Hydrofoil Pioneers...

The Up-Right Hydrofoil Kits

by Tom Lang

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This article was published in abbreviated form in The International Hydrofoil Society Newsletter*, Winter 97-98 Edition. However, the article appears here in full text. Published following the article is a fascinating email received from a (mostly) satisfied customer many years after purchasing, using, and modifying an Up-Right Hydrofoil Kit.*

- Click Here to see Helmut Kock's autobiography focused on hydrofoil boats
- Click Here to View Archived Correspondence About Adding Hydrofoils To Power Boats
- See Hobbyist Magazines to find articles about foil kits and motorboats with foils in *Popular Science, Mechanix Illustrated*, etc.

I was quite active in small-boat hydrofoil development from 1952 to 1960. During this period, I designed about 12 hydrofoil configurations, and then built and tested them with the help of my father. I obtained a patent on the final hydrofoil design, and licensed it to a company in California which made and sold about 80 all-aluminum kits for converting planing boats to hydrofoil boats. Although quite old by now, some of this information may be of use to those who would like to design and build a hydrofoil, or who would like to develop a hydrofoil kit for sale to others.

At the time, I worked at a Navy laboratory in Pasadena, California in the area of torpedo hydrodynamics. My father had a shop in his garage at nearby Redlands. I typically spent a few weeks designing each new hydrofoil configuration, and then my father and I would spend the next few weekends making hydrofoils, and testing them at Lake Elsinore or the Salton Sea. All designs consisted of add-on foils which converted existing 14-ft to 16-ft boats into hydrofoil boats. The hydrofoils typically added ten mph, doubled the fuel mileage, and smoothed the ride in waves.

All of the earlier hydrofoils were made of steel. Their upper and lower surfaces were curved plates welded at the leading and trailing edges, and then finished by carefully grinding the two edges to the required shapes. All of the later hydrofoils were made from 6-inch aluminum extrusions using a die that I ordered from Alcoa which had a 16-510 NACA airfoil cross section.

The first few configurations consisted of two surface-piercing, vee-shaped hydrofoils mounted in tandem on a 14-ft rowboat, with different kinds of roll-stabilizing means attached to each side. Figure 1 is a photo of one of these earlier hydrofoil configurations which was stabilized in roll on each side by a spring-mounted planing plate. The outer ends of the planing plates were bent upward to help keep the plates from submerging in turns. The bow foil angle was controlled by a control stick which could either be locked in position, or operated by a passenger in the front seat. The boat was powered by a 10-hp Mercury outboard, and achieved a speed of 32 mph with 2 people on board. We sportingly called it "the fastest rowboat in the world."

Figure 1. This 1952 hydrofoil boat design consisted of two vees in tandem with spring-mounted planing plates mounted on each side to stabilize the boat in roll. The outer ends of the planing plates are angled upward. This boat was powered by a 10 hp Mercury outboard motor, which provided a speed in excess of 30 mph with two passengers.

Other side-mounted roll stabilizers used on this early hydrofoil boat included: (a) a negative-dihedral hydrofoil, (b) the same foil with a tip extension welded on which had a positive dihedral, (c) a horizontal, arc-shaped planing hydrofoil placed flush with the bottom of the boat at the transom, and (d) a small vee-shaped hydrofoil attached to the underside of the horizontal planing foil. The latter design worked so well that we then eliminated the center vee foil at the aft end, leaving simply one bow foil and two stern foils.

The next major set of hydrofoil configurations began with the design shown in Figure 2. This hydrofoil design consisted of a three-vee, all-steel, clamp-on set of hydrofoils which could be mounted on most 14-to-16 foot boats without bolts. The kit weighed around 300 pounds. With a 25 hp Johnson outboard, the largest outboard available at the time, this hydrofoil boat achieved a speed of around 30 mph with a full load of five people, and a maximum speed of about 35 mph. The ride was remarkably good, even in fairly large breaking waves. The boat was so stable that it could be operated "hands off" in waves.

