The History of Hydrofoils

(Part II)

by Leslie Hayward

Probably the first mention of the dangers of cavitation and proposals for preventing it from occurring are referred to and described in United States Patent 1,852,680 granted during April, 1932 to Charles Shaw of Huntsville, Ontario, Canada. Shaw proposed a slightly "V" shaped foil and sought to eliminate cavitation by incorporating baffles arranged transversely to the foil supports and trailing rearwardly from them to prevent the flow of air to the upper foil surfaces. Fig 36 shows one proposed arrangement, the hydrofoil being equipped with a number of baffles and the tips of the foil breaking through the surface of the water.

An adaptation of a seaplane alighting gear was proposed by Henry C. A. Potez of Meaulte, France, in 1931. Anhedral hydrofoils pivoted to the hull are free to move against the resistance of shock absorbing struts in such a manner that movement of the hydrofoils about their pivotal axis does not affect any alteration of their angle of incidence relative to the water.

Henry B. Allen of Ardrosson, Ayr, was granted British Patent 382,812 in November, 1932. His invention resided in the provision of a hydrofoil having its undersurface formed as a continuous concave surface. A triangular plan form of foil, the trailing edge having a greater length than the distance from apex to base was suggested. Allen proposed to mount his foils on support arms adjustable at the hull to enable varying angles of incidence of the hydrofoils to be attained.

The story now appears to stagnate for approximately two years. Patentwise there was very little activity in the mid-thirties, although it was during this period that very valuable research and development work on hydrofoils was being undertaken by Baron Hans Von Schertel.

When and wherever the subject of hydrofoils is raised or discussed, the name of Von Schertel is one of the first that springs to mind. A very large amount of the credit for developing the hydrofoil craft from an unstable, unreliable, if ingenious craft, to what is today, a fast, safe and efficient method of transport must be given to Von Schertel.

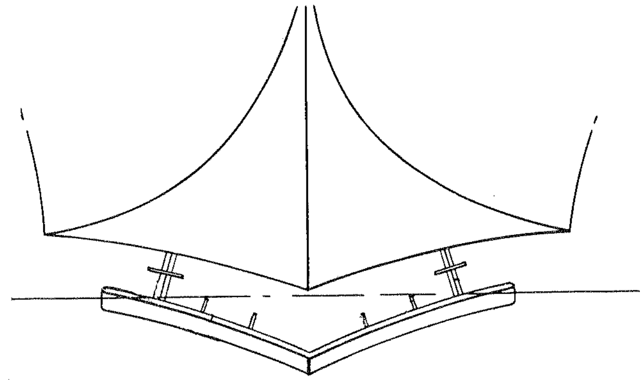


Figure 36

His success can possibly be attributed to three qualities; his undoubted genius, his determination, and lastly and perhaps most important, his deep-rooted faith in the practicability of the hydrofoil, a quality missing in many of the earlier exponents of such a craft. His interest in hydrofoils dates from his youth. In 1919 he built a boat employing a surface piercing foil system. This boat, although completed, was never tested, due to a visit and protracted stay in the United States of America.

During the period 1927-1935 Von Schertel built and tested seven boats employing various foil configurations and propulsion systems. As a result of early tests he decided against a surface piercing foil system and concentrated on a fully submerged foil system to prevent wave irregularities influencing his craft. His second boat employed a canard system of fully submerged foils, the front one being steerable. Propulsion was provided by a three-cylinder aero engine driving an air propeller, but soon after the start of a test run, the boat veered off course, the engine overheated, causing it to run on after the ignition had been cut and it had to be beached to avoid danger to spectators' boats, and other small craft in the area. As a result of this disastrous test run, Von Schertel abandoned the use of air propeller propulsion systems.

The third boat had limited success, as for the first time Von Schertel succeeded in "flying" short distances. This boat employed the same foil system as the second, but was powered by the most powerful outboard available at that time, unfortunately, however, the lateral inclination of the foils proved too small to prevent aeration.

