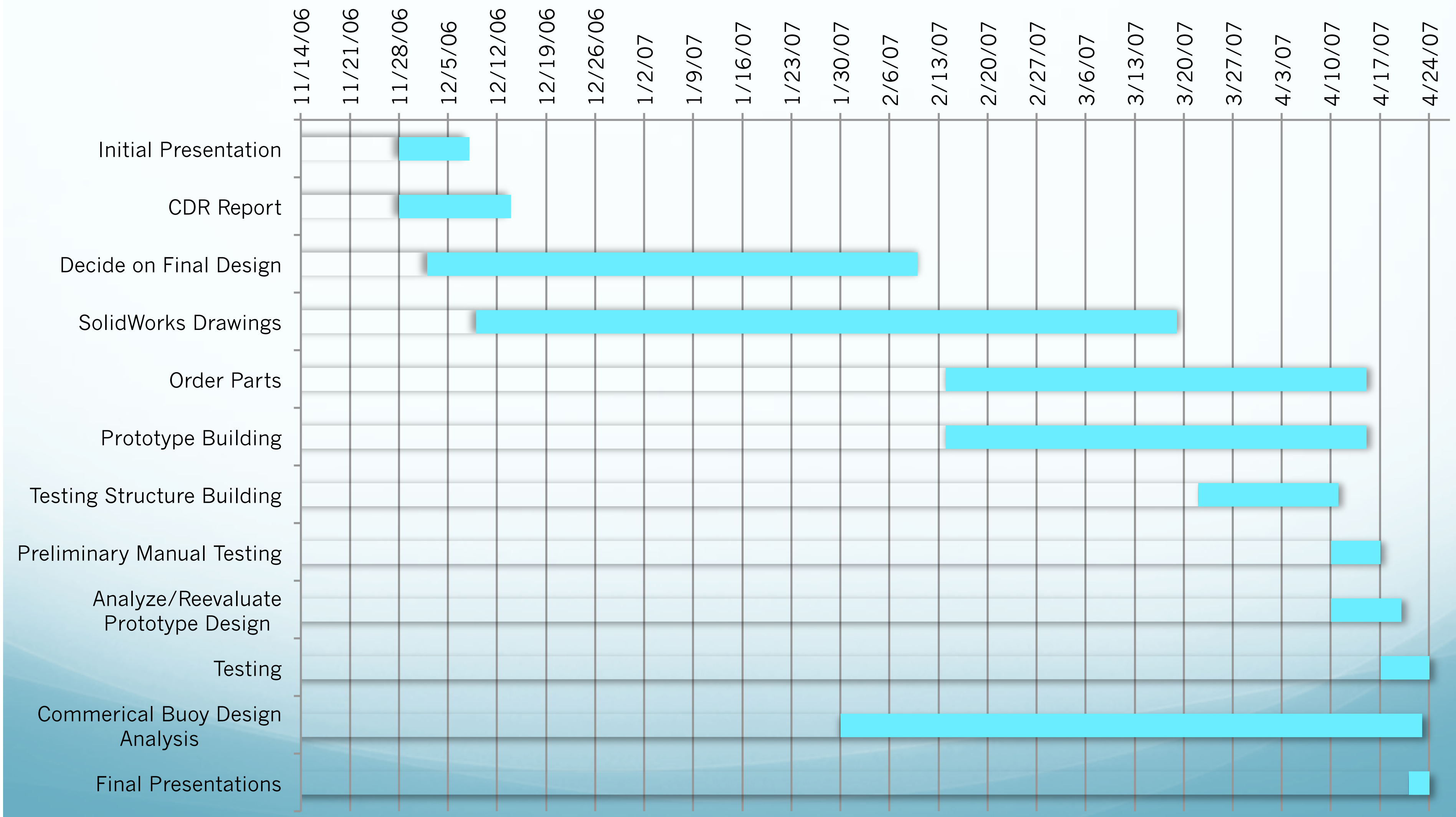
PROJECT REQUIREMENTS

- RO membranes require ~800psi to function properly
- Waves off the coasts of developing areas are approximately 2-4 meters high
- CTQs (Critical to Quality):
  - Low cost
  - Durable
  - Serviceable
  - Water quality standard
  - Minimize environmental impact



http://www.seafriends.org.nz/oceano/waves.htm

Timeline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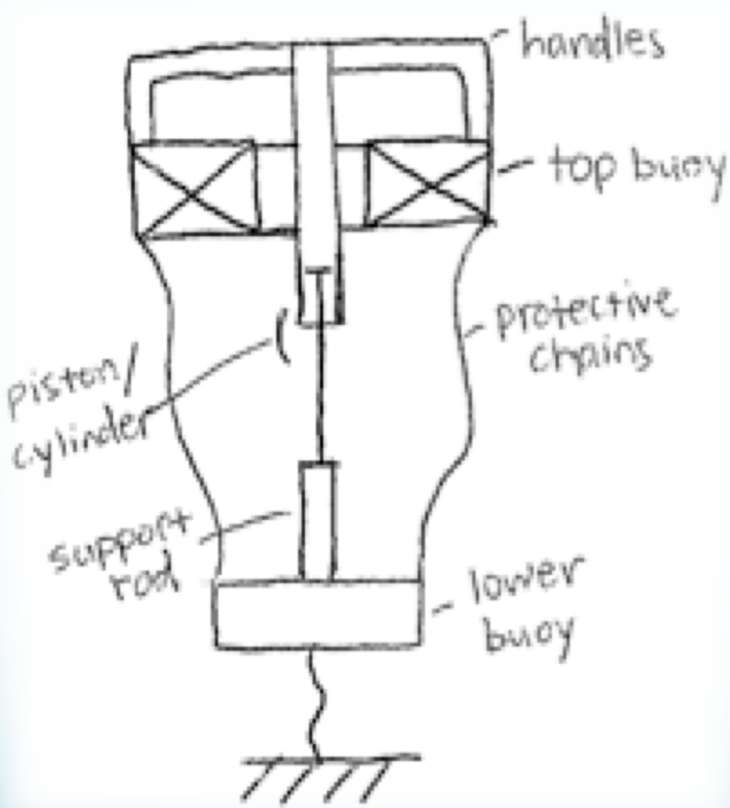
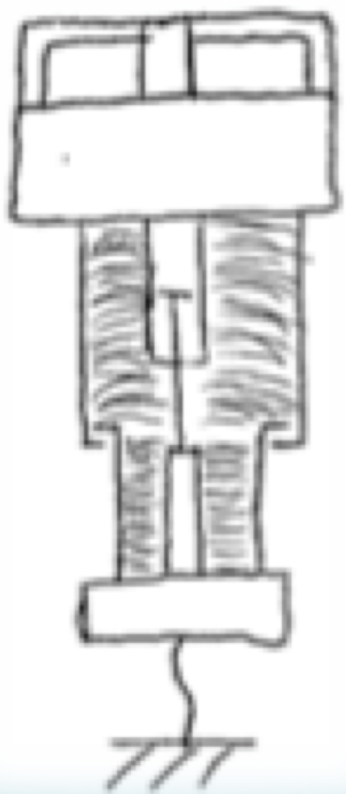
3/13/07
3/20/07
3/27/07
4/3/07
4/10/07
4/17/07
4/24/07
Initial Presentation
CDR Report
Decide on Final Design
SolidWorks Drawings
Order Parts
Prototype Building
Testing Structure Building
Preliminary Manual Testing
Analyze/Reevaluate Prototype Design
Testing
Commerical Buoy Design Analysis
Final Presentations