Figure 2. This 1954 three-vee hydrofoil configuration attained a speed of 35 mph with a 25 hp Johnson outboard motor. The all-steel, clamp-on hydrofoil kit weighed around 300 pounds. I am driving, and my father is seated next to me.

If the peak-to-trough height of breaking waves reached around twice the operating depth of the hydrofoils, then head waves would begin to hit the hull, and the larger following waves would occasionally cause the boat bow to plough into the wave crests, slowing the boat. This typically only happened under conditions when other boats of a similar size headed for shore for safety. This hydrofoil boat operated quite well in large ocean swells because they are typically fairly long, so the boat simply followed the water surface.

This hydrofoil design operated so well that I entered the boat in a predicted log race to Catalina Island from Long Beach, and back. The race was divided into two parts, with an overnight stay, and timed each way. My father and I left Long Beach with about 80 other boats early on a Saturday morning in a dense fog. Since our predicted time was based on an average speed of 32 mph, I gave it full throttle. We emerged from the fog as the lead boat, which was not surprising since boats were relatively slow in those days, and we had the largest outboard made. About 20 miles out, a head wind arose, and a large chop quickly formed. The boat handled the chop quite well, but I soon had to slow down to 25 mph when the chop got worse. We then hit an extra-large wave that came over the bow, leaving about four inches of water in the boat. After considerable bailing, we completed the last few miles at around 14 mph, just under takeoff speed. We clocked in at Catalina Island somewhat later than predicted. I then tied the boat to a buoy in Catalina harbor, and we went ashore. The next morning, we arrived well before the race, and found our boat was missing. Apparently, the tie rope had come loose, and the boat had washed ashore. The three foils were half buried in sand. By the time we had dug the foils free, and checked in at the start gate, the other boats had already left with a lead of several minutes. I again opened the throttle, and passed nearly all of the other boats. We came in fifth at Long Beach; however, our elapsed time was not close enough to our predicted time to win a ribbon.

After several months of use, it became clear that an all-steel kit was too heavy and expensive to be marketable. Therefore, I purchased an extrusion die from Alcoa, and all subsequent hydrofoils were made from extruded aluminum, together with their attachments. To save weight and cost, the hydrofoil units were designed to be bolted on. Figure 3 shows one of our next all-aluminum, handmade hydrofoil configurations attached to a fiberglass boat.

Figure 3. One of the first all-aluminum hydrofoil designs is shown mounted on an existing fiberglass boat. With a 40 hp Scott Atwater outboard motor, this boat achieved a speed of around 39 mph.

A photo of the bow foil is shown in Figure 4. Note the plate extending above the center of the foil tube; this plate is used for adjusting the hydrofoil angle. The plate angle is controlled by a short threaded rod which is attached by a universal joint to a long rod having a handle located near the driver. The bow foil angle is adjusted by rotating the rod, and can be adjusted when underway. The bow foil is retracted by removing two bolts from the central collar, and then pivoting it up and over the bow.

Figure 4. The handmade mount for the bow hydrofoil has the basic features of the later production kit. The bow foil is attached by four bolts. Note the angle adjustment plate and threaded rod positioned above the center of the cross tube.

Figure 5 is a close-up photo of a stern foil mount. The hydrofoil angle can be adjusted at rest by rotating the large knob shown in the photo. Also shown, is a spring-loaded motor mount which permits a short shaft outboard to be used with a standard short transom; this mount automatically lowers the motor about 5 inches when thrust is applied. Alternatively, a long shaft outboard can be mounted on a standard short transom. The motor shown in the figure is a 40 hp Scott Atwater. Alternatively, a 35 hp Evenrude was used on this boat. With either outboard, speeds of around 39 mph were achieved with two people in the boat.

