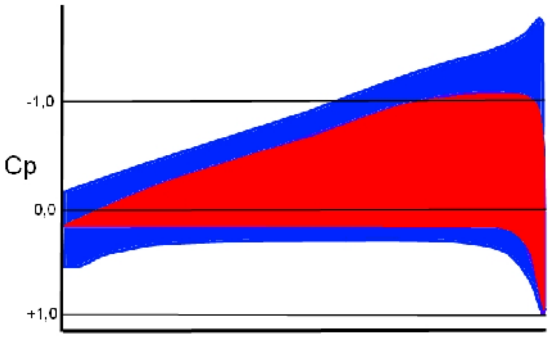
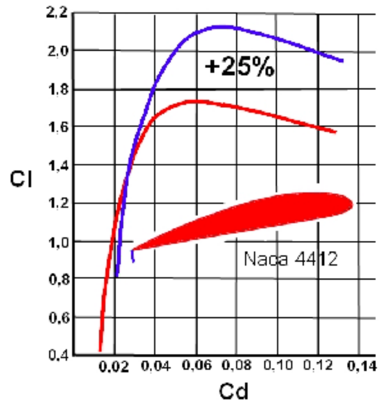
Interceptors in theory and practice

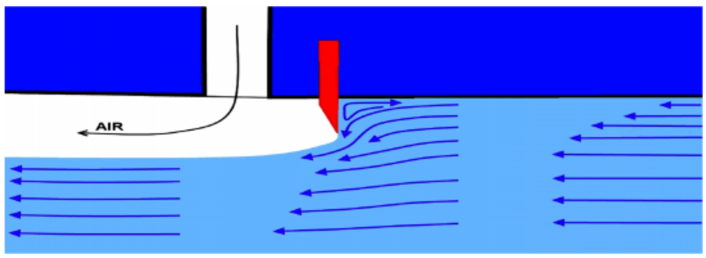
An interceptor is a small vertical plate, usually located at the trailing edge on the pressure side of a foil. The effect is a completely different pressure distribution and much higher lift than the original foil has.



Naca 4412 w interceptor



The above is an example; red shows the initial pressure distribution, blue the growth through the interceptor impact. In this example, the lifting force increased by 25% without any significant increase in drag. Note that the pressure force has doubled on the bottom of the foil, the pressure side. It is this effect that is active when interceptors are used on the bottom of boats.



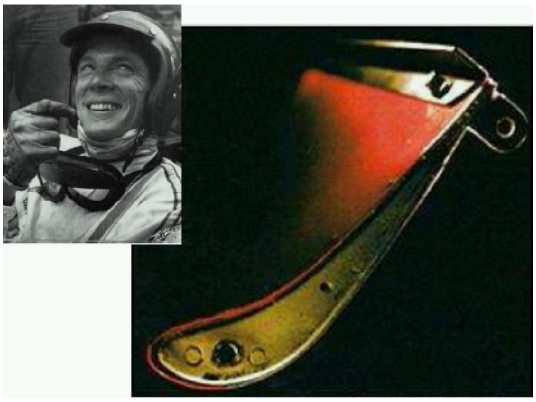
For many years I studied and practiced the use of interceptors in different boats. In doing so, I have been fascinated by its simplicity, efficiency and great opportunities. Properly designed and positioned can an interceptor generate double lift force or drag halved in comparison with conventional solutions.

For a long time I have collected over eight hundred pages about the interceptors. These are independent scientific reports from around the world. The oldest is from 1932. From this extensive material I have chosen what is of interest in order to generate a reliable calculation method.

A lot of new knowledge has been added in the last years of experimentation in model and full scale. Today, we can calculate the interceptor lift and drag, and thereby optimise the boats over all characteristics over the entire speed range. It is possible to calculate total lift force and power requirements.

