

# Solar Cup Boat Design

Information for rookies

BIG note: The information in the Tech manual is worth reading.

# Important reference info

- Weight and Drag are the enemy
- The propeller handbook by Gerr is a good ref.
- Good parts sources
  - Rex marine -- KTA
  - Glen – I Marine
  - Minnie's yacht surplus
  - Ev-parts
  - Cloud electric

# How Much Power?

- 400lb boat including driver running 5.8 mph requires around 1 hp of mechanical power
- Horsepower required =  $\text{Weight}(\text{Speed})^3/70472$
- Max power per the rules is 11.2 hp
- Sprint races use max power
  - 24 VOLTS x 350 AMPS = 8400 WATTS/W/HP = 11.2
- The big trick – Find a motor configuration that can do both- suggest reading AVEOX motion control primer by David Palombo

# Propellers: Does size matter

- Minimum size for control is 5 inch Diameter
- Any size works
  - RPM and propeller diameter determine the max HP output.
    - The smaller the Diameter the more RPM required
  - Propeller pitch relates to the required speed but not directly due to the slip in the fluid coupling
    - A smaller diameter prop would have less pitch
  - Typical pitches used for solar boats 9-15 in/rev

# Required RPM to transfer power to the water at different prop diameter

Propeller Handbook: Propeller Diameters For Minimal Slip										
RPM	hp	diameter		RPM	hp	diameter		RPM	hp	diameter
100	0.5	34.75		100	1	39.921		100	9.3	62.358
200	0.5	22.93		200	1	26.338		200	9.3	41.141
300	0.5	17.98		300	1	20.65		300	9.3	32.257
400	0.5	15.13		400	1	17.376		400	9.3	27.143
500	0.5	13.23		500	1	15.199		500	9.3	23.742
600	0.5	11.86		600	1	13.624		600	9.3	21.282
700	0.5	10.81		700	1	12.42		700	9.3	19.402
800	0.5	9.98		800	1	11.464		800	9.3	17.908
900	0.5	9.299		900	1	10.682		900	9.3	16.686
1000	0.5	8.73		1000	1	10.028		1000	9.3	15.664
1100	0.5	8.244		1100	1	9.4703		1100	9.3	14.793
1200	0.5	7.825		1200	1	8.9885		1250	10	13.901
1300	0.5	7.458		1300	1	8.5671		1300	10	13.578
1400	0.5	7.134		1400	1	8.1945		1400	9.3	12.8
1500	0.5	6.844		1500	1	7.8622		1800	9.3	11.009

# Slip calculations

- From calculations and measured data we estimate the RPM to be around 1600-1800rpm for sprint speeds and around 500-700 for the endurance.
- Our propeller has a pitch of 15 inches per revolution so at 1600-1800 rpm the theoretical speed in a solid would be  $=15 \text{ in/rev} * 1600-1800 \text{ rev/min} * 60\text{min/hr} / 63360 \text{ in/mile} = 22 - 25.5 \text{ MPH sprint}$
- The endurance rate would be  $= 15 * 500-600 * 60 / 63360 = 7.1 - 8.5 \text{ MPH}$
- The actual measure speed for the sprint is between 15 – 16 MPH
- The endurance is 5.5 -6.5 mph
- Why don't we go as fast as the theoretical based on a solid?
- Water is not a solid. The difference is known as propeller slip. The drag from the boat is as much of a factor as the fluidity of the water. The more horsepower required to move the boat the more slip the prop has.
- Slip can be calculated as
- $(\text{Calculated speed} - \text{actual}) / \text{calculated} = \text{sprint slip} = \text{around } 31- 37\%$
- $\text{Endurance} = \text{around } 21-23\%$

# Solar cup Propeller photos



# Power transmission

- Motors
  - Considerations
    - No load current – how much power is used to do nothing
    - Efficiency
      - Terminal resistance
    - RPM at 24 volts at sprint and endurance power levels
- Required reading
  - AVEOX.COM motion control primer by David Palombo @ [www.aveox.com/technical/dc.html](http://www.aveox.com/technical/dc.html)



# Matching Motor and Propeller

- Direct drive
  - Motor shaft connects to propeller shaft directly
    - Very hard to match must find the optimum prop.
    - Motor must have ability to support shaft thrust
- Transmission coupled
  - Motor/propellers can be matched by selecting the best gear ratio
- Required reading the Propeller handbook by Dave Gerr. Available at Amazon .com for around \$20