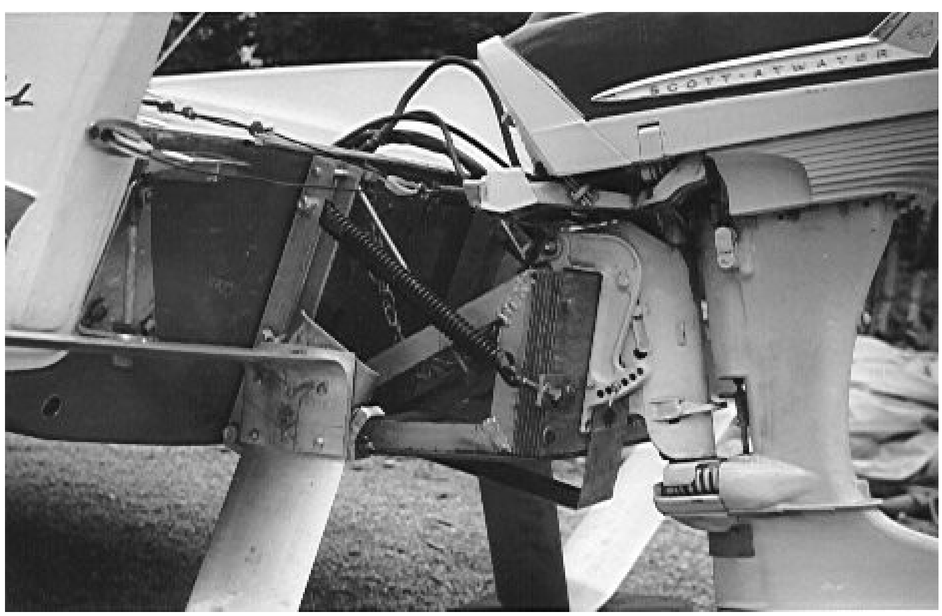

Figure 5. Each aft hydrofoil is bolted to the transom, and retracts about a 45-degree axis located at the inboard end. Note the adjustable spring-loaded motor mount, and the short-shaft outboard.

Several alternative bow foils were designed and tested in the 1950s including a base-vented bow hydrofoil, a superventilated bow hydrofoil, and a spring-mounted bow foil designed so that its angle of attack automatically reduced when lift and/or drag increased. The base-vented hydrofoil concept was patented as US #3,077,173 in 1963. However, these alternative hydrofoils did not seem to work as well as the final bow design. Figure 6 is a photo of my father with some of the various hydrofoil configurations that we built and tested in the 1950s.

Figure 6. This photo shows my father with several of the hydrofoil configurations that were designed and tested in the 1950s.

A note of caution for future hydrofoil designers: No matter how careful one is, the chances are that the hydrofoils will hit either a floating or a submerged obstacle if a boat is used often enough. For safety, I recommend attaching hydrofoils with shear bolts or shear links. To recover a sheared-off hydrofoil, a cord several-hundred-feet long is recommended. I once tried to retain a sheared-off hydrofoil with a 15 ft cable, but the cable snapped. Another mistake is to design a vee hydrofoil to rotate about a horizontal axis after hitting an obstacle. I tried this one time, and hit an unseen mud bar. The bow foil sheared off as designed, but the rear hydrofoils rotated back about 15 degrees, scooped up mud, and broke the transom. I found that a reasonable design load for shearing off a foil is around 500 pounds. If the design load is too small, the foils break free too often; alternatively, if the design load is too large, people can be hurt and/or the boat can be damaged. I once hit an empty soda can floating on the surface that wrapped around the bow foil. The drag of the can was not large enough to shear the foil off, but it caused my passenger and me to lose our seats and receive minor bruises, but fortunately nothing got broken.

Interestingly, during the 1950s I designed and tested a replacement for the bow foil consisting of a freewheeling, air-filled cylinder with segmented transverse stiffeners placed around its periphery designed so that the cylinder portion in contact with water deformed into a cambered, constant-pressure planing shape. This device was designed to operate much like an arc-shaped planing hydrofoil. Although this air-filled cylinder provided the necessary lift, its drag was larger than the drag of a vee hydrofoil, and it provided a rough ride in waves. Surprisingly, although mounted with roller bearings, and free to rotate, the cylinder did not rotate when underway.

