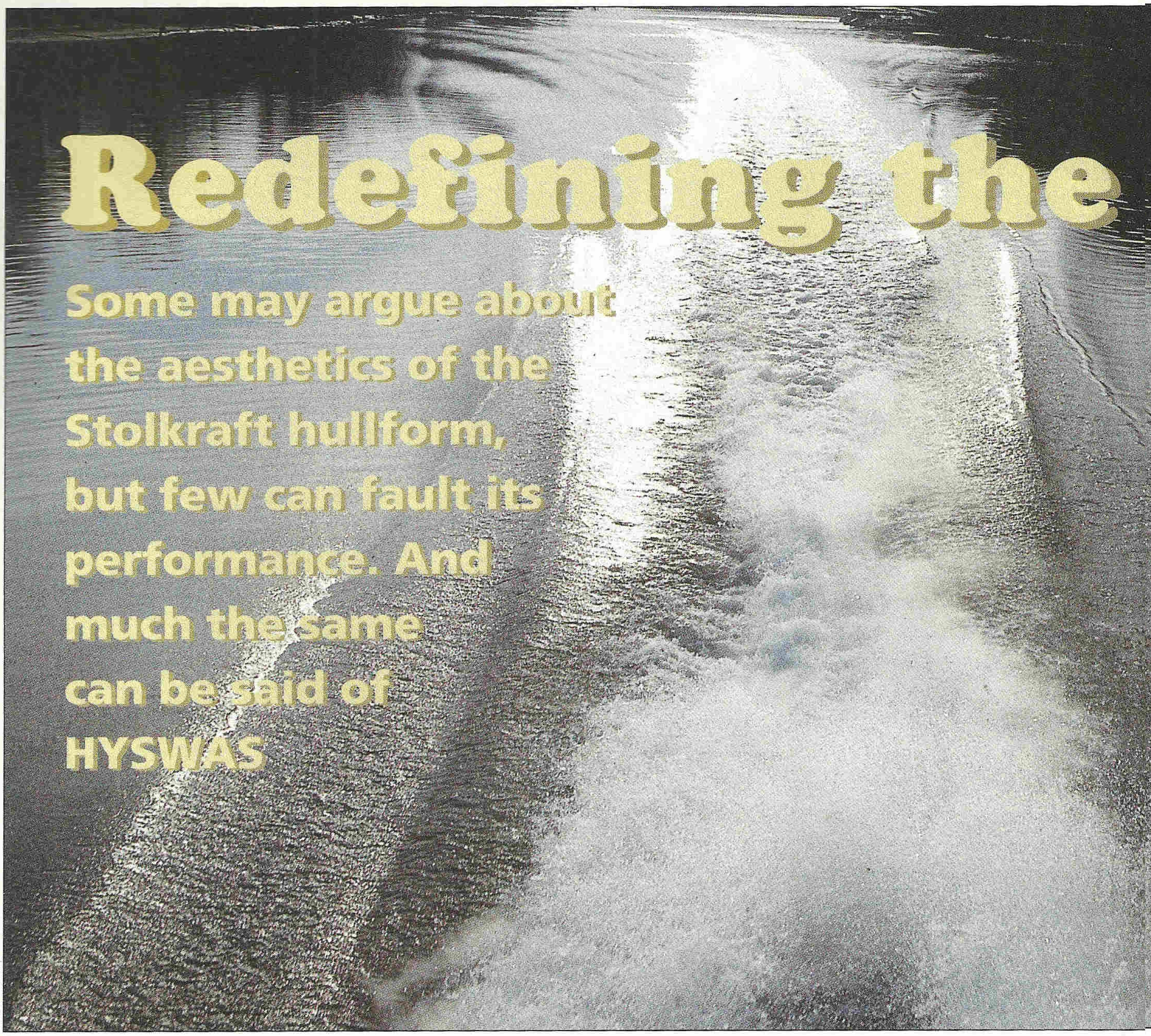
Redefining the

Some may argue about the aesthetics of the Stolkraft hullform, but few can fault its performance. And much the same can be said of HYSWAS