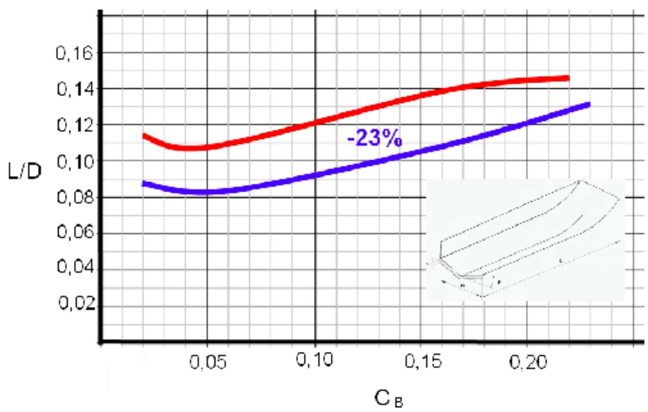
Interceptors can also significantly improve the characteristics of hydrofoils and propellers.

Already in the early thirties two German scientists, E. Gruschwitz and O. Schrenk, almost discovered the great opportunities of the interceptor. Their study was mainly focused on creating very high lifting power. Drag in relation to the lift force, the glide ratio, was of secondary interest. With the current knowledge, the interceptor penetration was far too large to create a favourable glide ratio.



It was not until 1971 that racecar driver Dan Gurney by chance discovered the interceptor effectiveness. Therefore interceptors are sometimes referred to Gurney flaps. When he reinforced the wing trailing edge, which had been deformed by rough handling, the car got entirely new quality. He managed to keep his discovery secret for several years. The competitors thought that the angle iron on the wing would only slow down the car. In fact, this increased the downward pressure considerably and thus the car could be driven faster.

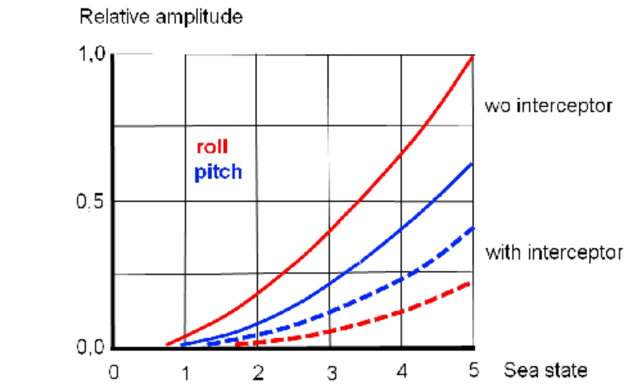
In 1978 Dan Gurney began collaborating with Douglas Aircraft to develop his discovery more systematically with the aim of a patent. This failed however, when it was found out that there was already a patent for a similar device from 1931.



L/D boat's weight / drag ratio
C_B boat's relative weight

Russian scientists led by Bannikova undertook extensive towing tank trials with prismatic hulls with different loads and bottom deadrise. The diagram above illustrates the results on a boat with 12 degree V-bottom in full planing speed. Interceptor depth must be adjusted to the boat's weight and speed. The drag can be reduced by 23% or speed can be increased corresponding to the same engine power.

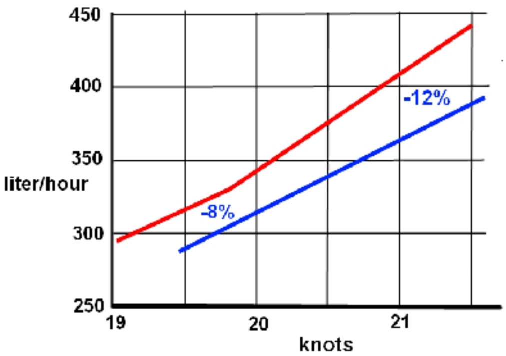
This work formed the basis of applications at full-scale boats.



In 1983-85 G. Fridman and others carried out practical tests with patrol boats equipped with interceptors amidships and at the stern. A speed increase of 24%, from 37.5 knots to 46.5 knots, was recorded. This work also showed that the boat's behaviour in a seaway could be controlled. By adjusting the interceptors could large reduction in the boat's motion be achieved, both longitudinal and transverse, pitch and roll. Transverse movements could be reduced to a quarter. They also discovered that several interceptors placed one after another did not work as expected, but were unable to explain the phenomenon. Today we know better.