I applied for patents on the final hydrofoil configuration and the spring-loaded motor mount in 1959, and the patents issued in 1963 as US #3,094,960 and #3,140,685. In 1960, I licensed these pending patents to the Up-Right Scaffold Company (Berkeley, CA). This company was interested in manufacturing hydrofoil kits because the kits would be made from the same kinds of materials as their scaffolds, namely aluminum extrusions and castings. I was introduced to this company by a fellow Caltech graduate who knew the vice president who was also a Caltech graduate. This company quickly designed and made the necessary tooling, and began selling Up-Right Hydrofoil kits in 1961 for $375. Figure 7 shows one of the kits.

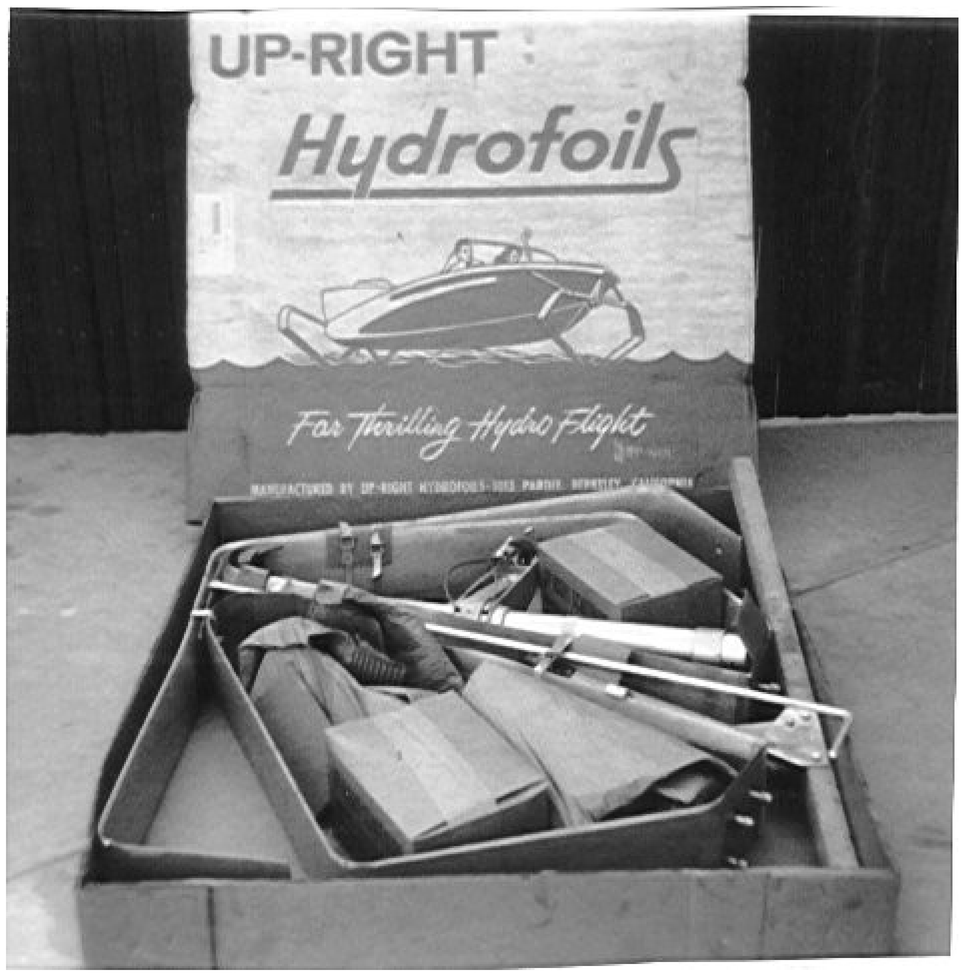

Figure 7. Up-Right Hydrofoil kit lying in front of the carton cover. About 80 of these kits were sold in 1961 and 1962 for $375 each.