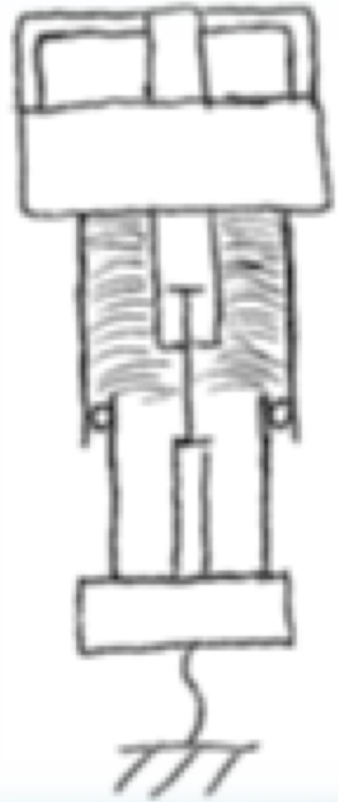
Preliminary Design Ideas



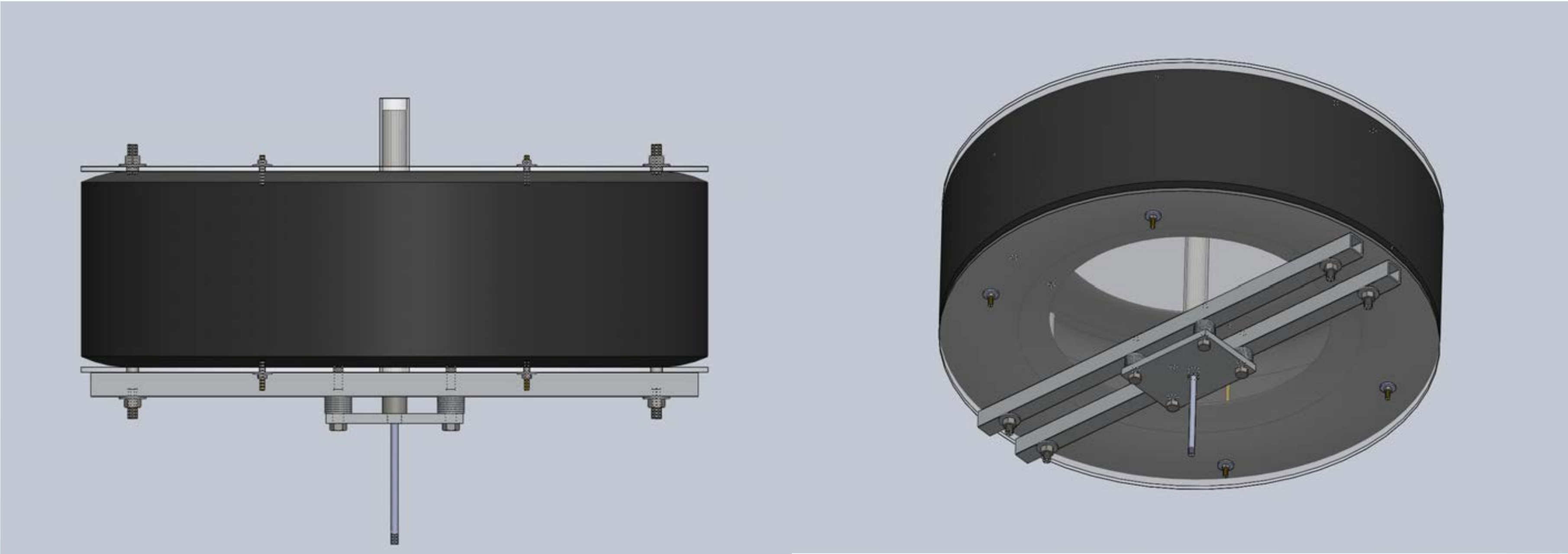
- Two super-buoyant floats
- Gripping rods to make handling easier
- Protective chains prohibit design from overextending
- Support rod screws on/ off

