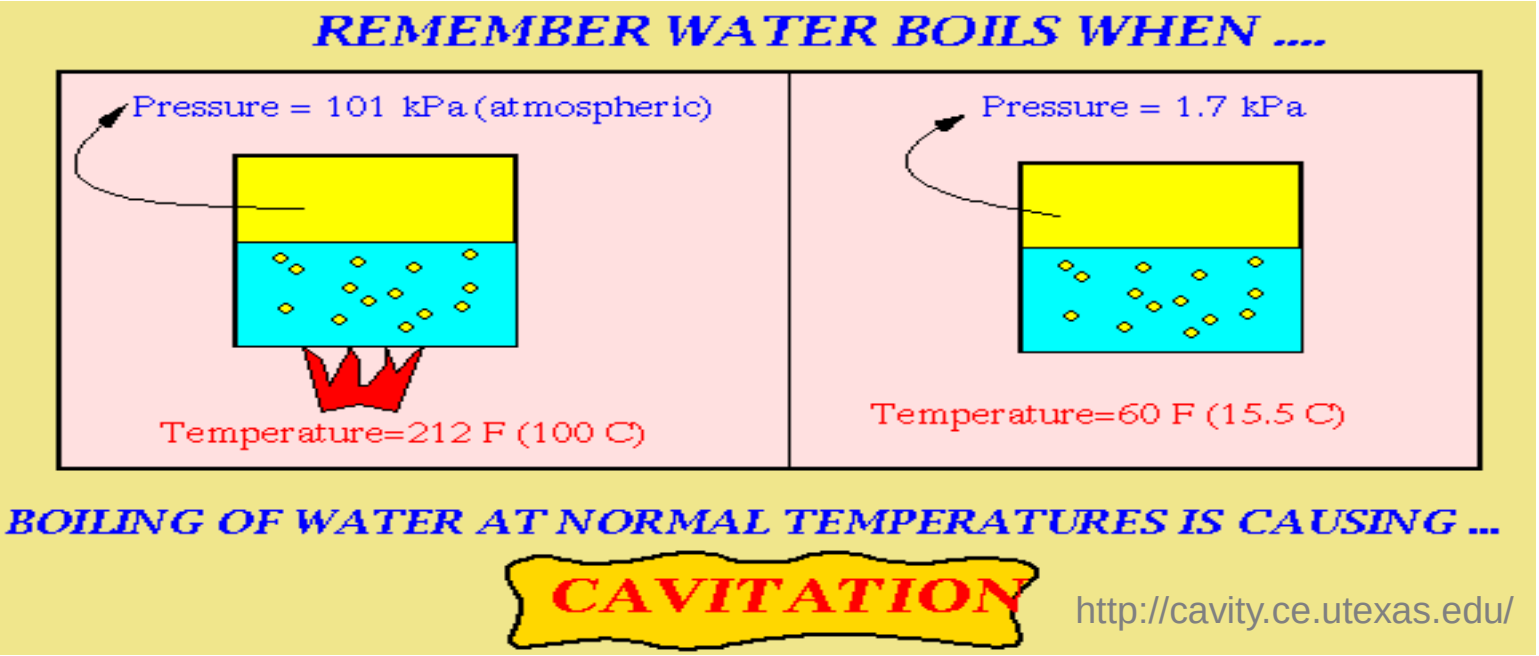
Cavitation and its Effects

(**A Case Study – Experiment performed by Dr. Kinnas and his students at MIT's Cavitation tunnel**)

What is Cavitation

"a general term used to describe the behavior of voids or bubbles in a liquid"

Cavitation occurs in liquids when the pressure is reduced to the vapor pressure at a given temperature of operation



Cavitation Number

$$\sigma = \frac{P_\infty - P_v}{\rho/2\, v_\infty^{\,2}}$$

$Where:\ \sigma = cavitation\ \ number$

$P_\infty ; P_v = ambient\ and\ vapor\ pressure (Pa)$

$\rho = \ fluid\ \ density\ (kg/m^3)$

$v_\infty = velocity\ of\ \ uptream\ \ flow/trifoiler\ \ (m/s)$

NOTE:

- Velocity (v_∞) ↑ ➔ cavitation number (σ) ↓ ➔ CAVITATION occurs

How it “works”

In local regions of low pressure:

Vapor bubbles start growing

In the regions of higher-pressure downstream:

Bubbles collapse on the solid walls and result into very high local pressures (~800 MPa!)