Figure 8 shows a production bow foil mounted on a boat, in its retracted position. This bow unit is mounted using four bolts. Figure 9 shows a stern foil in its retracted position. Each stern foil is attached to the transom with three bolts.

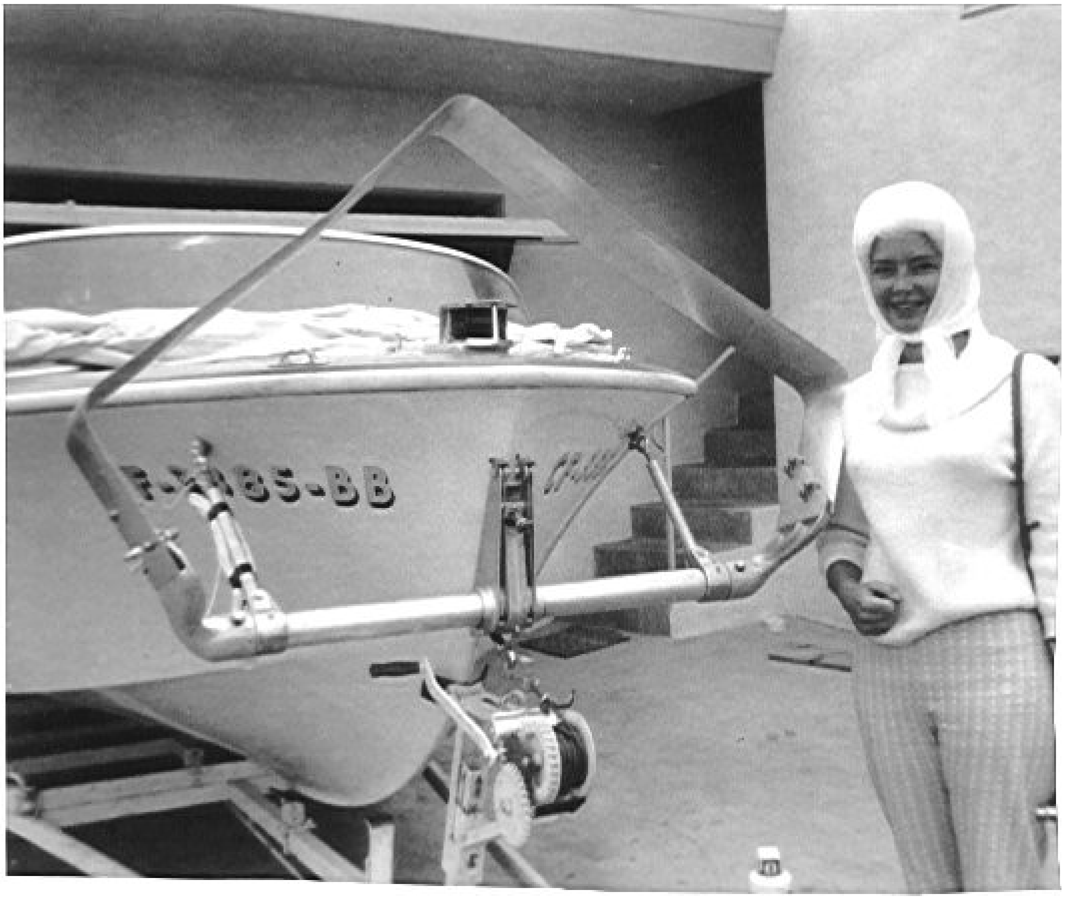

Figure 8. My wife with a newly-installed bow hydrofoil in retracted position. This hydrofoil can be retracted from the driver's seat, or adjusted in angle by the driver when underway.

