



Transmissions: Outdrives, waterjets and surface drives.

In today's powerboat market there are several different marine propulsion systems that can convert the power and torque of a yacht's main engines into propulsive thrust, in addition to direct drivelines with their various reduction gearboxes. Among these systems, the best known is probably the Z-Drive, otherwise known as outdrive, which is found on most small powerboats. Two other types of propulsion are also commonly used: waterjets and surface drives. The industry has seen some important developments in these two types of transmissions in the last fifteen years and they are now fitted on larger yachts as well as onboard commercial and military vessels.



A waterjet allows true emergency crash stop.

THE Z-DRIVES OR OUTDRIVES

In 1931, the Johnson Motor Company built the first steerable and tilting outdrives.

These sterndrives could be powered by marine engines up to 60 hp. Unfortunately, the economic climate and the onset of World War II

put a temporary hold on their development. In 1955, Volvo Penta

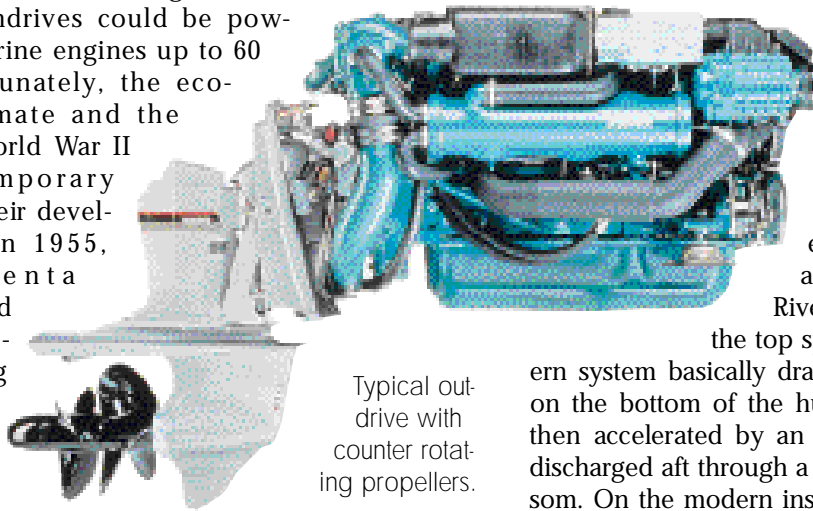
embarked on the manufacturing and marketing of a new Z-Drive

designed

by Jim Wynne, an offshore racing pilot and architect. This type of transmission became so popular that only three years after their introduction, 13 different companies were manufacturing similar sterndrives. These drives share some of the advantages of the outboard motors while being more closely associated with the advantageous features of inboards.

These drives have given the naval architects more freedom in designing the layout and accommodation of yachts. The engine room, located aft, does not interfere with the rest of the yacht's internal volume and can be more efficiently insulated. The auxiliary systems (cooling and exhaust systems, propeller shaft, steering gear, etc.) are limited and the engine installation is much simpler. Moreover, the location of the engine/transmission package allows the designer to optimize the vessel's longitudinal center of gravity, which is a key factor in the speed and performance of a planing hull.

As far as the performances are concerned, these drives offer a good propulsive efficiency with limited mechanical losses, a lower appendages resistance, and good maneuverability at high speeds. The propeller angle can be adjusted according to the longitudinal trim and therefore improve the overall efficiency. The latest generations of outdrives are fitted with counter-rotating propellers which reduce the parasitic torque and give better directional stability and maneuverability in reverse gear.



Typical outdrive with counter rotating propellers.

THE WATERJETS

Although this type of propulsion is considered relatively modern, it is stated in a

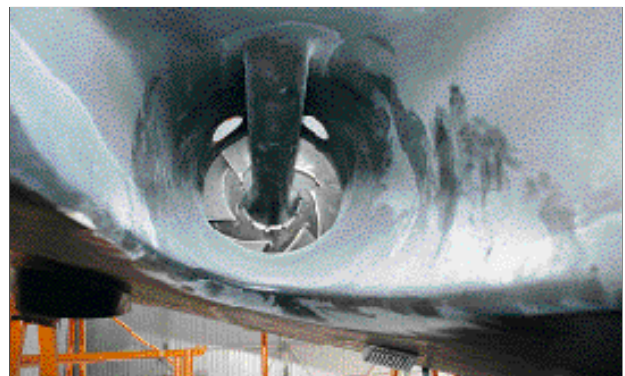
book by Philip Pratt entitled "The Birth of the SteamBoat", that this method of propulsion was first patented in Great Britain in 1661. The first prototype driven by a steam engine was built in the USA

