Boat Design / Performance --- Important Factors to Consider

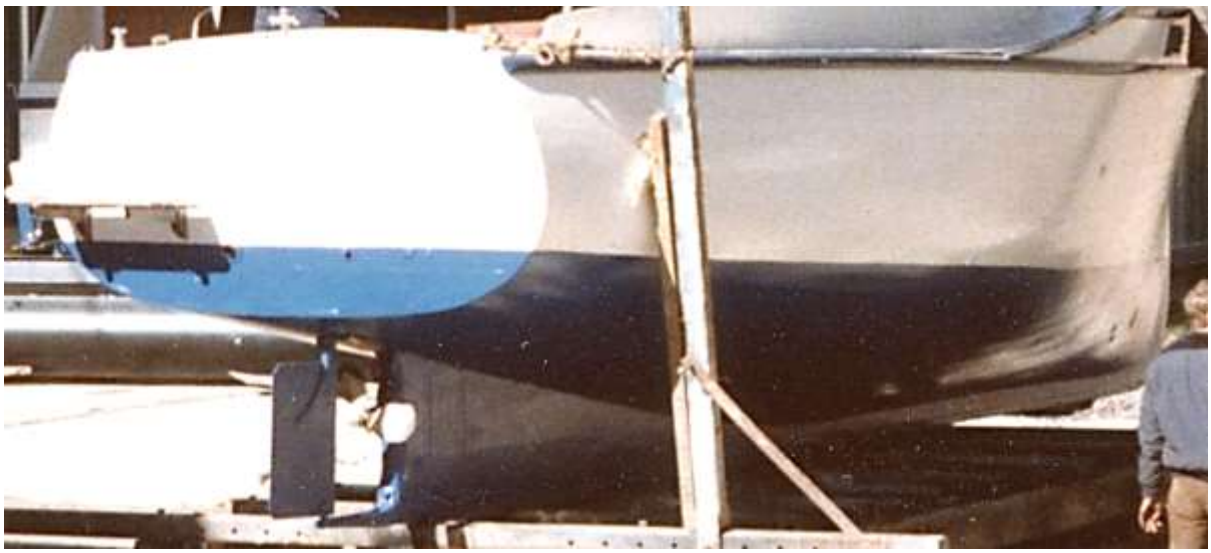
This document contains some important basics of model solar boat design. The document is aimed at the junior competition and assumes the use of Scorpio components in the manufacture of the boat. Scorpio solar panel, motor and two blade propeller.

Please note that the test boat motor mount is manufactured using 3D printing in plastic. Any form of motor and propeller shaft mounting is OK provided it is accurate and stable.

Hull type:

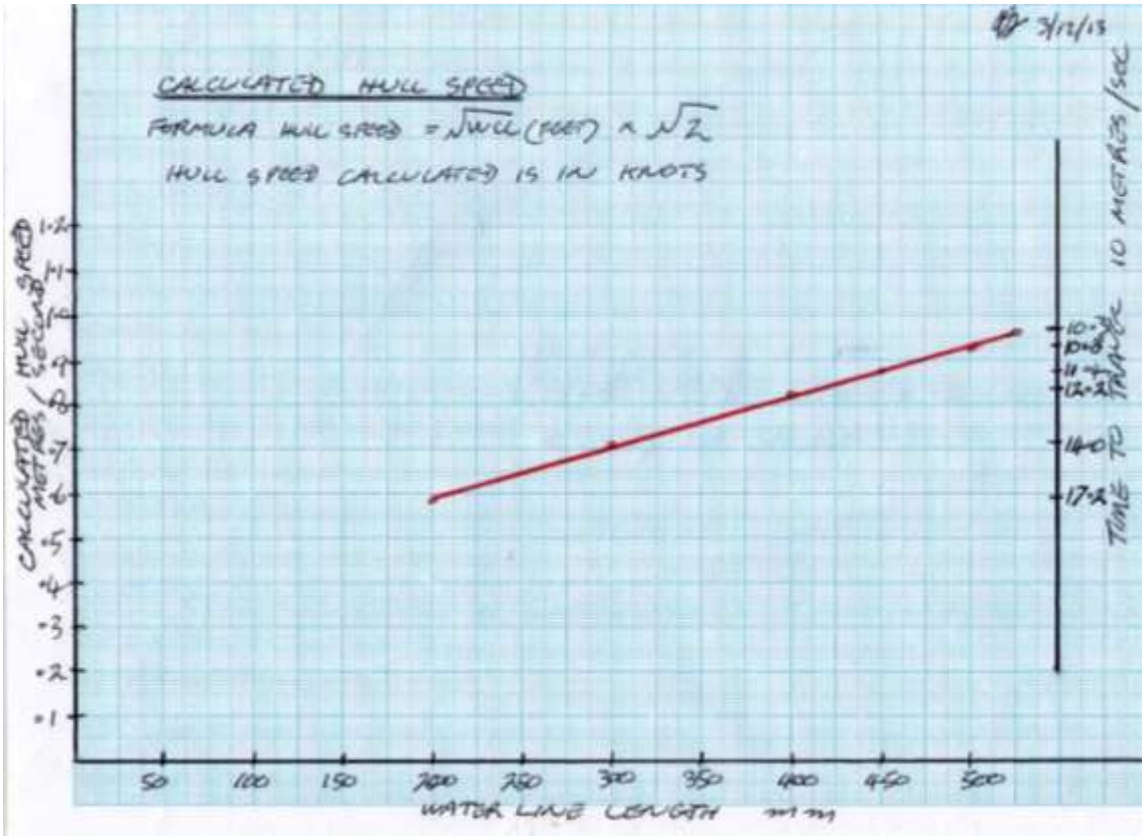
There are two basic boat hull types, displacement, which travels through the water, with the water flowing around the hull, and planing, which skims over the top of the water.