Stability Improvement Ideas





Final Prototype Design

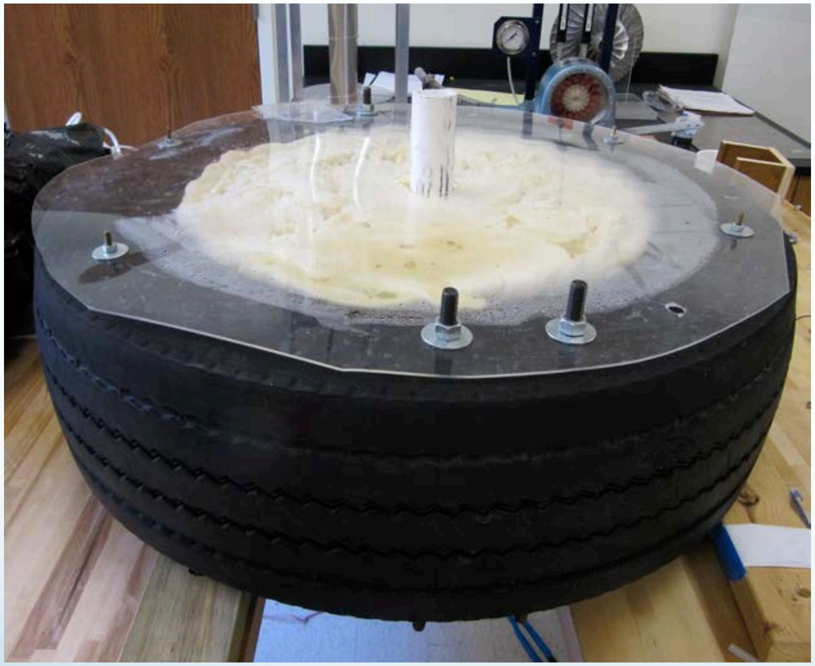


Scaling Down to Prototype

- Existing piston with fixed dimensions
  - Up to 250psi
  - 12in stroke length
  - 1.06in piston diameter
- Based on tire parameters, goal = 100psi
  - Calculations say ~200psi can be achieved
    - Does not include minor head/spring/friction losses
- Using scaled equations, we determined need for buoy of ~30in diameter and ~12in height
- Prototype piston is pneumatic, actual piston will be hydraulic

Design Features

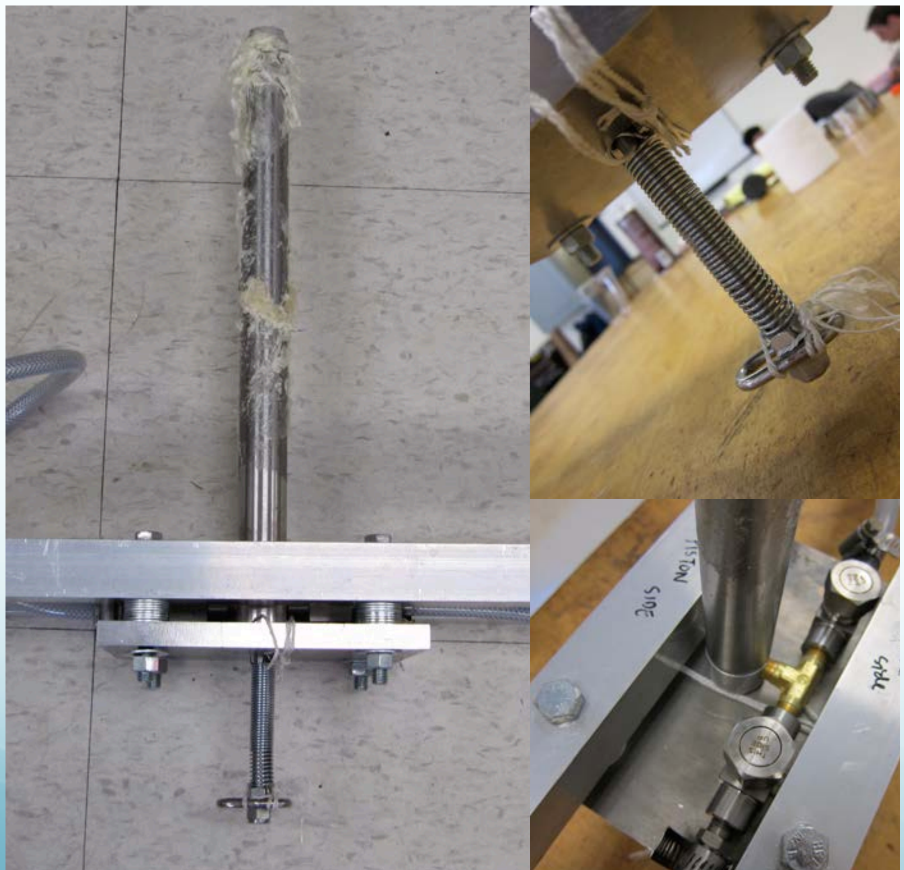
The Buoy



- Used bus tire
  - Cheap
  - Environmentally responsible
  - Durable
- Filled with “Great Stuff” foam for buoyancy
- Bolted acrylic support sheets to either side of the tire to keep the foam in

Design Features

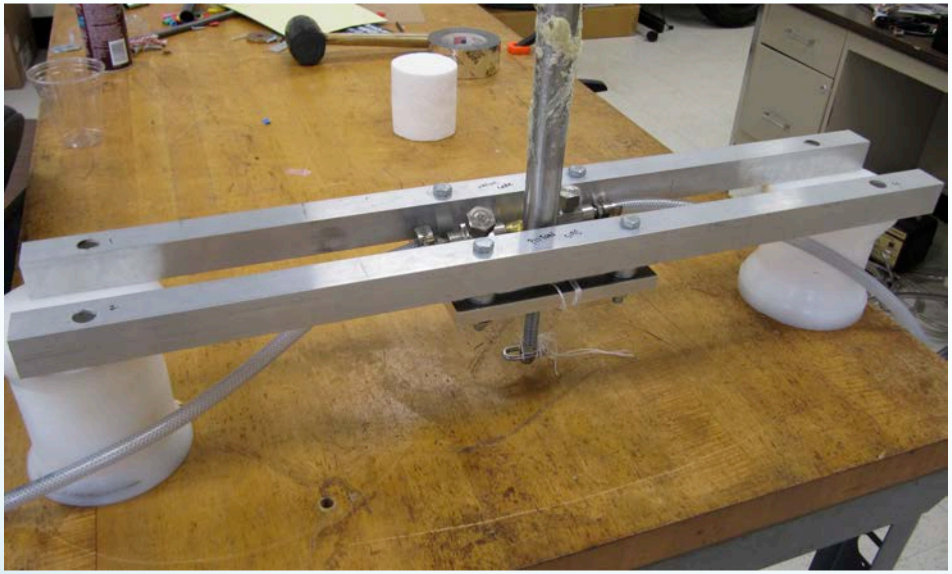
The Piston



- Specs:
  - Handles up to 250psi
  - 12” stroke length
  - 1.06” piston diameter
- Surrounded by PVC pipe for protection
- Connected to a spring at the base
  - Extends when the piston extends
  - Creates force to retract the piston after each stroke