On his fourth boat Von Schertel experimented with feeler arms, fitted with planing surfaces, to control the angle of attack of the main foils. This system proved unsuccessful, and on reflection, in view of later work by Hook, Von Schertel concluded that the feeler arms were too short and other essential elements present in Hook's craft were lacking from his own design. Improvements to craft number four were effected by the use of drag levers to control the angle of attack of the main foils, but despite the incorporation of oil dampers, performance remained unsatisfactory. As a result of this series of tests, Von Schertel concluded that immersion depth control could only be achieved by use of complicated mechanisms and installations.

Von Schertel temporarily abandoned experiments with automatic control systems and turned to a system whereby the foils derived the greater part of their lift from over pressure on the lower side.

His fifth boat employed a foil with a spring flap for reducing the effect of wave impacts and his sixth boat had foils, pivotally mounted about an axis near the leading edge. A spring force opposed movement about this axis and caused a decrease of angle of attack with increased lift, This boat proved successful, achieving 36 knots with less than 30 hp.

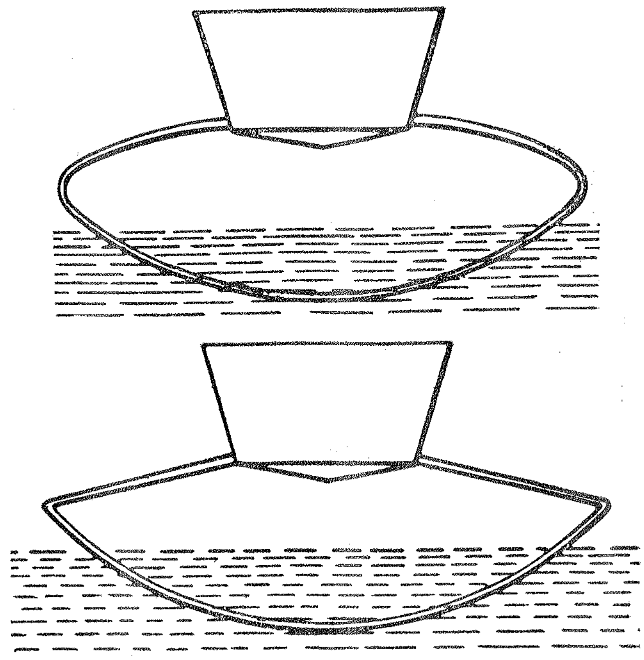
Many foil configurations were tested at different immersion depths before boat seven was built, and as a result of these tests the foils used were arranged to be automatically adjusted to give constant lift at high speeds. Although this system proved successful, laterally inclined surface piercing foils, fitted for a series of special tests, were found to be much more stable in a seaway. The results obtained from the special tests persuaded Von Schertel to return to the foil system which he first envisaged using in 1919. A large number of patents have been issued by many countries to Von Schertel. Discussion of each of these patents is beyond the scope of this article, but it is hoped to refer to them in detail at a later date.

In February, 1934, Robert Desmond Parker of Fernbank, Northern Ireland, was granted British Patent Number 405,615. Parker proposed a high speed, stepped bottom craft having hydrofoils located to the near of the centre of gravity to carry a proportion of the weight of the craft. the remainder being carried by the hull in front of the step.

Another famous name in the hydrofoil story is that of Oscar Tietjens. His United States Patent Number 1,976,046, granted on the 9th October, 1934, relates to a new type of foil system. Tietjens proposed fitting a hydrofoil boat with a surface piercing hoop foil system, the angle of incidence of the aft foil being manually controllable. His first hydrofoil speed boat tested at Philadelphia in 1932, displaced 240 kg, the craft reaching a speed of 40 km/hr with a 5 hp motor. A larger boat, built and tested in 1936, reached 25 mph. Tietjens' foil configuration was used on one of the German wartime craft, the VS-7, but was found to be unstable, because, unlike surface piercing V foils systems, it was sensitive to small degrees of roll. Types of foil proposed are shown in Fig 37.