Below is a photo of a typical displacement hull. The three-dimensional curves allow the boat to move through the water with smooth water flow around the hull. The boat moves through the water with minimal disturbance to the water and small wake.



A boat with this hull shape glides smoothly through the water requiring only relatively speaking low thrust (and consequently power) to propel it to the maximum speed it can attain. A good approximation to the maximum speed this hull type can achieve can be calculated using the formula, Speed = Square root of 2 x Square root of water line length (in Feet)
The speed calculated is in Knots. 1 Knot = 1.12 Mph
To make it easy for you, graph 1 below shows the calculated speed and expected race time for a 10 metre pool for boats in the length range possible in the boat competition, when operating in displacement mode.

In order to achieve a faster race time than predicted below your boat must plane.



Graph 1

The thrust or pushing force required to propel the displacement boat to its maximum speed, usually referred to as hull speed is approximately 2.7% of the total boat weight, quite low.

A true displacement hull like the one in the photo above will never plane. As more thrust is applied the boat, speed will only increase slightly, the stern will drop and the boat will push a huge wake with all the extra power applied being absorbed in the wake.

Below is a photo of a planing hull the boat is skimming over the water surface at 70 Kph.

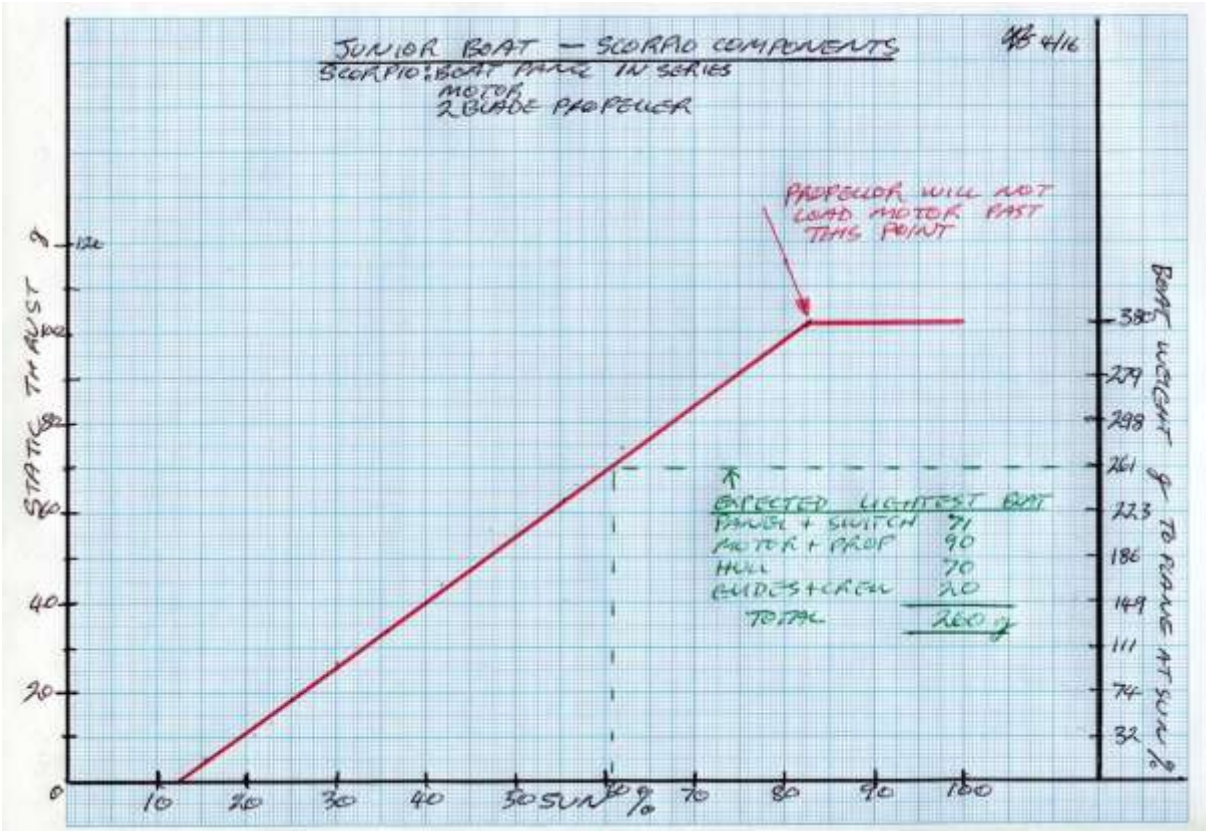
A boat with a planing hull will operate as a displacement mode at low speed. It is not as efficient as the displacement boat shown previously because of the turbulent water flow around the flat stern causing increased drag.
But as thrust is increased the hull shape allows it to skim over the water surface. It will start planning just above the hull speed if there is sufficient thrust available. To plane we need about 10 times the thrust needed to push it to hull speed when in displacement mode, a massive 27% of the boats weight. More thrust will further increase the boat speed.

What does this mean for your boat design:
Your boat design should be a planing type hull. From the race videos it is obvious that the better boats plane when the Sun level is high enough.
