The Shap of
A two part series in which Graham Taylor examines fast boat design as we speed into the 21st Century
perhaps more important than the fine-
ess of present hull design. Perhaps it
is time for a purpose built craft, which
is where the wave-piercer comes in.
On the face of it there is nothing par-
ticularly new about going through
waves rather than over them. After all,
the fine bows of warships have
ploughed the seas for the last century.
But have you ever noticed how even
modern destroyers still seem to make
hard work of moderate seas? Wave-
piercing aims to take rough water per-
formance to a new dimension.

**Going Supercritical**

In waves conventional boats just get
thrown about more the faster they go,
and there comes a time for crew,
machinery or RC gear, when enough is
enough. Indeed powerboat drivers can
'pull more G's' than a jet fighter pilot!
In contrast, beneath the narrow sharp
lines of the wave-piercer lies the rather
radical idea that the effect of waves can
be smoothed out by going faster. It is
to do with natural frequency. If we
return to image of the destroyer
ploughing through rough sea, notice
how the bows of these vessels rise up
and down like some kind of huge pen-
dulum. The thing about pendulums is
that they take only a small amount of
energy to keep them going provided
that it is synchronised with the 'nat-
ural frequency'. If, on the other hand,
you try to swing a pendulum faster
than its natural frequency it puts up
quite some resistance. A boat has a nat-
ural frequency, depending on its
length, weight distribution and other
factors, which makes it sensitive to
waves of certain critical frequencies.
The idea of going 'supercritical' is to
drive through waves quickly enough so
that they are encountered faster than
the natural frequency of the boat. In
this way the pendulum effect acts
against the wave forces rather than
with them, to give a nice smooth ride.

**Figure 1** illustrates the difference
between conventional and wave-pierc-
ing hulls. Although wave-piercing
seems to suggest that the boat would
be wetter and therefore subject to
more drag, advantages like the prop-
eller spending less of its time flailing
about in free air and more time actual-
ly pushing the boat along make it a
valid rough water solution. Because
conditions vary, an ideal craft needs to
combine both rough water and
smooth water performance.

The future so often begins in the past
and wave-piercing is no exception.
One of the early pioneers of wave-
piercing, Peter Payne (an engineer
and boat designer in the USA) revealed
the world a rather odd looking craft called the 'Sea Knife'
back in the 1970's. Some of us may
ever remember it appearing on
'Tomorrow's World' TV programme.
The Sea Knife's deep wedge shape
gave it a soft ride through most waves,
while the upper hull was flared to lift
the boat should it encounter really
large ones. In calm water the boat
planned on a small flat bottom.

The latest wave-piercing design is the
13 m long V50 of Paragon Mann.
This tremendously impressive craft
combines fine bow and round bilge
lines with large chine rails. Rough
water and calm water performance are
achieved by pumping fuel between
tore and aft ballast tanks, which moves
the centre of gravity forwards or back-
wards and so lowers or raises the nose.

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**The razor bow of the V515c cuts through waves at speeds of
over 5knots. (courtesy: Photographic Section, HMS Osprey)**
The narrowness of wave-piercing hulls can be clearly seen in this shot of an Australian built SeaCat ferry.

Running with the nose held high the craft adopts a planing posture for calm water, while with the nose low it runs in wave-piercing mode. Another feature of special note is the cleverly designed superstructure shape which makes the craft self-righting - a feature worthy of attention in model design.

**A Model Wave-piercer?**

The biggest problem the author foresees on building a model wave-piercer is the effect of propeller torque on the narrow single hull, which would tend to twist the craft onto one side. A water-jet system, which is relatively torque free, is a natural solution and several model units are now on the market. (Contrarotating propellers would be another solution.)