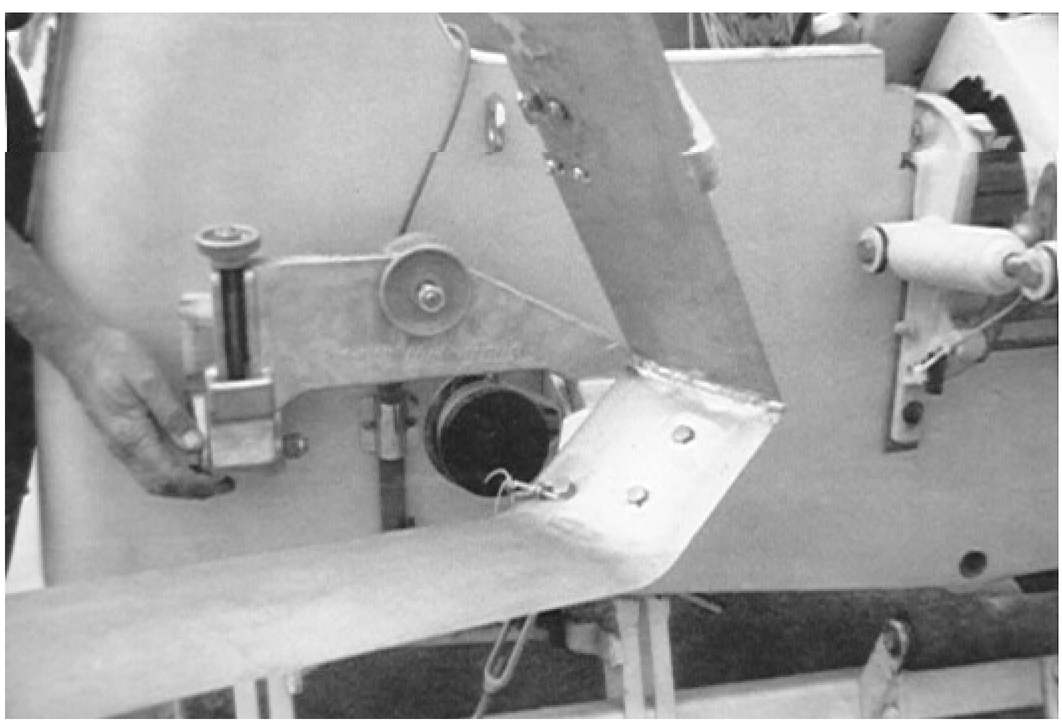

Figure 9. Each stern hydrofoil is mounted to the transom with three bolts, one of which is used to adjust its angle by rotating the large knurled knob. The small container with the black lid seen to the left of the inner end of the foil contains 500-ft of coiled cord for retrieving the foil in case it hits an obstacle and shears free from

its mount.

Figure 10 shows a 15-ft fiberglass boat outfitted with the production hydrofoils. With a 65-hp Mercury outboard, this boat achieved a speed of 47 mph. The unique aspects of this hydrofoil configuration related to the use of: (1) differential dihedral angles, (2) rear hydrofoil splay, (3) special overall shapes with quick-mounting method, (4) a retraction system, (5) methods for hydrofoil angle adjustment, (6) means to release foils upon impact, (7) an optional motor mount, and (8) an optional propeller design.

Figure 10. Hydrofoil boat equipped with the production Up-Right Hydrofoil kit. This boat achieved a speed of 47 mph with a 65 hp Mercury outboard, and could carry six people.