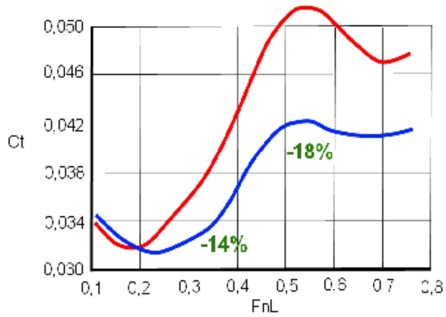
After several years of collaboration with J. Koelbel and E. Clement to develop their cambered step bottom, I started in 2006 experimenting with boats equipped with a midship positioned interceptor. By making the interceptor adjustable the boats efficiency could be increased over a wider speed range. Top speed with 8 horsepower increased from 15.0 knots to 19.3 knots.

http://www.youtube.com/watch?v=TyTutGvjP40



Under the leadership of Karl Garme, KTH in Stockholm, an extensive study was carried out on wave formation and fuel consumption of a passenger boat. The results were presented in a report in 2007. It is stated that the fuel consumption can be reduced by up to 12% with a transom-mounted interceptor.

In my collaboration with Peter Norlin the above 8.5-meter round-bottomed boat was provided with a fixed interceptor at the transom. With a 7.5 millimetres deep interceptor the boat top speed increased from 14 knots to 16 knots. This is a fifteen percent increase in speed. To accomplish this else would require a 25-30% larger engine and correspondingly higher fuel consumption



A. Day and C. Cooper studied stern interceptor effect on a boat in the Open 60 class. They were able to measure a resistance reduction in flat water of 10-18% at speeds between 8 and 20 knots. A revised report was published in 2011.

$$\Delta C_{LB} = \frac{\Delta L}{\frac{1}{2}\rho V^2 B^2} = 169.81\left(\frac{h_i}{B}\right)^2 + 3.78\left(\frac{h_i}{B}\right)$$

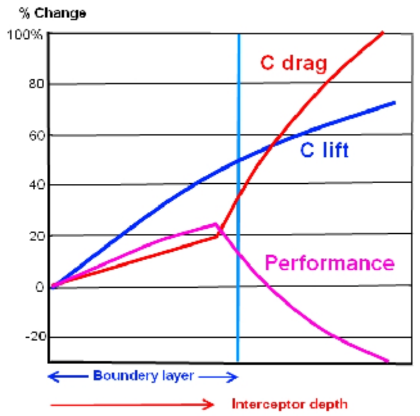
$$\Delta C_{TBL} = \frac{\Delta D}{\frac{1}{2}\rho V^2 B \cdot L_W \cdot \tau} = 292.18\left(\frac{h_i}{L_W}\right)^2 + 7.813\left(\frac{h_i}{L_W}\right)$$

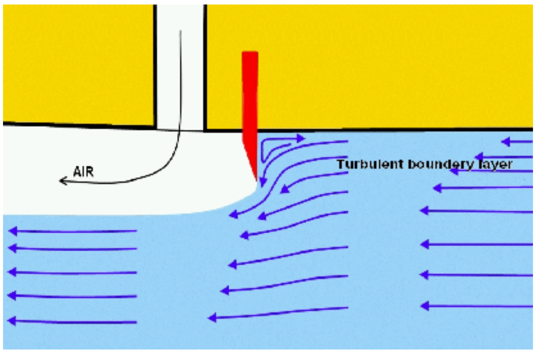
Under the leadership of Sverre Steen at NTU in Trondheim, extensive studies have been carried out. Model experiments have been mainly focused on improving the high-speed passenger craft efficiency. Measurement of the different parameters has led to preliminary calculation methods for lift and drag from interceptors.