GREG KINNEY

by Richard Akers

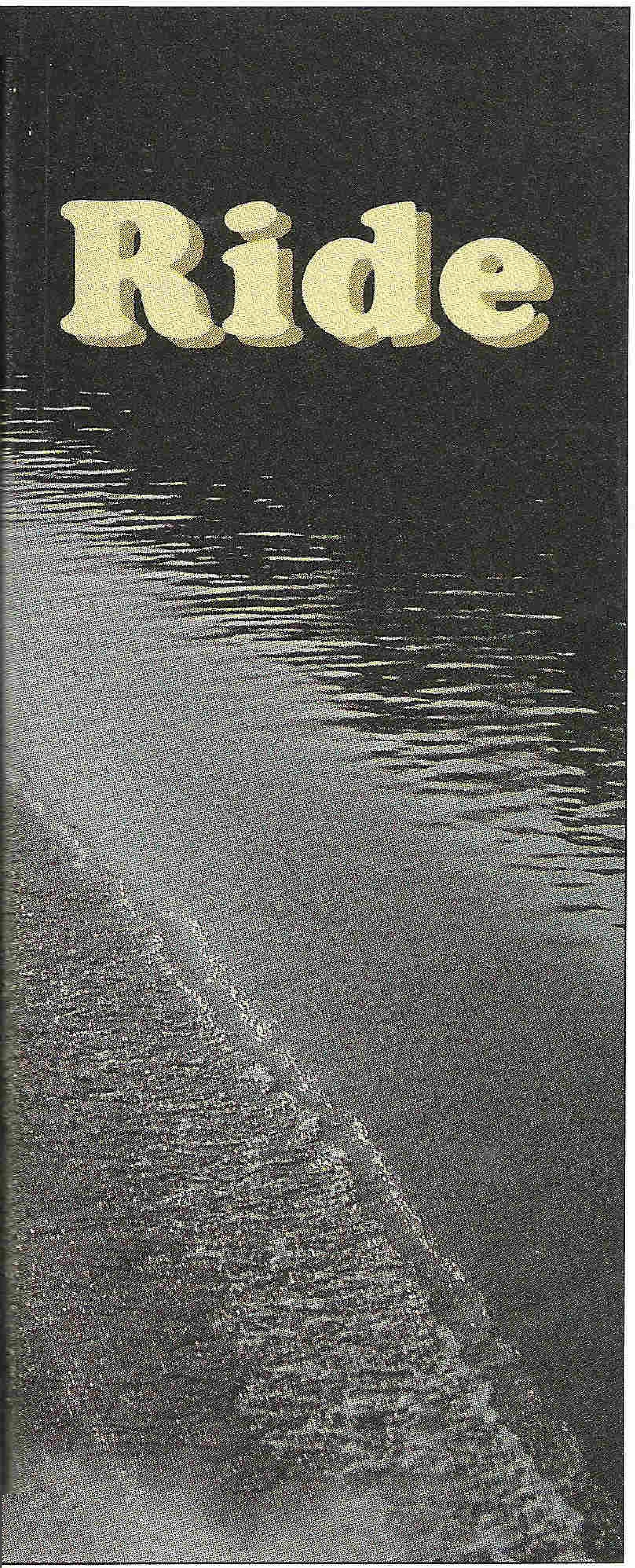
Imagine a planing hull that rides like a bird over the top of the waves, goes miles on a drop of fuel, and creates no wake. While the Stolkraft does not meet these lofty goals perfectly, it does do a good job of balancing the competing demands of each.

The Stolkraft is a patented hullform that marries a trihedral hull—one similar to the original Boston Whaler—with a stepped-cavity planing hull. The forward trihedral sections act as a scoop, channeling air and water under the step. The water flow separates from the hull at the step and reattaches to the "wet deck" aft of the step, providing additional hydrodynamic lift and stability.

The late Leo Stolk, an Australian aeronautical engineer, conceived the shape he named "Stolkraft." His search for a boat offering low wake, high efficiency, and an absence of porpoising led him to consider various unusual hullforms. Settling on and then refining a hybrid planing hull, Stolk obtained an Australian patent for the design in 1987, and another patent (number 5,140,930) in the United States in 1992. The patent rights are currently held and managed by Stolkraft International (Southport, Queensland, Australia).

Every inventor stands on the shoulders of other inventors, and Leo Stolk was no exception. The predecessors of the Stolkraft hull include other well-known and lesser-known hullforms—shapes that were themselves once considered advanced and innovative.

The forward sections of the Stolkraft are essentially trihedral hulls consisting of a shallow center keel and two deep outer keels. This type of hullform can be traced back to the ideas of designer Albert Hickman, who patented his inverse-V-bottom design in 1914. The Hickman Sea Sled, based on Hickman's theories about the advantages of inverse-V hulls, was both noteworthy and notorious. The hydrodynamics of his hull were fundamentally sound. In a conventional V-bottomed design, the water sprays laterally away from the hull in "jets." These jet sprays (no relation to waterjet propulsion) form the bow wave of a planing hull, and represent lost energy. By contrast, in an inverse-V hull, the jets flow inward, colliding and transferring some of their momentum back into lift. The result is a more efficient hull, one that basically rides up over its own bow wave. Hickman's Sea Sled, however, was notorious for structural problems, mostly due



A patented shape of recent development, the Stolkraft hullform combines several highly desirable performance characteristics: a flat, small wake; and little or no bow wave, climb to plane, or side spray. Not only that, the hullform is capable of high speeds with less power than comparably sized conventional monohulls, while offering, in the words of one professional skipper, "shallow draft, great maneuverability, and outstanding stability." The Stolkraft shown here coming and going is a 45′ motoryacht version built by Boating Corporation of America (Gallatin, Tennessee).

to the limitations of boatbuilding materials of 50 years ago.