Wsevolode Grunberg, a Russian National residing in France, proposed a futuristic looking hydrofoil craft powered by twin air propellers, during May, 1934. A single front main foil, wider than the craft, is fully submerged and rigidly attached to the keel. The front of the craft is supported by planing floats depending from outrigger surfaces. Vertical motion of the planing members adjusts the angle of attack of the main foil and gave immersion depth control of the foil. Models of craft built to this design were tested by Grunberg in the Saint-Cyr test tank, but little is known of the test results and French interest appears to have been discontinued. The wide track of the planing floats shown in Fig 38 was necessary to provide roll stability.

Theoretical work was carried out on wave drag on hydrofoils in Russia by Heldysch, Laurentier and Hotchin during 1934, but although practical work was reported, it appears that no serious effort in the Russian hydrofoil field was evident until after the second War.



O.G. TIETJENS. 1931.

Figure 37

In 1936, five British Patents were granted to J. Samuel White & Co Ltd, of the Isle of Wight. All of the designs illustrated relate to ladder foil systems, some with variable angles of attack.

The first of these patents shows a set of hydrofoils arranged in forward echelon carried by a strut projecting downwardly from the hull. The hydrofoils project from the opposite sides of the strut so that the leading and trailing edges of any one foil is in front of the leading and trailing edges of the next foil.

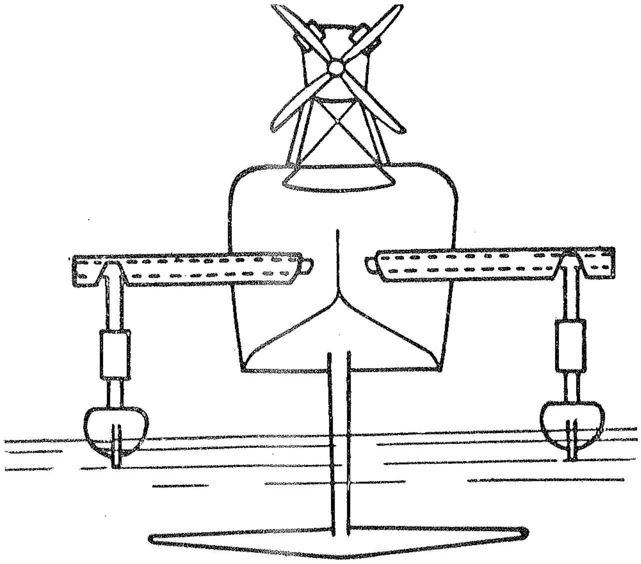
The second patent shows the same type of arrangement, but the strut on which the hydrofoils are carried can swing automatically from its initial position and towards the stern of the craft, under the force supplied by the water, to decrease the angle of incidence from the hydrofoils with increasing speed. Alternatively, the strut may be manually operated to swing forward or backwards to suit conditions under which the craft is operating.

British Patent 458,770 shows an arrangement of craft having a stern set of foils and two sets of forward foils. Both these sets of foils may be rotated about a vertical axis for steering purposes.

British Patent 458,771 shows the same type of foil arrangement, but in addition the rear strut is hollow so that at maximum speed water is able to flow up through the strut to cool the engine installed within the hull.

British Patent 485,581 shows a type of box-like girder structure providing an improved hull construction, having the necessary strength and rigidity to overcome the various loads to which hydrofoil craft are liable to be subjected.

A hydrofoil craft, commissioned by the British Admiralty, was built by J. Samuel White & Co Ltd in 1936. The craft, 67 ft 4 in long and 14 ft 6 in wide, was of aluminium alloy construction and utilised a stepped hull.



W. GRUNBERG. 1934.

Figure 38

An aircraft configuration of ladder foils was used, five foils being provided on each strut. Power was provided by three 1,000 hp petrol engines driving three propellers. Built as an experimental torpedo boat, the craft was extensively tested prior to World War II, and many consequent modifications were made. The figures for two test runs show that in a light load condition (i.e. 22.8 tons displacement) the craft recorded 41.35 knots, and in a fully loaded condition (28 tons displacement) a speed of 34.23 knots were attained.