Problems

- increased noise
- pitting, accelerated erosion and damage to components
- vibrations
- loss of efficiency.

Benefit Uses

- Used in high power ultrasonics
- Used to homogenize, or mix and break down particles
- Used to cavitating water purification devices
- Used for destruction of kidney stones via shock waves

Case study

TRIFOILER

The World's Fastest Sailboat

50.1MPH

http://www.wetasschronicles.com/HobieTrifoiler.jpg

Common Questions:

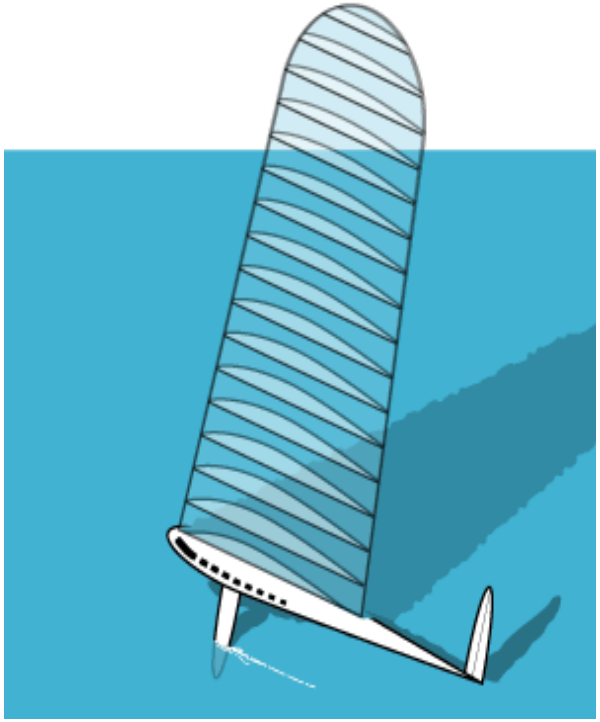
How can we overcome the resistance of water?

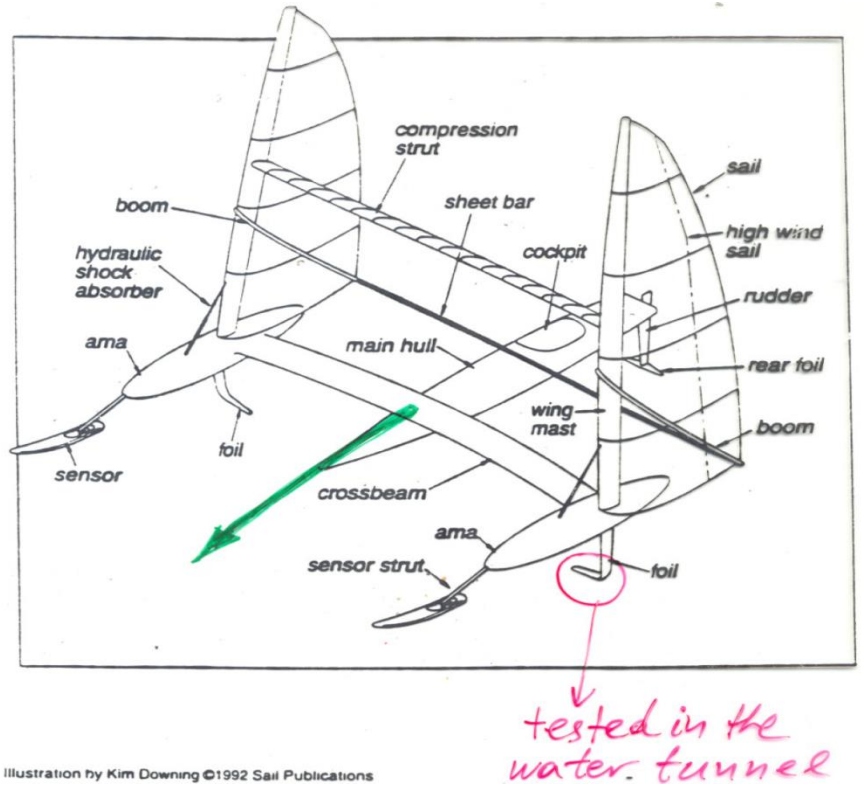
Why can't we make it go faster?