But Hickman's work was by no means the last word in inverse planing hulls. In the early 1950s, engineer Richard Fisher had the idea of building a sailboat shaped like a small version of a big, Great Lakes racing scow. Fisher discussed this idea with his friend, the designer C. Raymond Hunt, who persuaded Fisher to target the emerging outboard-motorboat market instead. To that end, Hunt came up with the lines of a 12′ boat resembling a Hickman Sea Sled.

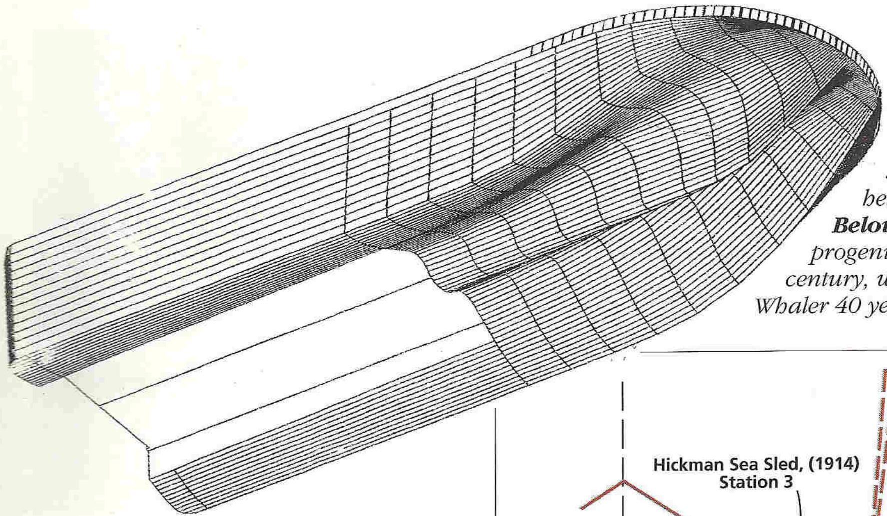
Fisher and Hunt proceeded to build and test a styrofoam model of Hunt's design, and its performance exceeded their expectations. It performed well in rough water (by the standards of the day), and did not broach in following seas (a problem for conventional V-bottomed hulls of that pre-deep-V period). There was only one problem with their new boat: the mixture of air and water in the tunnel caused the propeller to ventilate and run uncontrollably.

Fisher and his partner in the nascent boatbuilding venture, Eric Tasker, went to visit Albert Hickman to see if he had any experience with this problem. Hickman's response, though, was less than satisfactory to the two men. Not only would he acknowledge no problems with the Sea Sled hullform, he wanted credit for the Hunt design.

After this meeting, Ray Hunt went back to the drawing board and modified his design to solve both problems—the propeller ventilation and the alleged Sea Sled patent infringement. Hunt's solution: an additional center keel between the two outer keels, creating a trihedral hull. Following some additional experimentation, Fisher's shop built the first 13′ Boston Whaler and exhibited it at the 1958 Boston Boat Show.

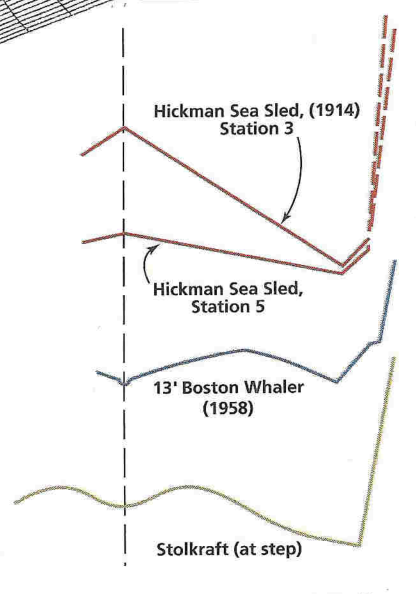
Trihedral hulls have a well-known tendency to pound in waves, as anyone who has crossed open water at fast speeds in such a boat will attest. Over the years, many boat designers and builders have tinkered with the trihedral hullform in an attempt to reduce the high accelerations due to wave slamming. Lately, naval architects have been experimenting with a lazy-S shape. This version has a shallow center hull when compared to a more traditional trihedral hull. Recent fast passenger-ferry designs, for example, incorporate lazy-S hull sections in an effort to eliminate slamming.