With the advent of war, the tests were abandoned, the hull being broken up in 1940. This is the first and only time the British Government has shown any practical interest in hydrofoil craft. Fig 39 shows the craft on a test run.

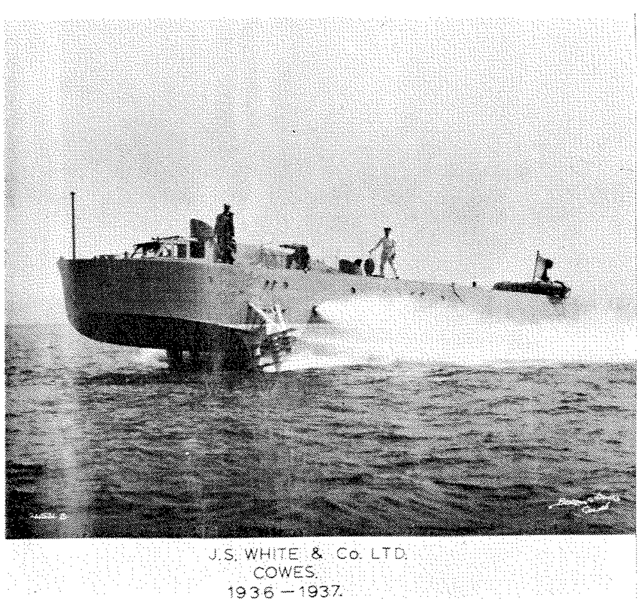


Figure 39
(Photograph Copyright Beken and Son, Cowes, Isle of Wight)

LEOPOLDO RODRIQUEZ
SHIPYARD
MESSINA – ITALY

Licensed by Supramar A.G. Zug-Switzerland

The
Greatest Experience
in
Hydrofoil Boat Building

60

RODRIQUEZ
Hydrofoil Boats Across
The World's Seas
in 15 Countries

ANY KIND
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The History of Hydrofoils

(Part III)

by Leslie Hayward

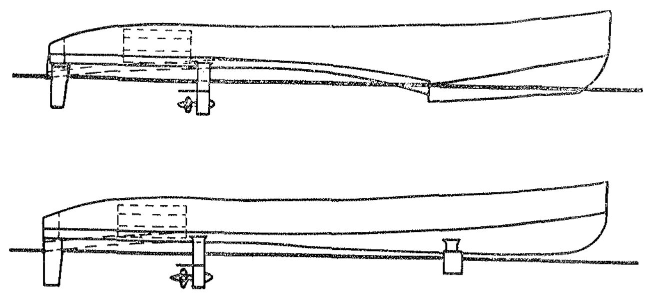


Figure 40

A FURTHER British proposal was made by the Dumbarton firm of William Denny & Brothers Ltd, during July 1938. As will be seen from Fig 40 the hull for the vessel, suggested as being 24 ft long, 5 ft beam, weighing approximately one ton and having a designed speed of 35 knots, has a front keel and chine profile ending in a hull step located about one-third of the hull length. A strut supported, high aspect ratio, fully submerged hydrofoil is fitted towards the rear of the craft and extends across the beam forward of the aft planing bottom. The propeller and its associated drive shaft are carried by the centre supported strut. Approximately 75% of the weight of the craft is carried on the hydrofoil and the remainder is carried on the bow. An alternative proposal suggested that the bow of the craft could be supported on large dihedrally angled surface breaking foils. Both proposals included the possible use of variable incidence main foils or the use of adjustable trailing edges on these foils and in both cases manual or automatic adjustment was envisaged.

William Denny & Brothers Ltd, were also engaged in experiments with the Grunberg principle of front planing floats but fore and aft foils were used instead of a single foil system.