Hydrofoil =Lifting surface

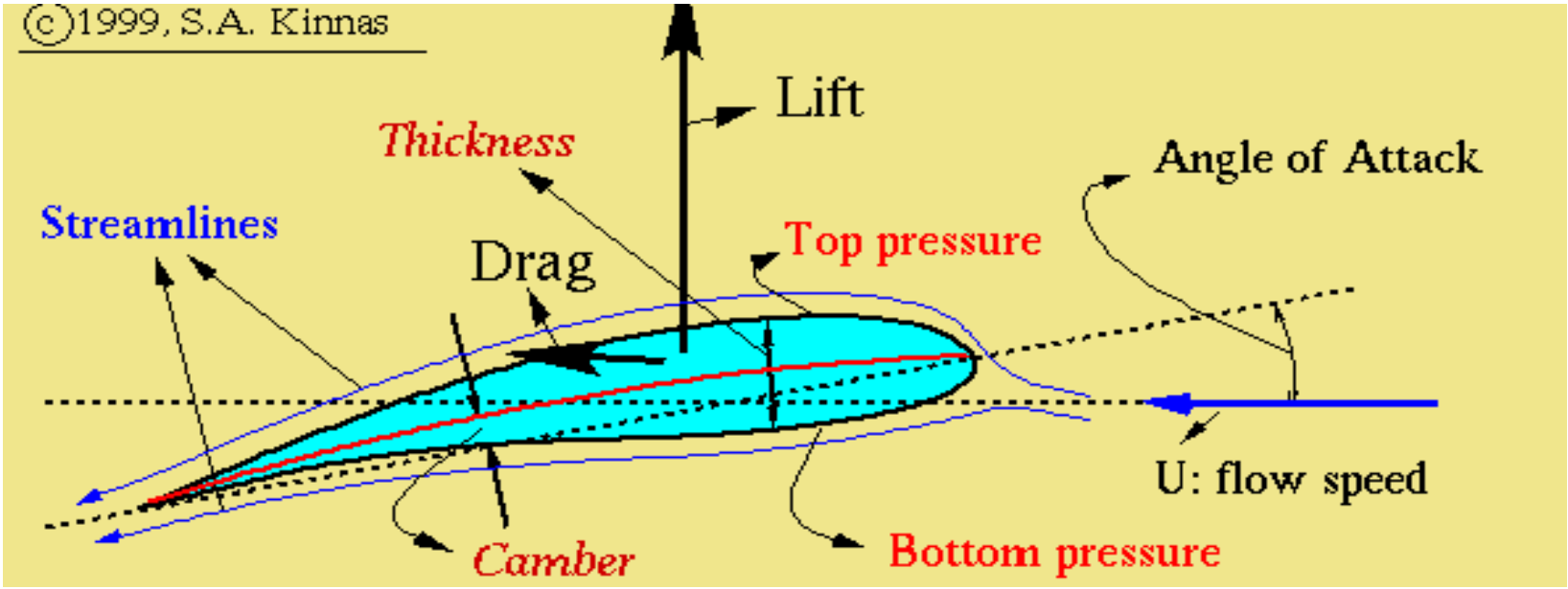
let a boat go faster by getting the hull out of the water

→ overcome the drag on the submerged hydrofoils instead of the drag on the hull





Hydrofoil



Top velocity HIGHER than bottom velocity ($v_{top} > v_{bottom}$)

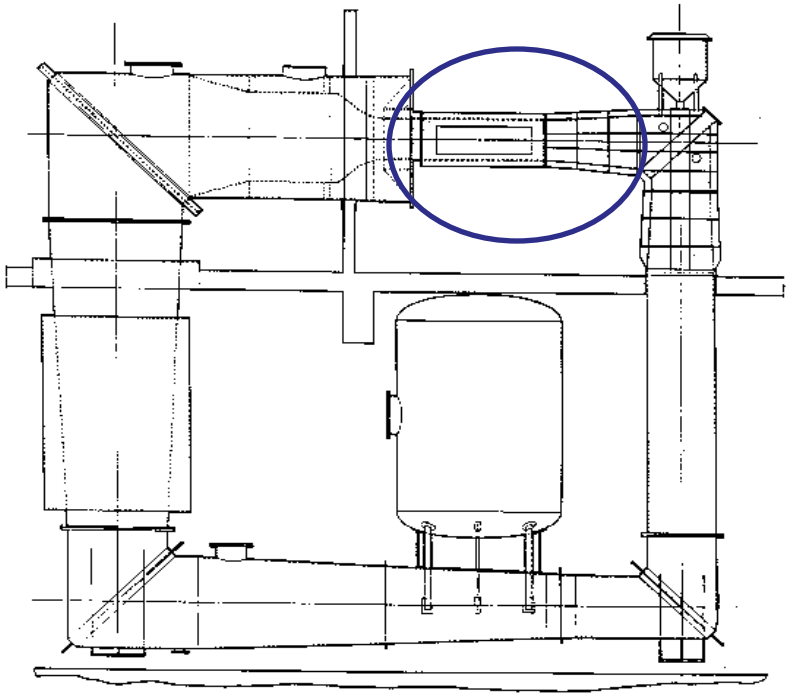
Top pressure LOWER than bottom pressure (Bernoulli's equation) → **LIFT**