What is the best hull shape for planing? A flat bottom boat offers the best option with maximum lift at any particular speed when compared to V hulls. You do not see many flat bottom boats as the ride is bone jarring over even small waves. This is not an issue here as your crew will not complain.
The flat bottom applies to catamaran type boats as well as monohulls.
You should aim for the lightest weight boat possible as it will commence planning at lower Sun levels.

Boat weight:

The graph below shows the static thrust obtained from the Scorpio SM 403 motor and two blade propeller powered by a Scorpio boat panel configured in series against Sun %. The calculated boat weight to allow planning based on the previous data of thrust required to plane is 27% of boat weight, is shown on the right.

This data can be used to determine if the boat you have will be capable of planning or only running at displacement speed. An indication of the Sun level required to commence planning can be read from the x axis. Note: this data is calculated, boat characteristics will vary this slightly. The graph however gives a good indication of what you can expect. Testing of your particular boat is the only way to obtain accurate data.



Expected minimum boat weight:
I expect the lowest boat weight that you will be able to achieve is in the order of 250 grams based on the data below. (all Scorpio components.)

Motor propeller and shaft	90 g
Scorpio solar Panel and switch	71 g
Hull	70 g
TOTAL	**231 g**

Boat general:

- Accurate alignment of motor to propeller shaft.
- Propeller shaft angle as low as possible to maximise forward thrust.
- Light weight so planing will occur at the lowest Sun level possible.
- Stable ie. will not roll over or sink.

- Weight distribution: when at rest in the water the boat should be level side to side and sitting down slightly by the stern.
- Hydrodynamic shape to encourage planing and reduce drag.
- Smooth surface in contact with the water to keep drag low.
- Ability to configure solar panel in series or parallel to suit the conditions.
- Motor, propeller and Solar panel matched for maximum energy transfer, **this is taken care off as we have chosen to use Scorpio Technology components. You can test your boat with different components to obtain the best performance.**
- Ensure your boat complies with the regulations.

Guides:

Aim for lightest weight as possible, minimum panel shading and low friction on the guide wire.

Solar Panel:

There are a few things to consider in the solar panel department.