As stated earlier, Leo Stolk's breakthrough design essentially wedded a trihedral to a stepped cavity. Naval architects have been aware of the advantages of



CARDEROCK DIVISION, NSWC

Left— *This fish-eye view of a generic Stolkraft shows the hybrid nature of the shape. Note how the trihedral sections forward change to a stepped cavity planing hull—a combination that helps account for the boat's ride qualities.*
Below— *The Stolkraft is an evolutionary form whose progenitors include the Hickman Sea Sled early in this century, which in turn, led to the aboriginal Boston Whaler 40 years ago.*



Evolution of the Tunnel Hull

RICHARD AKERS

stepped hulls for many decades. The introduction of a step in a planing hull adds a second pressure peak abaft the step, which dramatically improves the balance of the boat. Consequently, stepped hulls can tolerate large longitudinal variations in loading without major changes in trim, and are almost impervious to the perils of porpoising. Stepped hulls themselves, though, are hardly new: the Rev. C.M. Ramus published a paper in England in 1872 that describes model tests on stepped hulls. Later and also in England, Sir J.I. Thornycroft developed stepped-hull coastal patrol boats for service in World War I. But stepped planing hulls were of strictly academic interest until lightweight, high-output engines made planing craft practical.

So why aren't all planing-hull boats stepped? For one thing, the concentration of forces on small areas of the hull leads to structural design problems. For another, stepped hulls are often difficult to steer. Nevertheless, a stepped hull's benefits are real; the challenge is how to design around the problems.

The Stolkraft hull incorporates a clever variation on the conventional planing step. The Stolkraft step does not span the entire beam of the vessel; rather, it is limited to the bottom area between the two outer hulls. When the Stolkraft is on plane, the water separates from the step and re-attaches somewhere abaft the step, creating a confined air pocket, or cavity. This feature yields the low-drag advantages of a step, while the fully submerged side-hulls provide dynamic stability against yaw.

Designers of stepped hulls have periodically grappled with the problem of ventilating steps, especially enclosed steps. The Russians, for example, have been experimenting with cavity-stepped monohulls for more than two decades. A Russian technical work published in 1978 and entitled *Propulsive Performance and Seaworthiness of Planing Vessels* discusses cavities in stepped planing hulls. More recently, the Russians have been examining cavity stepped hulls using engine exhaust to ventilate the cavity.

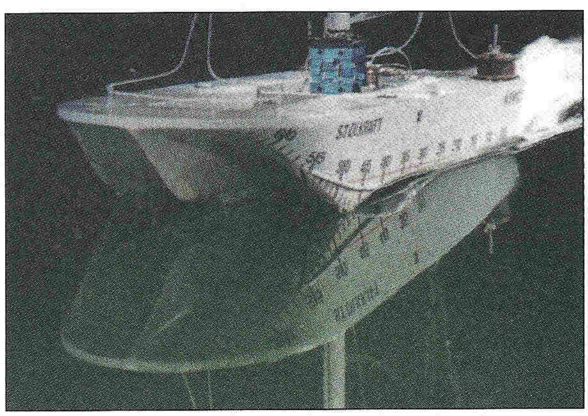
The Stolkraft, however, uses passive ventilation, initially scooping air in through the trihedral forward sections, driving the air under the step, and then trapping the air in the cavity. Although the after sections of the Stolkraft resemble a power catamaran, there is an important difference between the two types: The Stolkraft's wetted tunnel-top produces very good transverse stability at low speeds—much better than that of a power cat with a dry tunnel. And, unlike a conventional V-bottomed hull, particularly a deep-V (first designed, like the aboriginal Whaler, by Ray Hunt), the Stolkraft's transverse stability does not drop appreciably with speed. The restoring forces from the side hulls in a Stolkraft are applied to the side-hull planing surfaces, so the total restoring moment tends to be constant with speed. On a conventional V-bottomed hull, the roll restoring moment can drop precipitously at high speeds, sometimes resulting in chine-walking and other roll instabilities. This behavior is almost unknown for a Stolkraft hull.

The Naval Surface Warfare Center's Carderock (Maryland) Division—the U.S. Navy's principal research facility—recently completed calm-water and maneuvering tests on a generic Stolkraft-type planing craft. Carderock engineers tested a one-tenth-scale model of a 17-meter (56′) pilot boat. They built a precise towing-tank model by milling a foam plug and covering the plug with glass-reinforced epoxy. This technique yields an extremely accurate model that is light enough to meet the demands of high-speed planing craft tests.