Design Features

Support Structure



- Comprised of two aluminum support bars across an aluminum plate
- Plate: Has a threaded hole that the piston attaches to for support
- Support Bars: bolt into both the plate and the buoy

Prototype Calculations

Constant Values

$$D_{tire} = 32.5''$$

$$D_{PVC} = 1.5''$$

$$H_{buoy} = 10''$$

$$l_{piston} = 12''$$

$$A_{piston} = 1.04 in^2$$

$$\rho = 0.00112153 \frac{slug}{in^3}$$

$$g = 32.2 \frac{ft}{s^2}$$

$$W = 90 lbs$$

Pressure Calculations

$$V_{buoy} = \frac{\pi \cdot H_{buoy}}{4}(D_{tire}^2 - D_{PVC}^2)$$

$$= 8278 in^3$$

$$F_b = V \cdot \rho \cdot g = 298.95 lbs$$

$$F_{net} = F_b - W = 208.95 lbs$$

$$P = \frac{F_{net}}{A_{piston}} = 200.91 psi$$

Commercial Calculations

Piston Dimensions

$$V = 1000\,gal$$

$$\eta = 0.3$$

$$V' = \frac{V}{\eta \cdot 0.133680556} = 445.6\,ft^3$$

$$P_{req} = 800\,psi$$

$$f^{*}_{waves} = 6\,\frac{waves}{\min} \cdot 60\,\frac{\min}{hour} = 360\,\frac{waves}{hour}$$

$$l^{**}_{piston} = 2.36\,ft$$

$$V_{perstroke} = \frac{V'}{f \cdot 24} = 0.05157\,ft^3$$

$$A_{piston} = \frac{V_{perstroke}}{l^{**}_{piston}} = 0.02185\,ft^2$$

$$D_{piston} = 2.0017\,in \Rightarrow 2\,in$$

Pressure Calculations

$$F_{req} = \frac{P_{req}}{0.0069444 \cdot A_{piston}}$$

$$= 2517.5\,lbs$$

$$\rho_{seawater} = 0.0011509\,\frac{slug}{in^3}$$

$$g = 32.2\,\frac{ft}{s^2}$$

$$W^{**} = 400\,lbs$$

$$F_{buoyant} = F_{req} + W^{**} = 2917.5\,lbs$$

$$V_{buoy} = \frac{F_{buoyant}}{\rho \cdot g} = 7.8724 \times 10^4\,in^3$$

$$H^{**}_{buoy} = 25\,in$$

$$D_{buoy} = \sqrt{\frac{4 \cdot V_{buoy}}{\pi \cdot H^{**}_{buoy}}} = 63.32\,in$$