To summarize the unique aspects of this hydrofoil design:

1. The dihedral angles are unusual because the outer sides of the rear vee foils have a dihedral angle of 30 degrees, while their inner sides have a dihedral angle of 45 degrees. This differential dihedral produces a roll moment when turning that makes the boat bank nicely into turns. Also, the bow hydrofoil had a dihedral of 35 degrees in the upper part, and a dihedral of 45 degrees in the lower part; for a given hydrofoil depth, this design provided more takeoff area, and a higher turn rate at design speed than a hydrofoil with a constant dihedral.
2. The rear vees were splayed rearward about 1.5 degrees as a safety feature. This splay caused the outer part of each rear vee to operate at a lower angle of attack than the inner parts of the vees. In the tightest turns, without this splay, the outer side of the outer foil would ventilate first, causing the boat to suddenly tilt out of the turn. However, with splay, the inner side of the inner vee foil ventilates first, causing the boat to tilt strongly into the turn, which is much safer.
3. The rear foil extrusions were bent into a triangular shape which provided a continuous surface consisting of a vee foil with an inverted horizontal portion welded together at the upper inboard corner. Prior to bending, the horizontal portion was placed in a special press, and its camber was reversed so that, after bending, this portion provides lift when immersed. The horizontal portion of each rear foil was mounted above the bottom of the boat, but low enough so that it helped to reduce trim at hump speed before takeoff. During turns, the horizontal surface of the inner

hydrofoil dips into the water and generates lift to help increase the turn rate and control the bank angle. The bow hydrofoil assembly is mounted with two bolts through the bow stem, and one bolt rearward on each side. Each stern foil is mounted with three bolts through the transom.

4. The vee bow foil is attached to an above-water horizontal tube. To retract, the foil and tube are rotated until the foil is a little beyond its inverted position. The foil is rotated by two cables which are wrapped around the foil tube on one end, and around a ratchet winch on the other end which is located near the driver. After raising the bow foil, the boat bow can be beached, typically without raising the aft foils. After leaving shore, the bow foil is lowered by releasing a catch on the ratchet, and gently pushing the bow foil forward with a paddle until gravity takes over to rotate it back down until it rests against an adjustable stop. For trailering, the rear foils retract about a fore-and-aft axis, angled around 45 degrees from the vertical, which permits them to pivot upward and backward out of the water.
5. The bow hydrofoil can be adjusted in flight by rotating a rod with a handle located near the driver. Such an angle adjustment is needed if one or two passengers move from the front seat to the back seat, or if five or six passengers are carried instead of one or two. Generally, the rear foil angles do not require changing; however, they can be changed by rotating a large knurled knob which adjusts the angle of a plate attached to each foil relative to the transom.
6. All three hydrofoils are attached by shear links so that each foil will individually shear free of the boat if it strikes an obstacle with a force greater than about 500 pounds. Each hydrofoil is recoverable by means of a 500-ft cord attached to the boat.
7. Typically, a standard long-shaft outboard motor is mounted on a boat with a transom designed for a short-shaft outboard in order to lower the propeller 5 inches for hydrofoil operation. Alternatively, I designed and patented a spring-loaded motor mount which attaches to the boat transom so that the outboard motor will automatically lower about 5 inches when thrust is applied. When thrust stops, the springs automatically retract the outboard back to its original position, well above the waves.
8. Although not used with the production hydrofoils, I developed a special propeller which improved on the then-available propellers for faster boats. Basically, this propeller acted much like an automatic transmission with overdrive. The propeller was designed to superventilate (from exhaust gas emerging from its hub) when the boat accelerated from rest so that full engine RPM and power are available. The propeller then automatically base ventilated upon reaching a speed of about 25 mph, and the engine speed reduced about 1,000 RPM, providing the overdrive feature. The propeller then remained base ventilated up through cruise speed. However, if accelerated to maximum speed, the propeller again superventilated so that maximum engine RPM and power are available. I later found that this propeller worked well even when partly out of water; therefore this propeller would eliminate the need for either a long shaft outboard motor or a spring-loaded motor mount. This propeller concept was patented in 1963 as US #3,109,495.

Conclusion

About 80 of the Up-Right Hydrofoil Kits were sold around the world in 1961 and 1962, although most of the kits were sold in the US. I heard that one kit was used by the Boeing Company as a chase boat for their hydrofoil craft. Another kit was later resold and used by the Navy in Vietnam. The Up-Right company did a fine job of manufacturing design and packaging. About 300 kits a year had to be sold to be profitable, so production was discontinued in 1962. I still have one unused kit, and one used kit, both of which I would like to donate to a museum, but have not yet found one which has display space available.