After extensive testing in Carderock's several model basins, scientists there concluded that the Stolkraft is an efficient planing craft exhibiting a lower-than-average planing "hump" drag, compared to other hull types.

Still, while the Stolkraft hull has much to recommend it, no designer has yet to find the "perfect" hullform under all conditions. There is little question that the Stolkraft is a high-speed hull. Carderock's test data show that a 34-ton Stolkraft would exhibit significant drag at pre-planing speeds (less than 20 knots), but would begin to show its real potential at high speeds.

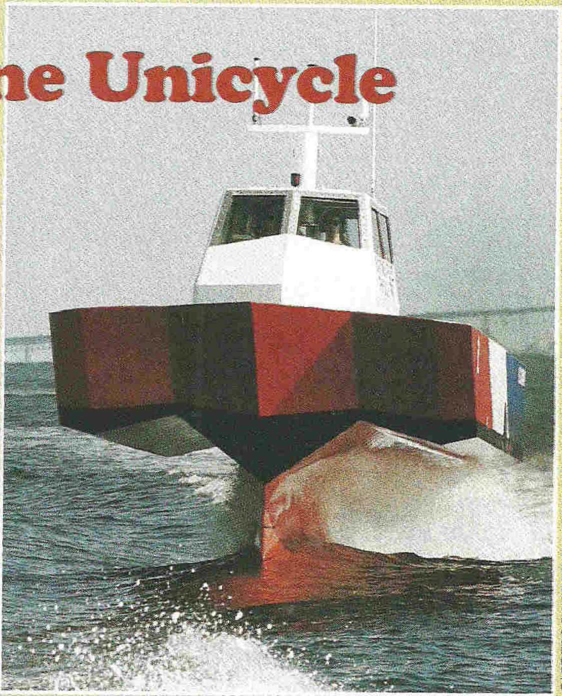
Carderock staffer, senior naval archi-



CARDEROCK DIVISION, NSWC

Hydrodynamicists at the Carderock (Maryland) Division of the Naval Surface Warfare Center studied a scale-model Stolkraft in a series of towing-tank tests, to better understand the boat's behavior. The full-size vessel's overall performance exceeded modeling predictions.

HYSWAS: A Waterborne Unicycle



CARDEROCK DIVISION, NSWC

If you were out on Chesapeake Bay near Annapolis, Maryland, about a year ago, you may have seen an unusual red, white, and blue boat seem to rise out of the water and balance on its keel.

The U.S. Navy's new HYSWAS (Hybrid Hydrofoil Small Waterplane Area Ship) demonstrator is a cross between a hydrofoil and a SWATH (Small Waterplane Area Twin Hull). The concept behind the HYSWAS is straightforward enough: Build a boat with a bulb keel whose displacement supports the machinery, and then add small hydrofoil wings so that the hull can rise out of the water. With the hull clear of the water, the boat offers minimal drag and great seakeeping.

The HYSWAS can "take off" at speeds lower than a conventional hydrofoil because the lift from the foils need only support the hull, crew, and cargo, not the machinery. But, at speeds greater than 40 knots, a HYSWAS requires more power than a hydrofoil because the bulb is still in the water.

Unlike a multiple-strut SWATH design, the HYSWAS has a single strut connecting the boat to its bulb. The strut keeps the boat from being too wide, and it reduces drag. HYSWAS maneuvers by means of a sophisticated fly-by-wire computer control system, which prevents this unicycle-like creature from falling over on its side. (Fly-by-wire technology originally appeared in high-speed aircraft. It means direct, electrical actuation of a mechanically operated moving part.)

Using data from sensors recording wave height and vessel attitude, the control system adjusts the angle of attack of four small foils mounted on the bulb. This system ensures that the HYSWAS boat hull maintains a level trim, impervious to the waves below. Without this control system, the vessel is limited to low-speed operation, the hull floating in the water.

A HYSWAS strut's small cross-sectional area offers improved seakeeping at speed, and the strut's very small waterplane area presents no lever arm for the waves to act upon. Moreover, the fully submerged hydrofoils are unaffected by conditions on the sea surface.

It was a challenge, however, for the HYWSAS designers to solve some substantial structural problems. The designers first considered using FRP for the hull/strut/bulb assembly, but after anticipating the large stresses likely to be encountered there, they decided instead to build the demonstrator in aluminum.

In this case, the hull shape was reduced to a series of developable surfaces; i.e., surfaces having curvature in only one direction. Navy shipbuilder Bath Iron Works (Bath, Maine) fabricated more than a thousand pieces of cut-and-formed aluminum plate (which accounts for the pronounced angular appearance of the final product); and Maritime Applied Physics Corp. (Laurel, Maryland) built the 27', 12-ton, 35-knot HYSWAS demonstrator.