Bar Stress Analysis

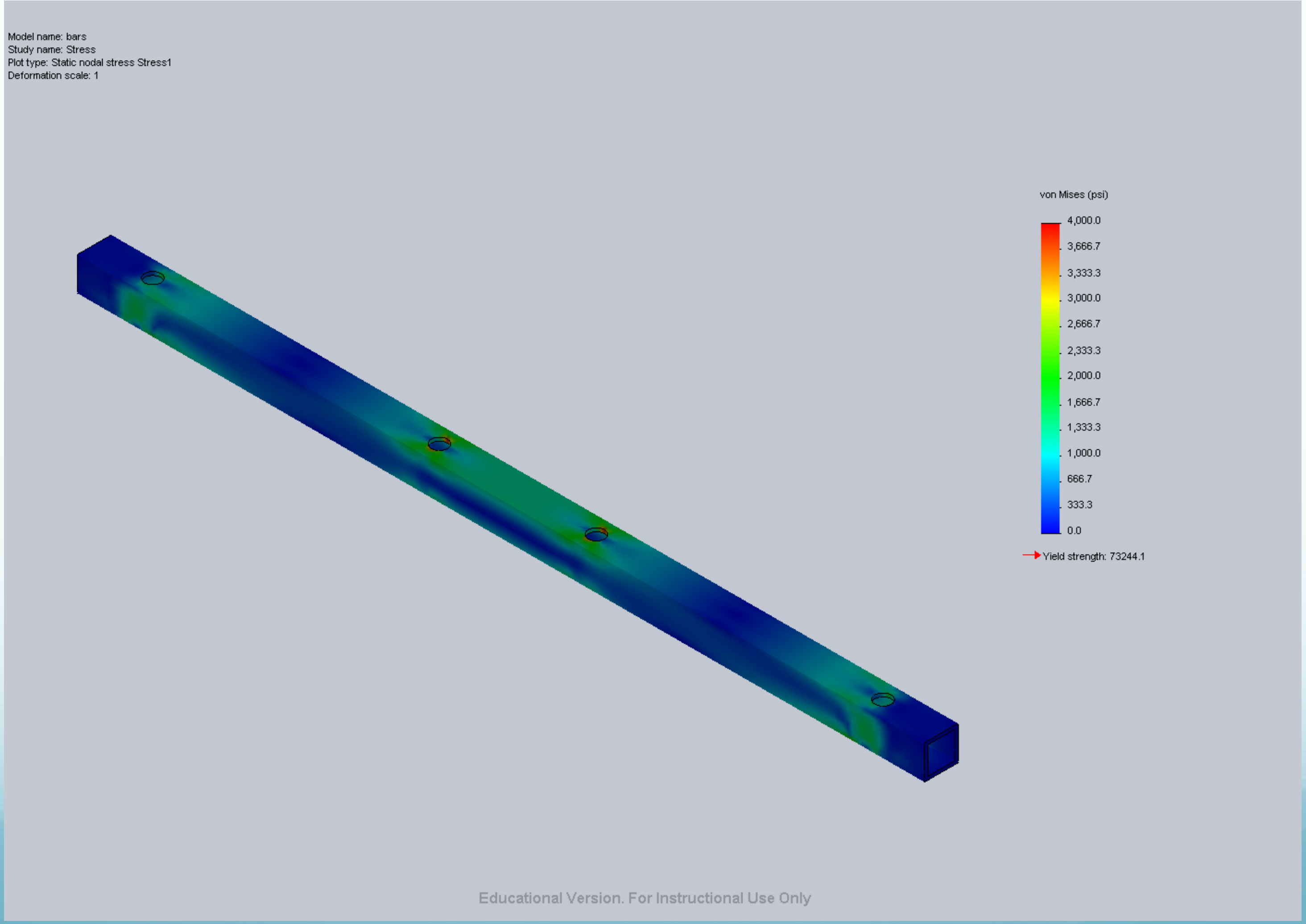
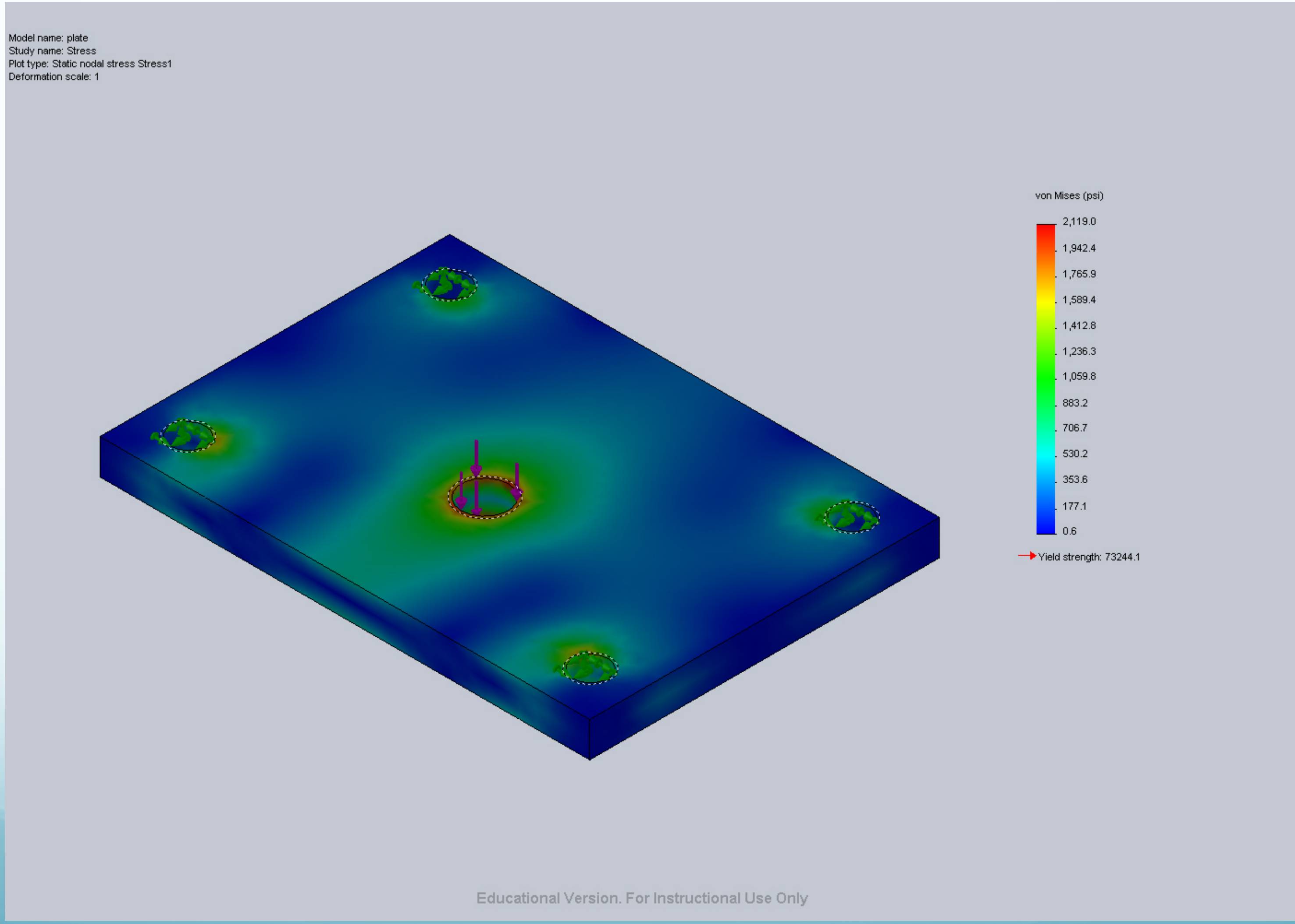


Plate Stress Analysis



Prototype Head Loss

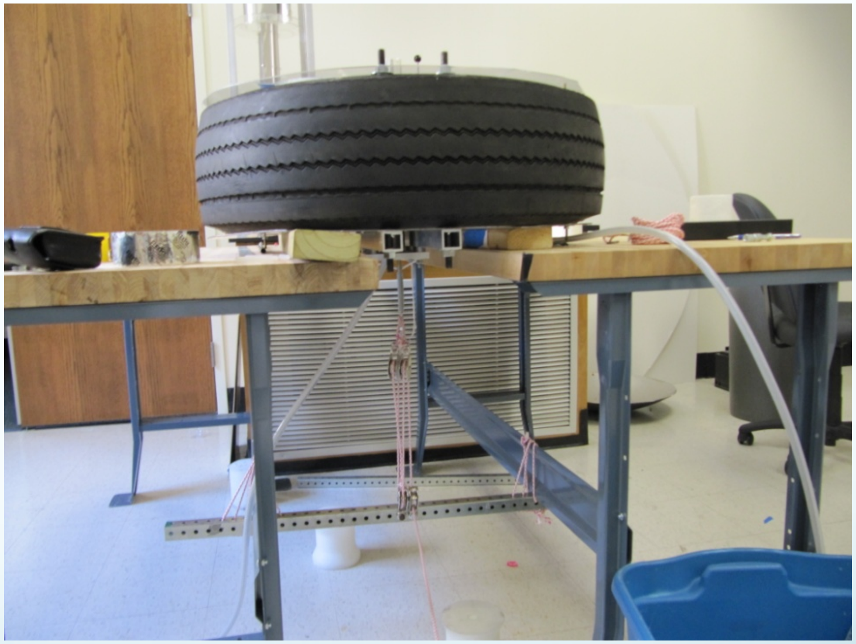
Point of Interest	Equation
Entrance	$h_{m1} = K\rho\frac{V^2}{2} = (1.0)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{172.6\ in}{s}\right)^2}{2} = 1.43\ psi$
Valve	$h_{m2} = f\frac{L_e}{D}\rho\frac{V^2}{2} = (0.045)(8)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{172.6\ in}{s}\right)^2}{2} = 1.03\ psi$
Tee	$h_{m3} = f\frac{L_e}{D}\rho\frac{V^2}{2} = (0.045)(60)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{172.6\ in}{s}\right)^2}{2} = 7.74\ psi$
Exit	$h_{m1} = K\rho\frac{V^2}{2} = (0.5)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{172.6\ in}{s}\right)^2}{2} = 0.715\ psi$
Valve	$h_{m2} = f\frac{L_e}{D}\rho\frac{V^2}{2} = (0.045)(8)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{172.6\ in}{s}\right)^2}{2} = 1.03\ psi$
Tee	$h_{m3} = f\frac{L_e}{D}\rho\frac{V^2}{2} = (0.045)(60)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{172.6\ in}{s}\right)^2}{2} = 7.74\ psi$
	$Total\ Head\ Loss = 19.7\ psi$