Almquist and Elkstom, Swedish nationals, also carried out independent experimental work on foil systems similar to Grunberg. Although they did not have knowledge of Grunberg's theory or design they designed, built and tested a similar hydrofoil system. In 1948 Almquist and Elkstom formed Aktiebolaget Supermarin and built passenger carrying craft

Following Von Schertel's reconversion to laterally inclined surface piercing foil systems, he continued the development of hydrofoil craft for commercial use. In 1935 he built a craft carrying seven passengers. This craft, equipped with surface piercing V foils, proved to be a great success; with only 50 hp it had a top speed of nearly 30 knots. Extensive tests were carried out on the Rhine and in April, 1936, after a successful run, in 3 hrs 40 min, between Mayence and Cologne an order was placed by the Holn-Dusseldorfer Steamship Co, for a thirty passenger tourist boat. This is a significant milestone in the history of hydrofoils, being the first time a shipping company had shown any practical and commercial interest.

Construction of the craft was entrusted to Gebruder Sachsenburg A.G. at Dessan/Rosslau and hence in 1937 the famous team of Schertel & Sachsenburg was formed with the founding of the Schertel & Sachsenburg Speedboat Syndicate to carry on future development in co-operation with Sachsenburg Shipyards.

This concern built a 150 hp 3 ton boat in 1939. Attaining a speed of 38 knots the craft was used for demonstration purposes and development testing and was operated on the Rhine, the Baltic, and the lakes around Berlin. During the early weeks of the war, a 30 ft boat was completed, this boat was initially powered by a 120 hp engine which was later increased to 160 hp and is reputed to have had a top speed of 39 knots. The war prevented commercial exploitation but Sachsenburg obtained orders for hydrofoil craft from both the German Army and Navy Authorities. Professor Weinblum, Herr Buller, and Herr Schalte formed the senior design team and the first and fastest boat which they developed, the VS-6 reached a speed of 47 knots; displacing 17 tons this craft was intended for air-sea rescue purposes, but although it was never used in service, the VS-6 was extensively tested in the Baltic until the end of the war. The following craft, the VS-7, employed a Tietjens type foil system but was not so successful as the VS-6.

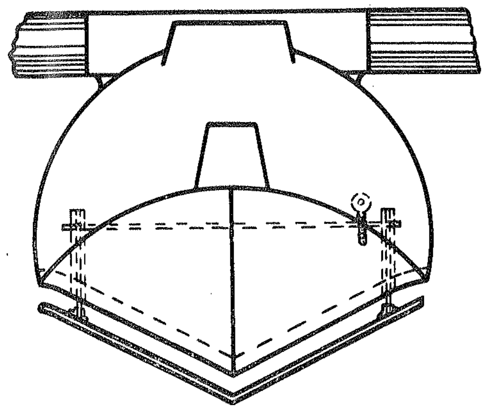
In 1941 the first of a series of 6 ton boats, intended as patrol boats, was launched. These craft were given the general designation "TS" series — TS-1, etc. The last of these craft to be built employed a "Z" drive, the drive being taken from the engine and turned through two right angles, by means of bevel gears, thus obviating the necessity of a steeply angled propeller shaft. Such a drive system was first suggested by the Meacham Brothers in 1907.

The VS-6 and VS-7 were followed by a much larger craft, the VS-8, an 80 ton vessel intended for use as an ammunition carrier between Sicily and Rommel's Army in North Africa, the craft being capable of completing the trip in the short Mediterranean summer nights. The VS-8, although generally considered to be under powered, was capable of 40 knots. Powered by two 1,800 hp diesels, speeds of 37 knots were attained in sea states of 6 ft. This craft, launched in 1943, was too late to fulfil its intended purpose, Rommel having already been pushed out of Africa. It remained in the Baltic, where, due to engine failure in a severe storm, it ran aground and suffered severe structural failure. Another craft, the VS-10, displacing 46 tons, and having a 6,000 hp engine designed for a speed of 60 knots, was completed in 1943, but destroyed by allied bombing before launching. A further craft, 29 ft long and designed for speeds up to 60 knots, was constructed and tested up to 52 knots. Adverse conditions due to the approach of the end of the war prevented further development.

At the end of the war Von Schertel carried on with purely theoretical work and it was not until 1950 that practical work was recommenced.