If you are blasting through waves rather than over them you will have a

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*A selection of Sir John Isaac Thornycroft's original stepped hull test tank models dating from 1877, perhaps the very ones in the story! (Hovercraft Museum Collection)*
Small steps can be seen in the underside of this 4 litre racing monohull.

attached to the bottom of the rudder, so that by tilting it fore or aft the boat is pivoted up or down about the centre of gravity. With the latest car ferries and the VSV 50 design the wave-piercing concept has definitely come of age. We can expect to see more wave-piercing thinking evident in the design of civil, military and racing craft in the future.

Step Back In History

Having explored latest thinking on how to go faster through the water, let us look at how to go faster across the water by the use of steps. The story of development of the stepped hull entered boat design folklore many years ago. Once upon a time, just after the turn of this century, a leading boat builder, Sir John Isaac Thornycroft, used model tests to compare three concepts for a torpedo boat: a planing hull, a sea sled and a stepped hull. He found that the stepped hull form was much faster than the other hulls of the same power. The findings led directly to the development of the stepped hull Coastal Motor Boat (CMB) of the First World War. These remarkable craft could achieve 40 knots, which is a phenomenal pace for a torpedo boat even by today's standards.

Such stepped hulls were not without disadvantages. They were sensitive to variation of centre of gravity, susceptible to 'porpoising' - bouncing between step and transom, while the step caused high drag at low speeds doing little for fuel economy. In addition the structural complications of manufacturing the step seriously challenged the engineering of the day. All in all, they exhibited the kind of highly-strung quirkiness you might expect from a 'thoroughbred' design. Nevertheless stepped hulls continued to be popular for both racing and military use until around the Second World War, after which the all-round versatility of the conventional 'monohull' took over. Meanwhile in the quest for speed, the stepped-hull evolved into the 'three pointer'.

So much for the history lesson; is there any point in resurrecting this technology? The answer is a resounding yes! For a start, the structural and engineering problems associated with the construction of the old craft have been superseded by today's modern materials and techniques. What was difficult to build from wooden planks is a cinch in epoxy and GRP. Besides, our fast models don't necessarily have to reflect the design criteria of full scale craft, so some of the disadvantages have little significance for us.

One Step at a Time.

Two advantages of steps in a hull are that they help reduce the wetted area
and therefore reduce the drag, and they control the angle of attack of the planing surfaces.

For an un-stepped monohull or catamaran (ignoring the effect of propeller thrust, aerodynamic lift and drag) the centre of gravity (C of G) of a boat cannot be ahead of the hydrodynamic (planing) lift or the boat will fall on its nose. This means that no matter how fast the boat is going you are stuck with a certain minimum amount of hull in the water: approximately a triangle from the C of G back to the transom - see Figure 1. As the boat goes faster this triangle gets narrower, but not shorter. The position of the centre of gravity therefore dictates pretty much the length and shape of the wetted area 'footprint' on which the boat sits.

The further forward the C of G is, the longer the wetted area footprint must be. For this reason many racing boats have all the weight at the back, so that the distance between the C of G and the transom is as short as possible. This in turn gives rise to the sort of boat that sits around with its bow pointing skyward, but flattens out at speed. Consequently the angle of attack of its planing surface varies throughout its speed range, to the detriment of its performance.

It turns out that a lot of the 'wetted area' towards the transom does not add much to the lift but does contribute to the drag. By using steps this area can be broken up, allowing air to be drawn in and help 'lubricate' the hull, so reducing drag and increasing speed. These sort of steps are appearing in many modern racing craft as a way of reducing drag on long boats. As on the early boats, steps can be used to create a front and rear planing surface, with the centre of gravity somewhere in between. This 'tandem' arrangement holds both front and back planing surfaces at their most efficient planing angle. As a result lift is generated fore and aft and the boat rises parallel in the water. Unlike the monohull, which needs to balance on a 'footprint' of a certain size, the stepped hull 'hydroplane' can reduce its footprint to virtually zero, cutting drag to a minimum and giving it a great speed advantage.

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In Part Two we look further at the bearing that the stepped hull technology of the turn of the last century could have on powerboating in the next, and consider how the aerodynamics of what happens above the water could change by the 21st century.