Commercial Head Loss

Point of Interest	Equation
Entrance	$h_{m1} = K\rho\frac{V^2}{2} = (1.0)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{90\ in}{s}\right)^2}{2} = 0.4\ psi$
Valve	$h_{m2} = f\frac{L_e}{D}\rho\frac{V^2}{2} = (0.045)(8)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{90\ in}{s}\right)^2}{2} = 0.3\ psi$
Tee	$h_{m3} = f\frac{L_e}{D}\rho\frac{V^2}{2} = (0.045)(60)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{90\ in}{s}\right)^2}{2} = 2.1\ psi$
Exit	$h_{m1} = K\rho\frac{V^2}{2} = (0.5)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{90\ in}{s}\right)^2}{2} = 0.2\ psi$
Valve	$h_{m2} = f\frac{L_e}{D}\rho\frac{V^2}{2} = (0.045)(8)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{90\ in}{s}\right)^2}{2} = 0.3\ psi$
Tee	$h_{m3} = f\frac{L_e}{D}\rho\frac{V^2}{2} = (0.045)(60)\left(\frac{0.0372\ lbm}{in^3}\right)\frac{\left(\frac{90\ in}{s}\right)^2}{2} = 2.1\ psi$
	$Total\ Head\ Loss = 5.4\ psi$

Land-Based Testing

- Goals
  - Verify that each part of the device functions properly
  - Verify that the testing configuration was dependable
  - Gauge approximate force-pressure relationship by measuring the head height
- Configuration
  - 4 pulleys – 2 at the end of the piston rod, 2 anchored to beam below
  - Magnified force by 4 and reversed direction
  - Input hose in water
  - Output hose was oriented vertically to measure head