More on the Historic Upright Hydrofoil Kit...

[24 Feb 00] It is extremely interesting and exciting to read your history of the development of the Up-Right Hydrofoil Kit. I first saw this hydrofoil when I was newly married (1963) and on a business trip with my wife in Coeur-Delane Idaho. They were mounted on a 17foot boat and seemed to be the answer to my dreams of making a boat go faster and easier. I had to have a set and not long later purchased a set from the Up-Right company. My wife went along with it even though she must have felt there were much better things to spend our money on.

They were mounted on my 14.5ft Fiberglas runabout with 40 hp Johnson outboard. It was soon apparent that they worked like everything but the motor was not properly loaded and could overrev. I then was told that the OJ Johnson propeller company in California was excellent at making propellers for fast boats so I contacted them. They sold me a three blade bronze propeller with about three more inches of pitch and cupped trailing edges. It worked beautifully. More than one fellow with a V-8 inboard speed boat was a little surprised and annoyed when I passed him with my little outboard boat. Also the foils worked very well in Georgia Straight off Vancouver harbour where I used it often. They did dive though, when in a following sea. This was a frustrating deficiency.

The major problem was the "shear plate, string-in-the-bottle" system. I believe I did strike small debris a few times and the foils separated as intended and I was able to retrieve them. One day though, I was travelling under the Lions Gate Bridge In Vancouver, B.C. and one of the rear foils broke loose. The nylon line payed out OK but there was too much current and I could not pull the hydrofoil back up. The string even cut into my hands a bit. I let the foil go and there was no way we could find it later. I was able to buy a replacement from a man in Oregon and was back flying again for a while. Eventually other things became more important (two sons as example) and I sold the boat. I did keep the foils though and they moved with us from place to place. (Vancouver to Pine Hill Alabama, To Aberdeen Washington, to Vancouver, to Mackenzie B.C., to Tswassen B.C., to West Vancouver, two moves)

In about 1986 my 15 year old son expressed an interest in the propeller and the foils that had been in the household all his life. We bought a fourteen foot aluminium boat and an older 40 hp Johnson so the propeller would fit. Remembering the problems with the shear plates I modified the mounting of the foils so they would tilt up like an outboard does when it hits an object. Once again we were foil borne. All went well for a while and the set-up performed like the good old days.

One day the front foil hit a submerged plastic bag and the foil rotated back against the boat. It then acted like a huge brake in the water and the boat very abruptly stopped. Luckily my son was not hurt although he was not impressed. Another time one stern foil hit something and rotated back out of the way, however it did not rotate completely out of the water and it too acted like a huge brake. It actually pulled hard enough to bent the foil out of shape.

Next I cut the front foil in two at the point of the V. The two pieces were held together at the V with a shear bolt. The foil was made so that the main tube would not rotate on impact but the join between the top of the foil and the cross tube would allow each half of the foil to rotate away from the centre towards the outside of the boat when something was struck. This actually worked very well.

The rear foil was straightened and a different solution was used to make it continue rotating until it was completely out of the water. A fairly large piece of plywood was attached with hinges to the top support extrusion of the foil. This was held up in the horizontal position by a pin in the side of the boat when the foils were in use. If the foil started to rotate backwards due to striking something the piece of plywood would come off the pin and swing down and be caught by the water. It would go against the leading edge of the foil so the water could not pass through the triangular inside shape of the foil and therefore the water would push the foil up and completely free of the water. This system also worked very well.

By this time we were getting tired of experimenting and the young fellow indicated that he was not really interested in foils but just wanted a nice boat to play with. The foils went back in the basement where they remain to this day. I still have dreams of buying a suitable boat and using them again but it is hard to justify when I already have two boats not suitable for these foils. -- John Hards (johnhards@shaw.ca)

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