and tested on the Potomac River in 1787 where it reached

the top speed of 3.5 knots. The modern system basically draws water through an intake on the bottom of the hull, where the water flow is then accelerated by an engine-driven impeller, and discharged aft through a nozzle mounted on the transom. On the modern installations, the inlet geometry is optimized to increase water flow efficiency and limit cavitation. The second element is a single or multi-stage pump, depending on the size and speed of the boat. The outlet is generally fitted with an adjustable nozzle, controlled by hydraulic rams to



Two directional waterjets and one fixed power waterjet at center.



A water inlet onboard a Mangusta 105' TS.

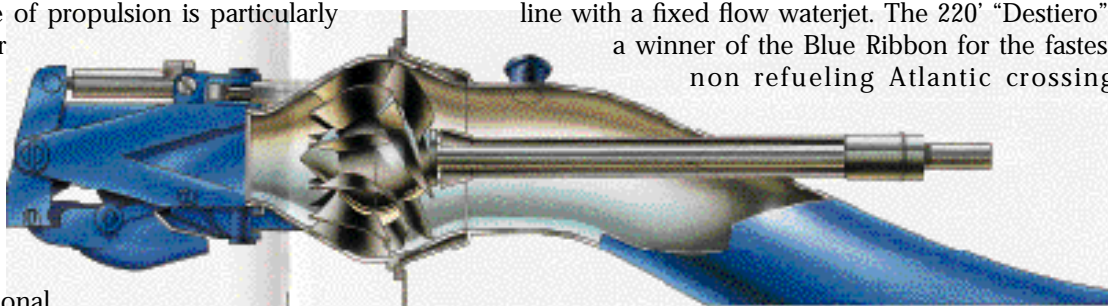
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provide directional and sometimes trim control. The usual means of going astern is through a movable bucket or cowl arranged to redirect the flow of water from the nozzle so that it discharges forward. It must be noted that the best output is obtained when the outlet nozzle is installed just above the dynamic waterline, i.e. in planing mode.



On board Eco, the waterjets appear enormous.

This type of propulsion offers several obvious advantages. The unit is compact and therefore easy to fit on board. Its installation requires only two outlets: one on the bottom of the hull and one on the transom. There are no shaft alignment problems and, providing the main engine and waterjet are matched, the installation of a reduction gearbox is not needed. Moreover, the impeller is enclosed, which drastically reduces the risk of personal injury for swimmers and damage by collision with floating debris. With no appendages (struts, rudders propellers, etc) the maximum draft of this vessel is limited to the hull draft. This type of propulsion is particularly well suited for vessels operating in shallow water. Finally, the vessels fitted with these systems incorporating directional



Section through a waterjet.

and reverse controls have very good maneuverability. The turning radius of a yacht equipped with a waterjet is about twice its waterline length. The reverse motion is created by reversing the flow of water so that the engine and the gearbox don't have to withstand high loads during the maneuvers. Hence, the stopping distance is reduced and the reverse flow

efficiently acts as a brake.

Waterjets have been installed on numerous commercial and military crafts of all types and sizes as well as on many pleasure yachts. Among the large pleasure boats fitted with waterjets, the King of Spain's 100' yacht "Fortuna" is powered by two waterjets driven by diesel engines which has a cruising speed between 20 to 25 knots, while the centerline water-

jet driven by a gas turbine allows it to reach a top speed of 52 knots. The 135' "Octopussy" is also powered by diesel engine driven waterjets. In 1983, the launch of the yacht "Shergar", with a displacement of nearly 240 tons, pushed the limits of these installations even further. With two gas turbines developing a total of 14,000 hp and coupled to a single box which drives a KaMeWa waterjet, "Shergar" reaches a maximum speed of 45 knots. Waterjets are even being fitted on the production built Mangusta 105 TS, powered by two MTU engines driving two steerable waterjets and one 4000 hp gas turbine on the centerline with a fixed flow waterjet. The 220' "Destiero", a winner of the Blue Ribbon for the fastest non refueling Atlantic crossing

record, was powered by three KaMeWa hydrojets driven by gas turbines providing up to 18,700 hp each, for a combined total of 56,100 hp!