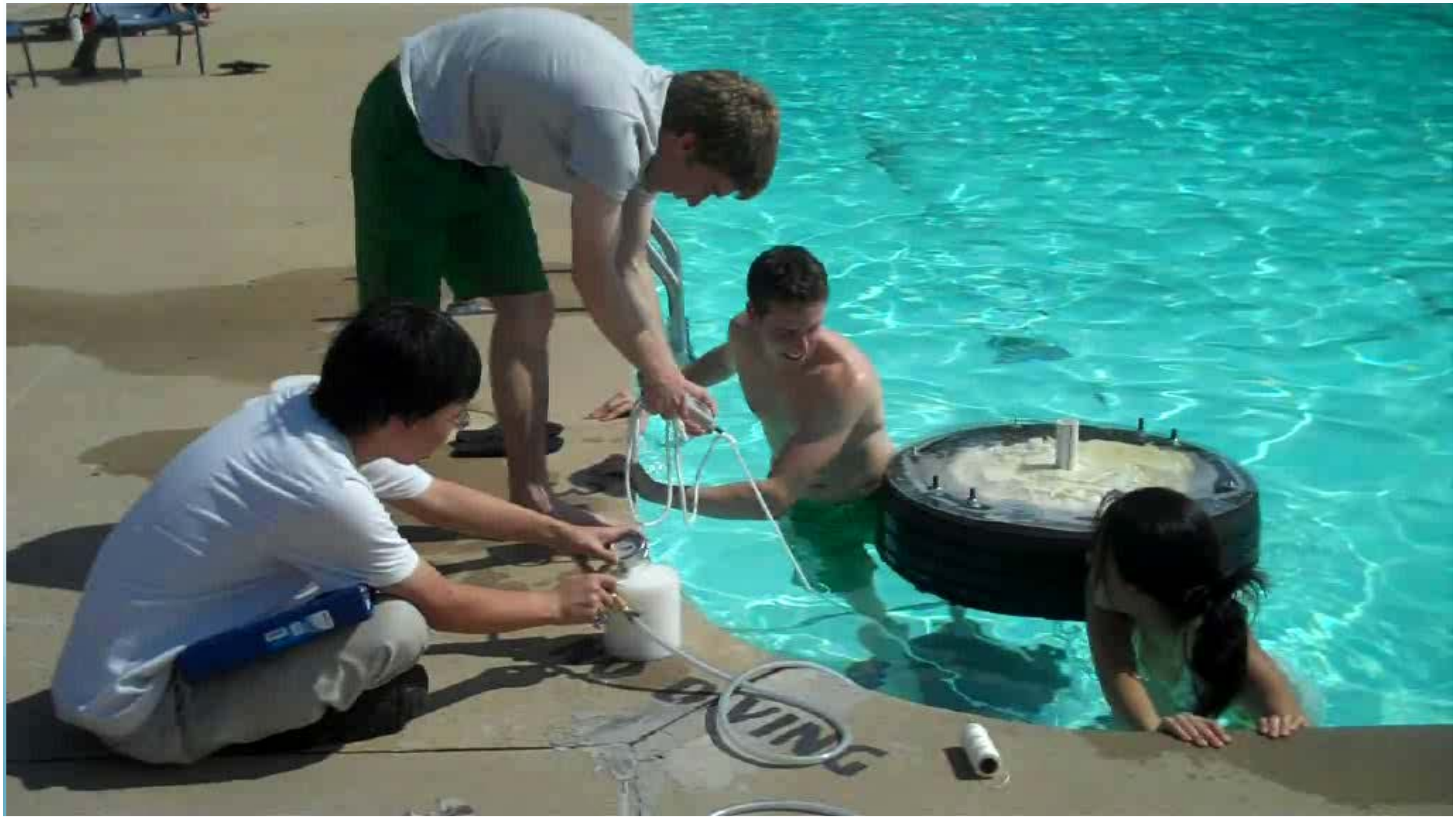
Location: Energy Lab, Hudson Hall

Water-Based Testing

- Goals
  - Verify that predicted pressures can be generated using only buoyant force to support the tire
  - Obtain force-pressure relationship using precise force meter and pressure gauge measurements
- Configuration
  - Same configuration tested previously
  - Anchored to the floor with the weight of sandbags

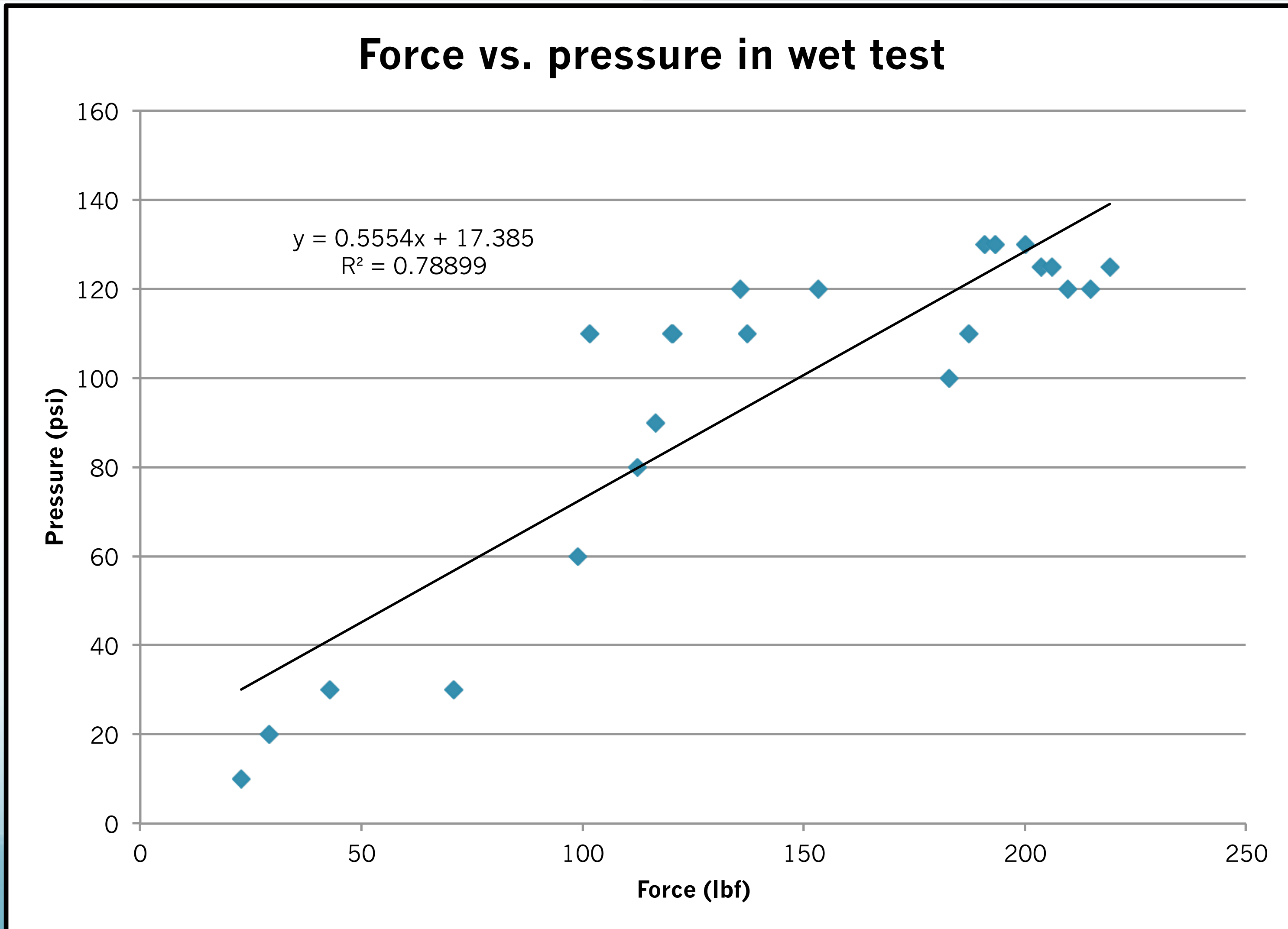
Location: Central Campus Swimming Pool

INDIVIDUAL TRIAL PULL



Consecutive Pulls

RESULTS



Force vs. pressure in wet test
y = 0.5554x + 17.385
R² = 0.78899
Pressure (psi)
Force (lbf)
0
20
40
60
80
100
120
140
160
0
50
100
150
200
250

Results

- Based on results and derived regression, 209 lbf generates approximately 131 psi of pressure
- This does not quite meet theoretical expectations of 180 psi, but is well above our goal of 100 psi.
- Discrepancies can be attributed to:
  - reduced stroke length
  - the use of a pneumatic vs. hydraulic cylinder
  - Friction losses (pulleys, ropes, piston)

Prototype Budget

Part	Price
Threaded bolts (large)	$22.56
Threaded bolts (small)	$11.32
Great Stuff	$39.80
Acrylic sheets	$39.96
Aluminum rectangular tubes	$28.08
Aluminum plate	$19.76
Check valves	$159
Tube fittings	$8.70
Reducing coupling nut	$5.28
Threaded rod	$1.37
Springs	$7.69
Sandbags	$11.92
Rope	$11.70
Additional nuts	$0.22
Tire	$0.00
Piston	$0.00
Total	$367.36