CARDEROCK DIVISION, NSWC

HYSWAS stands for "hybrid hydrofoil small waterplane area ship"—a new type of hullform developed at Carderock for the U.S. Navy and other possible end-users. The 27' diesel-powered demonstrator, seen here undergoing trials, was built by Maritime Applied Physics Corp. (Laurel, Maryland); she is maneuvered via a so-called "fly-by-wire" computer control system. The HYSWAS can "take off" at speeds lower than a conventional hydrofoil, and her seakeeping characteristics are excellent. The hull itself need not be this angular; the demo boat happened to be built from aluminum plate, using developable surfaces.

As with the Stolkraft hull, the HYSWAS concept is a new variant of an older idea. Since the 1970s, the U.S. Navy has been experimenting with hybrid hulls that combine two or more lift mechanisms (selecting among and between buoyancy, dynamic lift, and powered static lift). The limiting factors on adoption of HYSWAS are the cost and reliability of computerized control systems, and the difficulty of designing high-strength structural components.

The availability of relatively inexpensive computer power, combined with advanced structural design techniques, may eventually allow more designers to entertain possible HYSWAS applications. Even then, these vessels are not likely to be economy models: designing a HYSWAS's requisite computer-control system is beyond the capabilities of most small naval-architecture firms.

On the other hand, the potential of this hullform makes collaboration with control-system specialists worthwhile. After all, helicopters once looked odd to us and require complicated control systems, but the special capabilities of these craft have long since come to justify their high cost.

The HYSWAS nicely fills a niche between high-speed hydrofoil vessels and lower-speed conventional planing hulls. The exceptional seakeeping and relatively low drag of the HYSWAS hullform make it attractive for use as a water taxi or patrol boat, or for any other application that demands a fast, stable platform.

For more information on the HYSWAS demonstrator, contact: Jim Scott, Public Affairs Office, Carderock Division, Naval Surface Warfare Center, Bethesda, MD 20084-5000, tel. 301-227-1142; or Rhonda Hatton, Maritime Applied Physics Corp., 9010 Maier Rd., Unit 119, Laurel, MD 20723, 301-470-2222.

—Dick Akers

tect John Hoyt, notes that there are some speed-resistance points that are actually inferior to a so-called Series 62 hull (which I'll explain in a moment). This phenomenon is not unique to a Stolkraft, however; many displacement hulls perform better at low speeds than do planing hulls.

Now, about Series 62. A classic point of reference among researchers in powerboat hydrodynamics, Series 62 is the name given to a group of simple planing hulls tested in the early 1960s at the David Taylor Model Basin, the system of towing tanks that are now part of the Carderock organization. *[For a detailed description of the different model basins there, see PBB No. 42, page 39—Ed.]*

John Aitkenhead, managing director of Stolkraft International, reports that the Stolkraft hullform has been tested to 100 knots by outside research agencies (including Carderock), "and the efficiency ranges are well beyond those of similarly sized monohulls. For example, in the case of a 35m (115') vessel, the area of greatest efficiency for a Series 62 hullform would be up to, say, 35 knots; for a Stolkraft of that size, best efficiency occurs between 35 to 60 knots. Incidentally, we've designed a 32m (105') fast ferry with a top speed of 60 knots, and our perusal of the *Guinness Book of Records* suggests this to be a world first."

Carderock researchers confirm that Stolkraft's high-speed performance is "excellent"—provided the boat is properly trimmed. If the craft's center of gravity is too far forward, then the trihedral portion of the hull immerses and the drag increases dramatically. This effect precludes use of a Stolkraft hull as a seaplane float, and may also have an impact on its application for hauling large loads in a bow-down configuration.

Besides measuring a Stolkraft's hull resistance, Carderock scientists evaluated its seakeeping performance. They found that, at high speeds, the hull tended to "wave-hop" over large waves, but they observed a complete lack of spray under most conditions. "In head seas," says Hoyt, "nothing comes over the bow. We never even had to take a towel to dry the model. The craft does start to get wet in quartering seas, but nothing major." This lack of spray is an important feature in both the recreational and commercial boat markets.