The world's largest waterjet companies, KaMeWa of Sweden and Ultra Dynamics (ex Dowty Hydraulics) of North America, continue to design more and more powerful and efficient systems for military and civil applications.

→ SURFACE DRIVES

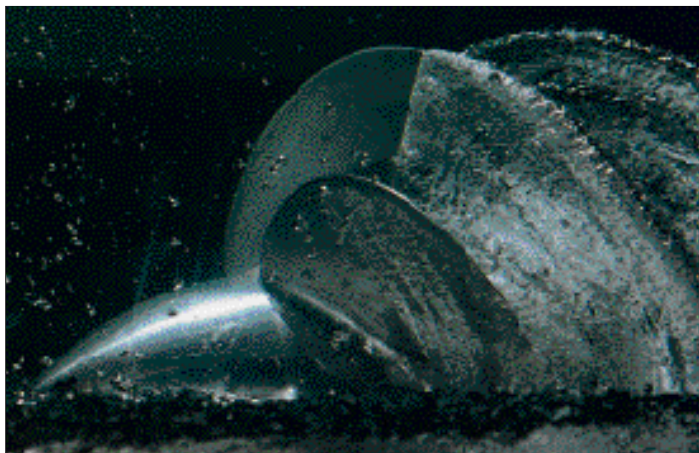
These transmissions first appeared on offshore racing boats, but in the past 20 years, the technology has been applied to the commercial, military, and pleasure boat industries. The excellent performance of surface-piercing propellers combines the simplicity of sterndrives with increased torque, maneuverable with hydraulic controls. In fact, these propulsion systems are very simple. The torque of the engine is transmit-



ted in a straight line from the engine to the propeller through a universal joint system to allow for the adjustment of the trim and the steering of the boat.

These eliminate the output losses associated with the use of Z-Drives, thus allowing more efficiency for the same nominal power. The thrust of the propeller is transmitted directly to the transom requiring that the engineering and construction of the vessel be particularly suited for the resulting stresses. Manufacturers such as France Helices or Arneson Surface Drives offer

A surface-piercing propeller seen inside a cavitation tunnel.



Surface-piercing propellers at a running speed of more than 50 knots.

a wide range of transmissions which can be fitted on crafts up to 135' in length.

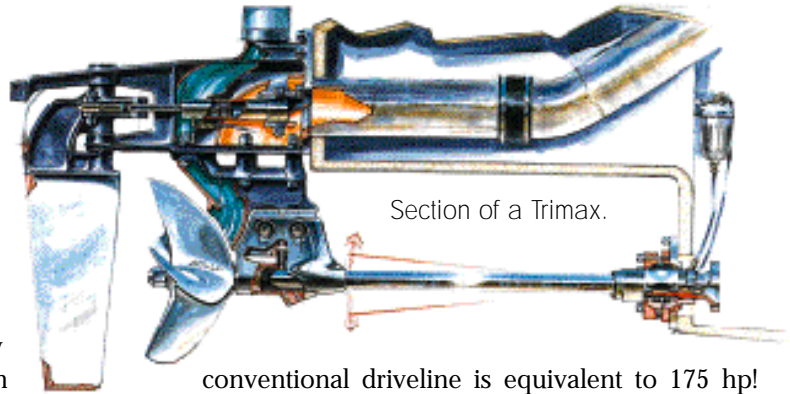
In simple terms, a surface-piercing propeller has the axis of its hub at the level of the dynamic waterline and at some distance from the transom. The main feature of these propellers is that each blade is out of the water for half of each revolution. Although it seems to be far from efficient, this intermittent thrust is in fact more efficient than a fully immersed propeller. In theory, a larger diameter propeller has a better output, but on a conventional driveline, the propeller diameter is limited by the location of the engine, the angle of the shaft, and the clearance between the hull bottom and the tip of the blades. All

these factors contribute to limit the maximum propeller diameter to something substantially smaller than the optimum dimension. These limitations disappear with a surface drive. Furthermore, the parasitic phenomenon of conventional propellers, known as cavitation, is replaced by ventila-

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tion with surface propellers. At each revolution of the blade, an air bubble fills the void in front of the blade. This eliminates the cavitation phenomenon and its adverse consequences (blade erosion, vibrations and noise).