With the interceptors in the right position, all boats properties can be improved over the entire speed range, reducing drag, wave formation, trim angle, rolling, pitching, turning radius and fuel consumption.

As mentioned above, I started my own interceptor experiments in 2006 with extensive model tests that confirmed my assumptions. Some of the ideas were based partly on the model test I had previously done with cambered arrow shaped transverse step in my partnership with Koelbel and Clement. The results from the tow experiments formed the basis for a conversion of a 5.5-meter boat that was originally designed for rowing and electric drive.

http://sassdesign.net/InterceptorpresentationengJGK%20JS.pdf

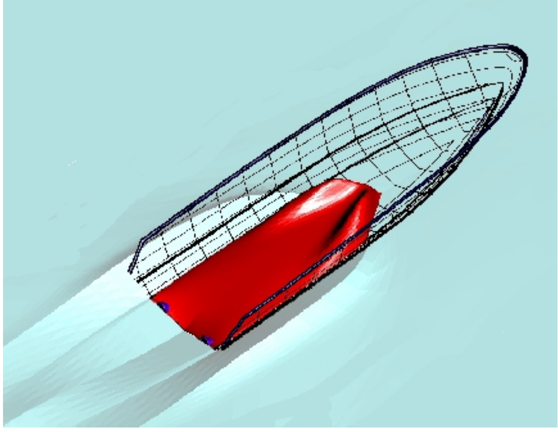


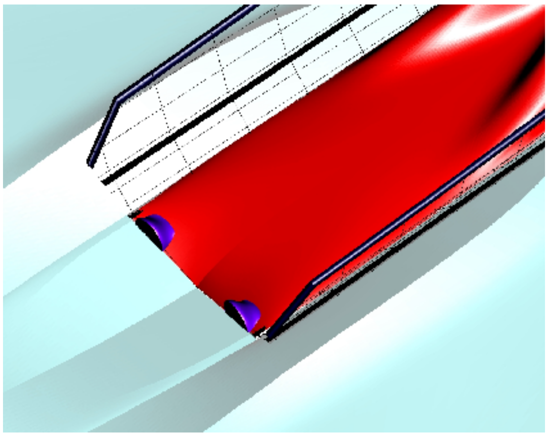


At an early stage it was detected by these experiments that the interceptor efficiency somehow was related to the boundary layer thickness and the penetration of the interceptor. The boundary layer thickness is dependent on the speed and the forward wetted surface length, and the water characteristics. In addition, it was discovered that the interceptor depth must be adjustable during operation to the current need for lifting power.

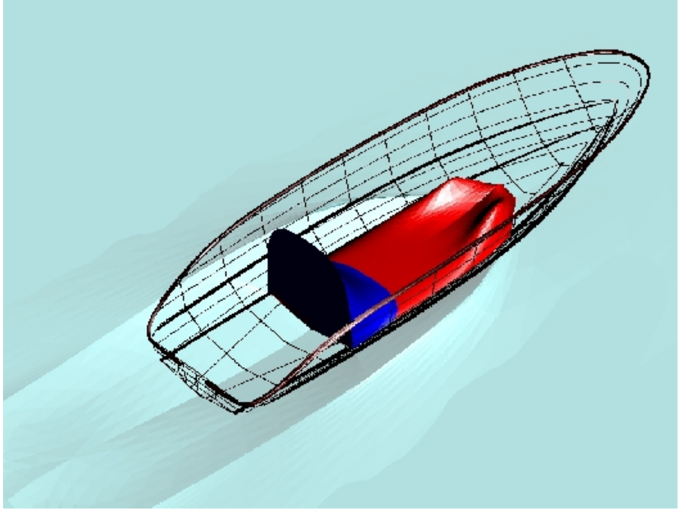
If the interceptor create too high lift it reduces the forward wetted length and thereby the boundary layer thickness, wherein the interceptor efficiency drops. The result may be that the boat starts to jump up and down, similar to what is called porpoising. Travelling in seaway requires a little more lift, corresponding to the imaginary weight increase through the vertical acceleration, the g-force. In order to get the bottom aft dry rapidly and the friction surface thereby minimized, an effective air supply behind the interceptor is required.