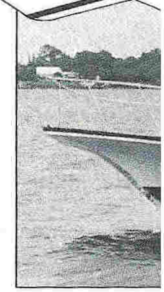
Carderock data show that the overall ride quality compares favorably with deep-V hulls of similar displacement. Hoyt notes that the peak acceleration due to slamming is lower in the Stolkraft than in comparably sized deep-V hulls, but that the duration of the shocks is longer. In other words, the shape of the forward sections of the Stolkraft hull tends to blunt the slamming loads, resulting in a smoother ride. Hoyt theorizes that the response of the Stolkraft to waves is that it heaves more than it pitches. This elevator-like motion gives the boat a dry, soft ride. He summarizes the seakeeping characteristics: "It is a very benign and safe boat. It wave-hops beautifully—if you're crazy enough to want to wave-hop."

Boating Corporation of America (Gallatin, Tennessee) is an established manufacturer of high-quality houseboats and coastal cruisers. Recognizing the market potential for the Stolkraft hullform, BCA early on negotiated a license agreement with Stolkraft International. Currently, BCA has in production a 45' motoryacht, the Stolkraft 4500.

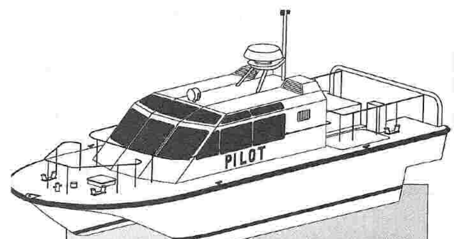
Clyde Head, BCA's executive vice-president, argues that the Stolkraft hull has a number of notable advantages over more conventional craft. The hull is extremely stable, he says, both in waves and sitting at the dock. It is fast for its size and power. And, he continues, the Stolkraft is very efficient when operating at cruising speeds. By way of example, Head states that a Stolkraft 4500—powered by twin MerCruiser 502 fuel-injected gas engines equipped with 2.5:1 reduction gears connected to V-drives with four-bladed propellers—can achieve fuel efficiencies of 0.7 mpg running at a steady 27 mph.

Possibly the most important characteristic of the Stolkraft hull is that it generates such a remarkably low wake. This is an important feature in today's crowded waterways—sure to become more crowded in the future. On its 45-footer, BCA has measured a maximum wake of 3.5" inches above the water, taken 100' aft of the boat running at full throttle (about 37 mph). Compare this wake with that of a similar-sized motoryacht from BCA's successful Harbor Master line: that boat produces a 7" wake under the same operating conditions.

Furthermore, BCA's Head says there is little wake outside of a narrow band the width of the vessel. This is in contrast to the wake of a high-speed V-bottomed hull of comparable size and displacement, which can extend far beyond the beam of the vessel. Also, BCA's on-the-water accounts of the seakeeping characteristics of a Stolkraft hull (besides its 45, BCA has been testing other Stolkraft prototypes) match those found by Carderock's engineers. Head reports that a West Coast dealer once test-drove the Stolkraft 4500, taking the boat at speed beyond the Golden Gate Bridge in 6' seas. According to Head, "The dealer said that he did not realize the waves were as high as they actually were because the ride was so smooth."



Jeff Kelton, a senior naval architect at Art Anderson Associates (Seattle, Washington), is an enthusiastic proponent of the Stolkraft hullform. For many years, Kelton worked on high-speed ferries at a Japanese shipyard. The yard had occasion once to consult with Dr. Peter Van Oossanen of the MARIN (Maritime Research Institute Netherlands) testing facility in Waganingen, The Netherlands, on a particular design problem. Kelton's



Queensland, Australia-based Stolkraft International, which holds and manages rights to the hullform, believes the strongest market potential for Stolkraft designs is in commercial applications, such as fast ferries, patrol craft, or pilot boats **(right)**. *Still, the 50-mph speeds achieved by a fully loaded 24' prototype* **(below)**, *powered by twin-175 outboards, would appeal to recreational interests as well.*

study of previous research done by Van Oossanen (who had tested the Stolkraft hullform and declared it to be "the most significant advance in marine hulls of this century") subsequently committed Kelton to the architecture of Stolkraft.

Two years ago, he joined Art Anderson Associates and worked with Stolkraft International to quote on a police boat for the City of Seattle. That design was not built, but as a consequence of Kelton's preliminary design work, Art Anderson Associates secured "design priority" for Stolkraft hulls in North America.

According to Kelton, tests conducted more than a decade ago show that air is not compressed aft of the Stolkraft's step, but is in fact at atmospheric pressure, or close to it. The tri-hull forebody, he adds, effectively cushions slamming loads for the same reason that contemporary catamarans are being fitted with a small centerline hull forward: it dissipates the wave forces over a longer period of milliseconds, functioning like an automobile's shock absorbers.

Another feature of the Stolkraft hullform is its exceptional fuel efficiency, attributable to a reduction in friction due to air in the cavity, along with relatively high lift due to recaptured momentum from the water flow that re-attaches to the hull in the cavity tunnel.