Lift increases with fluid velocity (U); Angle of Attack, Camber

INCREASE in U causes DROP in Top pressure

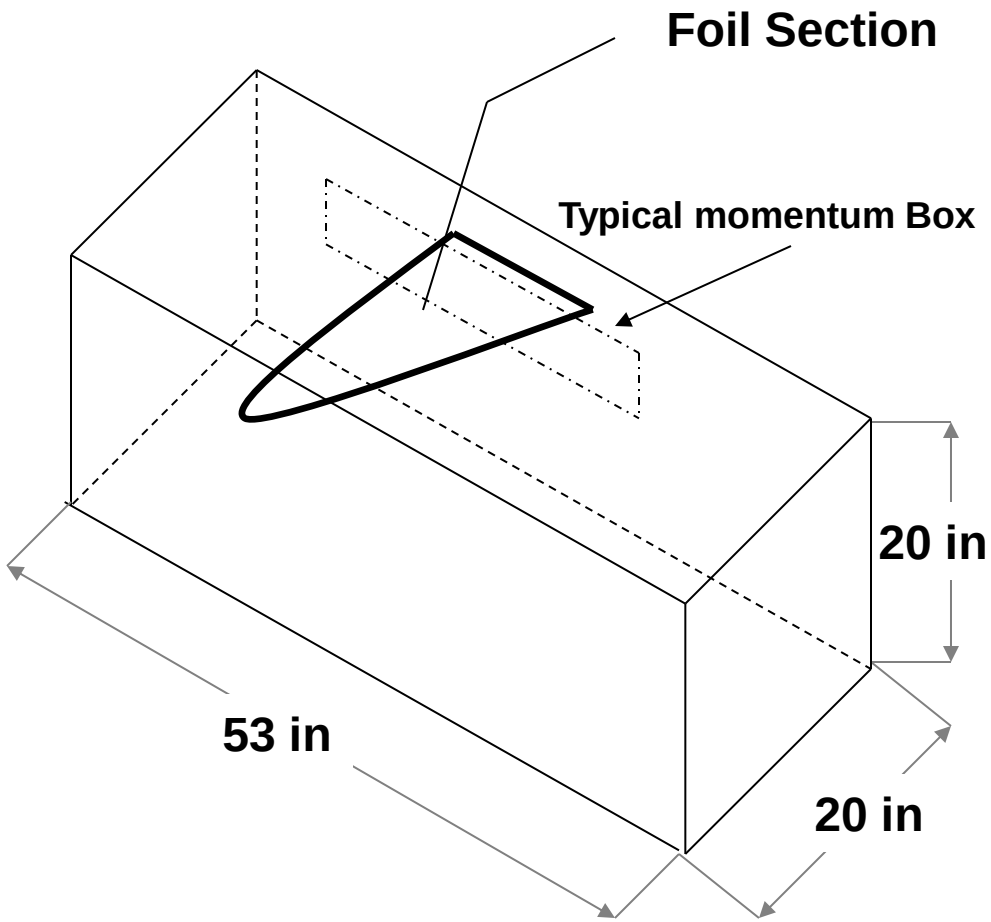
Cavitation Tunnel

Pressure is decreased in order to simulate the effects of high speed flow



MIT Water Tunnel

http://web.mit.edu/mhl/www/photos.html



Super-Cavitation

Top pressure DROPS → CAVITATION

Cavitation causes - loss of lift
- Increase of drag force

➡ **Slowing down the sailboat**

MOVIE
on Cavitating Hydrofoil

Take-home Messages

√ **Cavitation number** characterizes the amount of cavitation

$P_{ambient}$ INCREASES ➔ Cavitation DECREASES

√ **Forces** and **Foil Vibrations** become excessive as the cavity crosses the trailing edge of the foil

√ **Lift** is significantly decreased as the cavity becomes a super-cavity

Super-Cavitation causes the barrier in the speed of the TRIFOILER