Commercial Budget

Part	Price
Tire	$0.00
Great Stuff	$378.50
Rectangular tubes	$487.50
Plate	$266.00
Check valves	$300.00
Tube fittings	$20
Spring	$10
Piston	$2200.00
Threaded bolts (large, stainless steel)	$50
Threaded bolts (small, stainless steel)	$30
Chain	$110
Anchor	$20
Labor costs (capital)	$300
Labor costs (O&M)	$100
Total	$4272.00 - bulk discount

Future Considerations

- Tidal activity
  - Tides have less effect further out to sea; will need to evaluate buoy placement on a case-by-case basis to minimize tidal interaction
  - Consider SEARASER height-adjustable wave powered pump configuration: UK Patent No. GB 2445951
- Corrosion
  - Stainless steel parts for final design; may need to use replaceable cathodic protection
- Brine dispersion
  - Desalinating water produces ~2000 gals/day of concentrated brine solution → NEGLIGIBLE

The Buoy Business

- Two approaches to commercialization
  - Manufacture in US and distribute abroad
  - Partner with local manufacturer near target site
- Must establish maintenance system, oversight
- Requires trained partners in the region for site-visits and maintenance

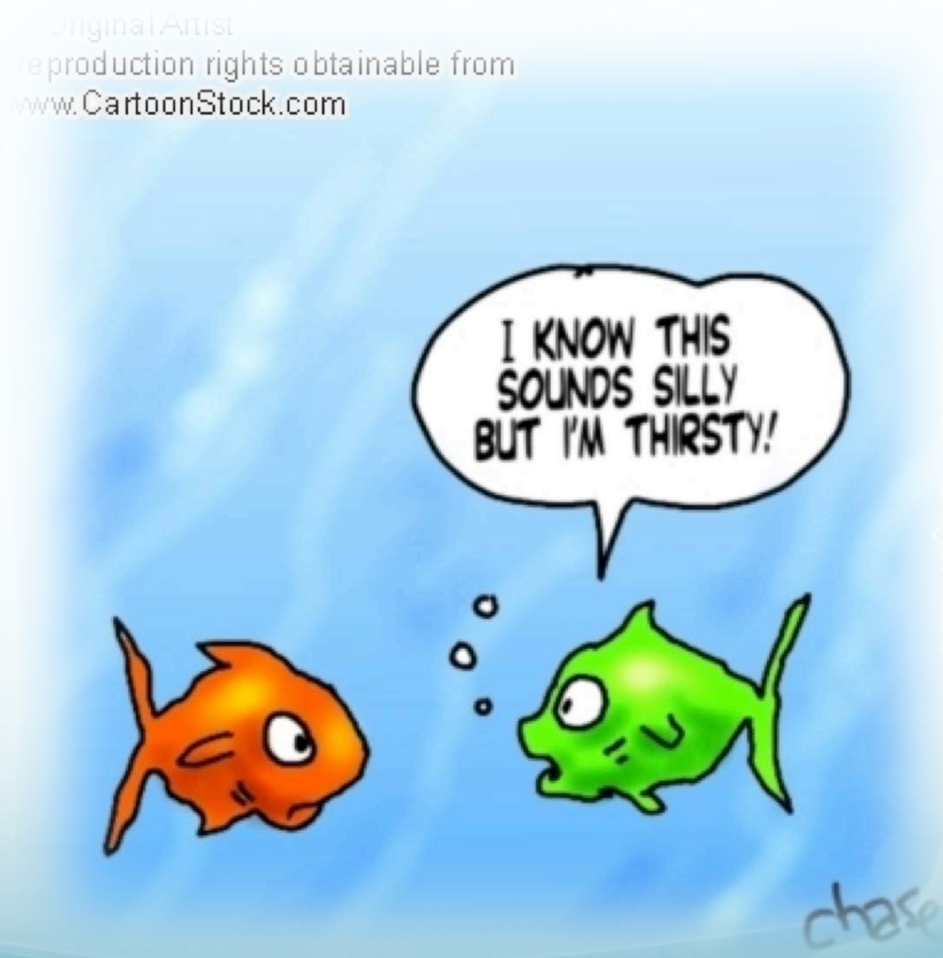
Local Implementation

- Public Use
  - Governments purchase and maintain the buoys
- Private Use
  - For areas underserved by governments
  - Purchased by an individual or a cooperative of residents
  - Potential for income, or income-enhancement
  - Strong candidate for microfinance loan

Microfinance Intermediaries

- 50% failure rate of clean water projects, so bank loans not viable
- Sustainability organizations supporting microfinance programs
  - Providing technical solutions, attracting lenders
  - Water.org and WaterCredit – securing funding for local water projects
  - ACCESS Development Services – supporting clean water projects, partnering with UniLever to develop technology for local use in India
- Intermediary firms would serve as go-between for project management team, local microfinance institutions, and customer

QUESTIONS?



Preliminary Pressure Calculations

$$\check{F}_{Net} = \check{F}_B + \check{F}_g + \check{F}_{ext}$$

$$V_{buoy} = V_{water,displaced}$$

$$V_{buoy} = \Pi \times (r_o{}^2 - r_i{}^2) \times l$$

$$F_B = W_{w,disp} = \rho_w \times V_{w,disp} \times g$$

$$F_{Net} = \rho_w \times \Pi \times (r_{tire}{}^2 - r_{PVC}{}^2) \times l \times g - W_{buoy} - F_f$$

Preliminary Pressure Calculations

Large Tire

$$d_{tire} = 32.5''$$

$$d_{PVC} = 1.5''$$

$$l = 10''$$

$$W = 90lbs$$

$$F_{Net} = 209lbs$$

$$P = 201psi$$

Small Tire

$$d_o = 22''$$

$$d_i = 1''$$

$$l = 6.5''$$

$$W = 23lbs$$

$$F_{Net} = 66.0lbs$$

$$P = 63.5psi$$