The universal joints and hydraulic controls of the surface-piercing propeller transmission give it a variable geometry so that the immersion of the propeller can be permanently adjusted. The result of varying the immersion of the propellers is the same as if one were able to vary the diameter of the propellers. Finally, this type of transmission limits the draft and reduces the drag caused by appendages and their influence on the performance. For instance, a pioneer of this type of propulsion, the well-known power boat designer Renato Levy, reports that a 31 ft water-line fast commuter, powered with a total of 750 hp engines, reached a maximum speed of 41.5 knots with conventional drivelines and propellers. Another vessel with the same engine power and displacement



conventional driveline is equivalent to 175 hp! The single real problem of boats equipped with a surface piercing propeller is their poor performance in reverse. This is mainly due to the geometry of the asymmetrical propeller blades which have very thin leading edges and very thick trailing edges. Furthermore, the water flow of the propeller is directed onto the transom.

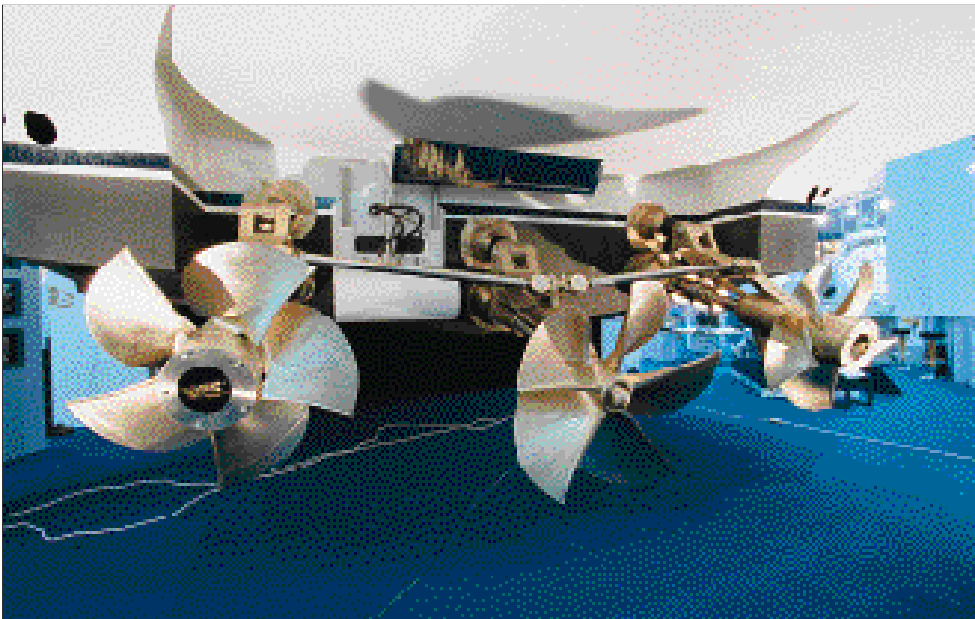
Other types of surface-piercing propeller transmissions have been developed during the past few years, such as the Trimax, by Italian offshore racer turned manufacturer, Fabio Buzzi, and by Levy Drive. These

transmissions were designed on the same concept, but the propellers are located even further aft of the vessel, have a limited diameter, and are only half immersed, so that they produce a similar yet improved performance. Nowadays, the designers and owners of yachts of all sizes can select the transmission system which best fits their performance and operational requirements, together with the space limitations for engine installation and/or interior layout. The use of stronger and lighter materials associ-

ated with more sophisticated and efficient control systems will continue to improve the efficiency and output of these "new" propulsion systems. Their use by commercial operators, such as the owners of high speed ferries, will eventually be beneficial to the pleasure yacht industry as well.

By Eric Ogden

For the first time, France Helices is fitting variable pitch propellers on their surface drive system for P.R. Marine's "Galactica" (formerly known as "Golden Eye").



reached 50 knots with surface propellers. This gain represents a speed increase of nearly 20%, due entirely to the reduction of the appendage resistance. At high speed, this resistance amounts for more than half the total resistance. To reach the same speed with conventional drivelines and propellers, the total power must be increased to 1100 hp. The conclusion is fairly obvious, the appendage resistance of each