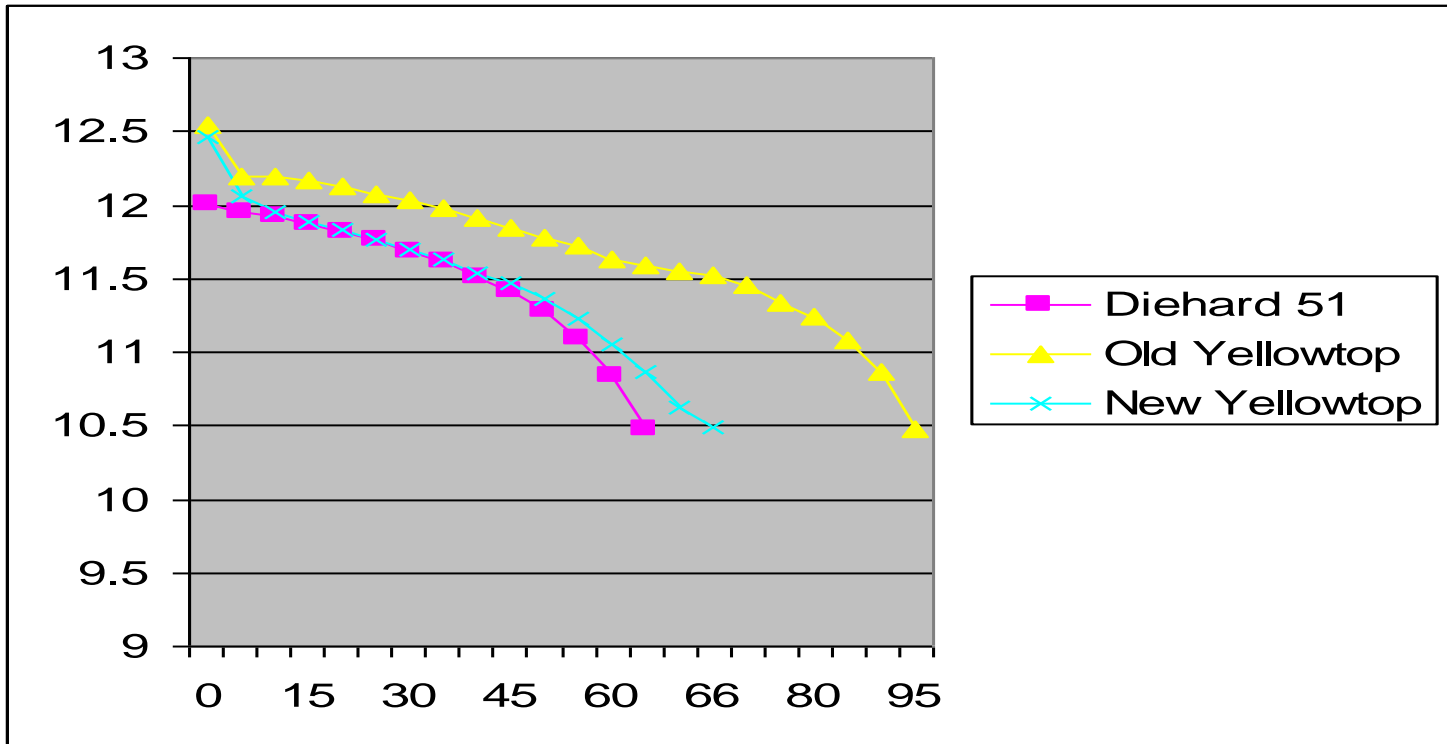
# Photos of Solar cup boat drives



# Rudders

- Too small, and you can't steer
- Too big, will slow you down
- Rule of thumb: The rudder area should be 50% of the propeller disk area minimum.
- See propeller photos & rudders

# Batteries consumable power 2/3 endurance requirement



# Solar panels

- Per the rules 320 watts of panels are allowed
- The solar panel supplies around 1/3 of the endurance power required
- Weight of the panels is important
  - At 6mph with the boat weight @400lbs 2.2watts per pound is used to propel the weight.
  - A solar panel array @ 80 pounds uses 160 watts
  - Keep this in mind when looking

# Instrumentation

- On the boat Volt meters and amp meters are required
- Measure only the consumable power
- Solar power is variable and endless.  
Measuring it is pointless. (it will determine your speed)
- Power management can not be done without instrumentation

# Floatation

- Inflatable floatation has proven to be the best choice
- Kayak floatation bladders work great and fit the hull shape
- Foam works but requires more work
- Some teams have used sparklets bottles
- Provide flotation for things that sink.