Failure of the German wartime programme was mainly due to the insistance of the German High Command on quick results and also the lack of suitable materials and trained engineers.

American activity during the period 1937-1943 shows considerable diversification of ideas. In July, 1937, the Consolidated Aircraft Corporation engineered a retractable V foil



CONSOLIDATED AIRCRAFT CORPORATION. 1937.

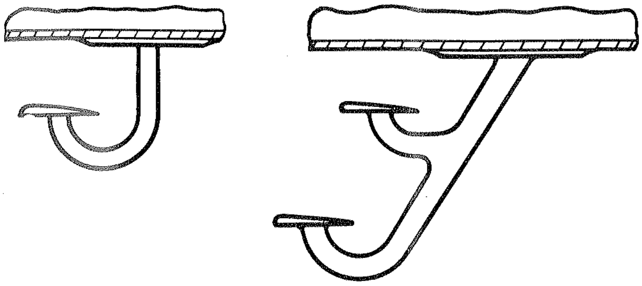
Figure 41

system for use with seaplanes and flying boats. Recognising that considerable turbulence and drag are caused by the stepped hulls of flying boats, H. E. Weihmiller, of Consolidated, designed a hydrofoil to assist take-off from the surface of the water and then to be retracted to fair off the stepped portion of the hull as shown in Fig 41. During retraction the linkage mechanism adjusts the angle of incidence of the hydrofoil so that a streamline type of fairing is achieved.

One of the major problems met with in the use of hydrofoils is cavitation, that is, the presence of air above the foil which destroys or reduces the suction lift created on the upper surface of a submerged cambered hydrofoil. Edward J. Hill, of Detroit, Michigan, became interested in the problem during 1938 and writes: "It is recognized that when hydrofoils are supported below a hull at an angle dihedral to the water line and the foils raise in respect to the water line "reefing" occurs, that is, the outward ends of the foils break through the surface of the water and are exposed to the air. As reefing occurs, air is admitted to the suction surface of the hydrofoil causing cavitation along the top surface which almost entirely destroys its suction lift.

Reefing is not the only cause of cavitation. The struts between the top of the hydrofoils and the craft to which they are secured create a cavity at their trailing edge which communicates with the top, preferably cambered surface, of the hydrofoil and admits air forming cavitation bubbles which destroys the suction lift.

In order to avoid cavitation of hydrofoils via the supporting struts they must be deeply submerged. However, as soon as a craft having deeply submerged hydrofoils is propelled through the water at high speeds, the craft and hydrofoils are lifted with respect to the surface of the water, which lifting during propulsion is termed "planing". As soon as the distance from the top of the hydrofoils to the surface of the water is materially reduced, cavitation via the struts occurs and the craft settles with respect to the surface of the water only to be lifted again as soon as the suction lift of the hydrofoils is built up at the deeper submergence. This alternate raising and lowering of the craft in respect to the surface of the water which may be termed "porpoising" is highly undesirable and reduces the speed of the craft to such an extent that any advantage derived from the use of hydrofoils is lost in many instances.



E. J. HILL. 1938.

Figure 42

In order to overcome the undesirable effects of cavitation some craft have been built having a multiplicity of vertically spaced hydrofoils upon the theory that when upper hydrofoils become ineffective because of cavitation the lower hydrofoils remaining some distance below the surface of the water will maintain their suction lift. Such construction is not only freakish but impractical because of the danger that the multiplicity of hydrofoils in sets or tiers will foul the slightest obstruction at or below the surface of the water. Also, a multiplicity of hydrofoils cause a great resistance to propulsion through the water requiring a tremendous amount of power to propel the craft at a sufficient speed to permit planing.

An attempt to overcome cavitation via supporting struts has been made which comprised the use of small baffles on the strut between the hull of a water craft and the top of the hydrofoil. Such baffles have been found to be ineffective in as much as when the craft planes the baffles become located so near the surface of the water that cavitation around the baffles and down the struts occurs which admits air to the cambered surface of the hydrofoil forming one or more cavitation bubbles which destroys the suction lift. The above is especially true in choppy water.