- Try to keep your solar panel facing the Sun. Maximum power is obtained when the Sun strikes it at right angles. Remember that as you tilt the panel air drag and wind effects become important. (The pool is usually laid out in a North – South direction.)
- Choose panel configuration ie. series or parallel connection to suit the Sun levels prevailing. For the test boat using Scorpio components the switching point from parallel to series is around 60% Sun. See graph below. This point will change with boat weight and design. Operate the solar panel in series as soon as possible as when connected in parallel motor losses are higher than in series resulting in decreased performance. (See Dynamometer test graph in "For the Engineer") When in parallel the motor speed is halved when compared to series resulting in the propeller not spinning fast enough to give you higher speed.
- Keep your panel cool, there is a power drop of 0.43% per degree C of temperature rise of your panel. Remember a panel left in the Sun for around 15 minutes can reach 70 degrees C. this means a power loss in the order of 17%.
- **Check that your solar panel has not been damaged and is still producing full power.** The web site has details of how to conduct an in Sun test which will give a reasonably accurate indication of power.
- Take care not to shade the panel as shading of only one cell in your array will significantly reduce power.

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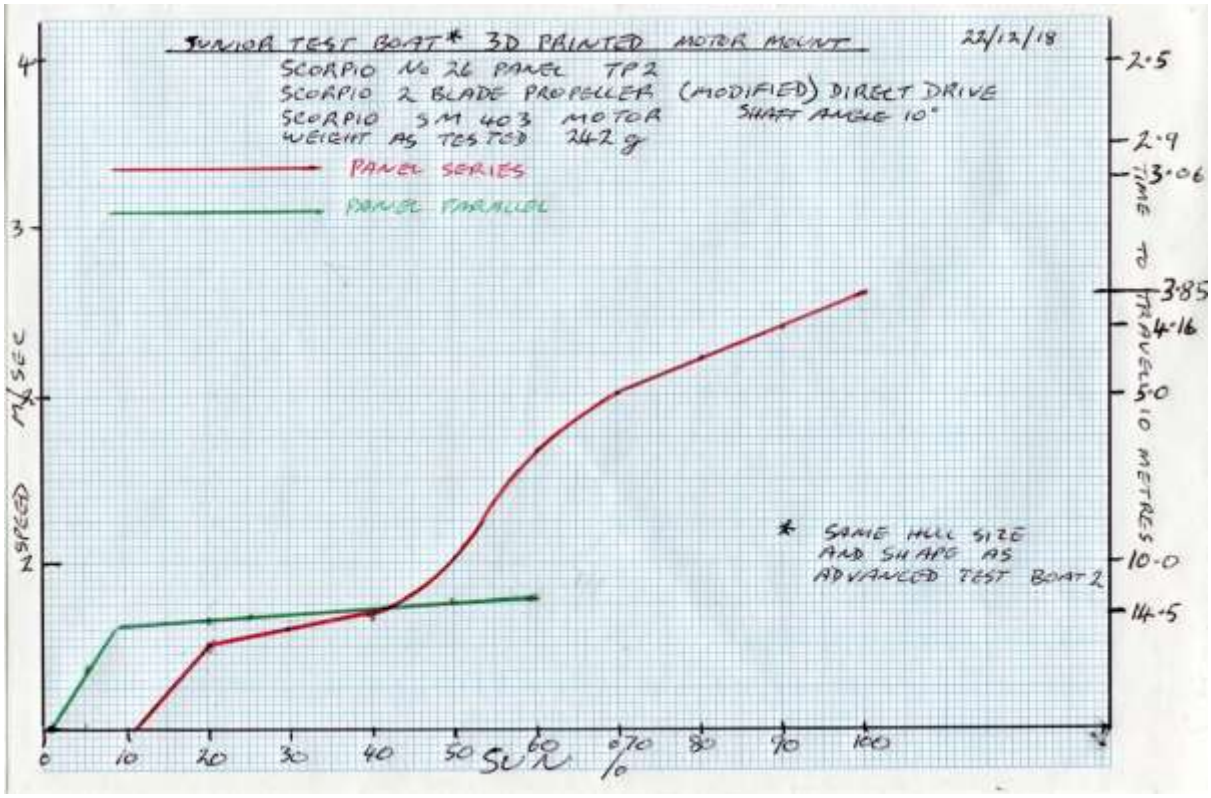

Junior test boat 2A performance at various Sun levels.

Test boat running at speed in a pool. (100% Sun race time expected is 3.9 seconds)