Scientists who have examined the Stolkraft shape agree that it has excellent propulsion efficiency. There may even be some positive interactions between the water flow and the propulsion systems. Indeed, hydrodynamicists, including Van Oossanen of the MARIN test facility, were worried that their models were not producing reliable data, because the model data does not match the performance of full-size boats. For that reason, MARIN investigated scaling and other nonstandard ways of getting better correlation with the attributes of full-size hulls.

This phenomenon was confirmed by Carderock's John Hoyt, who says that Dutch and American test facilities alike found the same lack of correlation between Stolkraft test models and full-size vessels: the full-size vessels perform better than predicted.

Most Stolkraft designs to date have twin propulsion arrangements, and many have waterjets, including the BCA Stolkraft 4500. Dual propulsion systems, however, are not mandatory. Smaller recreational Stolkraft have been successfully powered with a single outboard mounted on the centerline. There is no doubt, in any case, that the Stolkraft hull can be pushed to speeds well beyond the planing-speed power hump. Working with a large recreational-boat manufacturer, BCA tested a 24′ prototype powered by twin 175-hp outboards. Fully loaded, the test boat achieved speeds of 50 mph.

BCA wanted to know what the performance would be with a single engine. With one of the outboards tilted out of the water, the prototype sped along at 37 mph. Head notes that BCA ran tests comparing a 24′ Stolkraft prototype with a 25′ moderate deep-V offshore center-console outboard, and found the Stolkraft to be about 30% more efficient.

This is probably a good hullform for jets. According to Carderock's Hoyt, boats with waterjet problems often have inlets located at or near the "water flow stagnation point." The stagnation point is just aft of the leading edge of the water, and is situated on the dividing line between water that curls forward and outward, and water that flows aft. In theory, at least, the water is not moving at the stagnation point on the hull. The relatively low flow rate at the stagnation point allows air to remain trapped in the water. Conversely, if the inlet is positioned away from the stagnation point, air tends to ventilate out. The narrow runners on a Stolkraft hull let air escape to the sides, which means very little air passes in the vicinity where you would normally place an inlet.

Designers are often concerned about the maneuvering characteristics of planing hulls. Some of this concern dates back, in fact, to early Hickman Sea Sleds, which tended to heel outboard in turns. Stolkraft users report that this particular hullform exhibits little of the bad behavior of its ancestors. Kelton of Art Anderson Associates states that Stolkraft owners and operators report absolutely no tripping in turns; they liken the procedure, he says, to running on the proverbial set of rails. Kelton does acknowledge, though, that the typical Stolkraft turning circle is wider than that of a conventional V-bottomed hull, but not by a large amount. He says that Stolkraft designs to date have exhibited a slight outboard heel during turns, but never more than five degrees. By way of confirmation, BCA's Clyde Head reports that the BCA Stolkraft 4500 does heel outboard very slightly, but not uncomfortably so.

Stolkraft design and construction in the United States is controlled, to a certain extent, by Stolkraft International in Australia. Currently, BCA is licensed to build and sell recreational Stolkrafts in the U.S. up to 60′ in length, and only in glass. Should a customer prefer a yard other than BCA to build his or her composite boat within that size range, then BCA will subcontract construction to the preferred yard. The customer would work with both BCA and the boatyard, but BCA would handle any and all patent-related business issues with Stolkraft International.

On the design side of the equation, Art Anderson Associates' "design priority" is meant to assure the quality of Stolkraft designs and to maintain the integrity of the Stolkraft patent.

It remains to be seen whether these "special arrangements" will inhibit Stolkraft's widespread acceptance here.

Stolkraft International's Aitkenhead believes "the best long-term potential in the United States for Stolkraft vessels is in the realm of aluminum high-speed ferries, patrol craft, and workboats." In any event, interest in the Stolkraft hullform is certainly not limited to the United States; world market potential for Stolkraft is substantial. Numerous nonrecreational operators are looking for high-speed vessels, particularly for fast-ferry and patrol-boat applications.

Stolkraft International has been busy designing and building Stolkraft hulls to serve these commercial and military markets since the mid-1980s. The company has already produced a number of ferries and pilot craft, and is currently under contract with the Vietnamese government to deliver four 22.6m (74′) customs patrol craft, with the prototype scheduled to be launched in August. An additional 16 sisterships will be built under joint venture in Vietnam.

If those vessels perform anything like the models and boats cited here, Stolkraft's future—outside the United States, at least—would seem to be fairly secure.

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About the Author: *A graduate naval architect and marine engineer, Dick Akers is the principal of Ship Motion Associates, a firm specializing in marine software for hydrodynamic analysis. He is based in Portland, Maine.*