The trials also included interceptors amidships at the waterline in order to control the transverse stability.





On a normal V-bottom planing boat the lifting force is highest at the stagnation line. At the transom the pressure equalized completely, that is, there is no lifting force. This kind of lifting force distribution makes that the boat can get very high trim angle at certain speeds and thus considerable drag. In order to optimise the trim angle are trim tabs or small interceptors on the transom used. The lifting force is limited by of the interceptor span. The above is an example; red shows the initial pressure distribution, blue the increase by the interceptor.

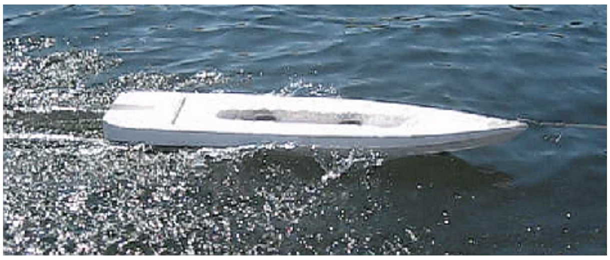


If the interceptor is spanned over the entire transom or the entire bottom, this technology can be used much more efficiently. Somewhat simplified, we can now regard that the boat has two separate systems for the lift and drag acting around the boat's overall centre of gravity.

The lift force and the drag of the planing surface depends of the shape, angle of attack and the speed. The planing bottom is usually calculated according to Savitsky, Almeter, Radojcic and others. The lift force and the drag of the interceptor depend of the span, the penetration into the boundary layer and the velocity.

There is an optimum of how much lifting power can be taken from the planing surface respectively the interceptor to obtain maximum efficiency.

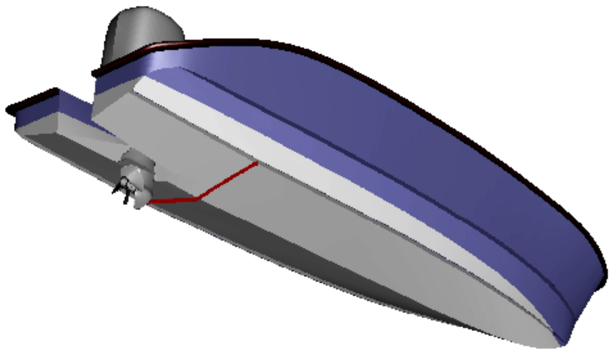
Based on this extensive background material, I have managed to create a reliable method for calculating interceptors lifting power, drag, pressure distribution and thus its effectiveness.

To get the new calculation method confirmed model tests and full-scale tests with a 5.5-meter boat were carried out in 2012.

http://sassdesign.net/Akterskepps%20interceptor.pdf

Based on the positive results could certain assumptions come true in practice. It is now possible to calculate the interceptor function in a satisfactory manner. Using an adjustable interceptor can control the pressure distribution over the bottom. The relationship between the interceptor span and distance to the total weight of gravity, CG, is critical for efficiency. The shorter the distance is, the more efficient is this concept. But it is more difficult to control the longitudinal stability.



Ecodream is an example of an optimised boat with an aft-ship interceptor. The interceptor has two tasks. Primary it is to provide lift with low drag, secondary to create a dry surface in the aft, thereby limit the frictional surface to a minimum. About half the lift force is created by the interceptor. Its position fore and aft must be notably positioned to get the desired fore and aft stability.

A number of applications of this technology are available at:
http://sassdesign.net/Langfardsbat.pdf

Most important information's I currently have attained through my research are:

to separate out interceptor effect by itself, and the effect due to change in trim angle
the interceptor lifting power is related to the penetration and span
the interceptor drag is related to the penetration and the boundary layer
that it is possible to halve the drag with maintained or improved seaworthiness

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