Dihedrally disposed hydrofoils have been baffled with small baffles disposed normal thereto spaced along the top to prevent cavitation during reefing; however, such baffling is ineffective inasmuch as air bubbles can travel vertically down both sides of the vertical baffles and destroy the suction lift of the dihedrally disposed hydrofoils".

Hill proposed anti-cavitation type hydrofoils, located forward of their supporting struts as shown in Fig 42.

A boat which combined the advantages of hydroplaning and hydrofoils was proposed in March, 1942, by C. N. Neklutin, of Missouri, U.S.A. The hull, having a "V" form at the bow, has a gradual change of form so that it terminates in a flat-bottomed inclined planing surface at the stern. A transverse hydrofoil, rigidly secured below the "V" form part of the hull, is supported by a series of plate type fins. Neklutin suggested that the hydrofoil should have increased width at its outer ends and that it should have a dihedral form. In addition to a keel plate which extends below the undersurface of the foil the supporting fins may also extend vertically below the foil to counteract side slip

April 24th, 1945, is the issue date of United States patent 2,374,467 applied for by James E. Sykes, of Seattle, Washington, in June, 1943. Probably the most fantastic design and patent ever issued in connection with hydrofoils, it is mentioned here for its entertainment value! A large ship of cylindrical form, having marine propulsion and steering apparatus for use in harbours, is fitted with a huge hydrofoil mounted on the bottom of the rear portion of the hull. An aircraft having six engines driving four tractor and two pusher propellers, is mounted on the top surface of the front part of the hull for propelling the ship and lifting the forward end of the hull. The aircraft may be fixed to a turntable to aid in manoeuvring the ship!

The Specification of British Patent 637,232 granted to Ettore Bussei, of Genoa, Italy, shows and describes a craft supported well clear of the water on a large fin type support connected to a fully submerged foil system The Specification gives details of a gyroscopic control device automatically governing foil incidence, stability and height of the craft above the water level.

(*To be continued*)

The History of Hydrofoils

(Part IV)

by Leslie Hayward

SINCE writing the early part of this history I have become aware of a proposal put forward in December 1921 by Gustavus Green of aero and marine engine fame. Many of the early aviators, including Lord Brabazon, Cody and A. V. Roe, used his engines.

The Sphere of September 29th, 1923, draws attention to "Strange Craft at the Olympia Exhibition" and illustrates Green's "skimming boat, rising completely from the water, eliminating all skin friction upon hydrovanes planing almost at the surface, the propeller and the tip of the rudder only remaining immersed when the speed, it is claimed, will reach 70 knots".

British Patent 196,335, issued to Green on April 24th, 1923, gives details of a skeleton type or moulded hull construction. Ladder type foils are shown.

The name of Christopher Hook is known in hydrofoil circles all over the world. Caught in Vichy, France, during World War II, Hook studied naval architecture and aerodynamics prior to escaping to Lisbon and eventually to Kenya. Here, his theory and experimentation resulted in the construction of three development craft. Materials and engines being almost unavailable, Hook persevered with aircraft scrap and various types of salvaged engines. Fig 43 shows HN.1 *Genesis*, and Fig 44 shows a converted Walrus hull having a rebuilt 150 hp aero engine and propeller at Mombasa during 1943.

In November 1942 Hook applied for the first of his hydrofoil patents, British Patent 572,179 and US Patent 2,387,907. Both patents were granted in 1945 and relate to a craft having submerged hydrofoils set at a predetermined angle of incidence, the incidence angle being automatically controlled by a control float arranged to skim along the surface of the water in advance of the lifting foils. The control float is mechanically coupled by suitable lever and linkage mechanisms to the lifting foils. With this arrangement the distance of the craft above its normal floating position and its stable attitude remain more or less constant provided that forward speed is above a predetermined minimum. The foil units may be of the single or multiple type and each unit is independently controlled from its associated control float.

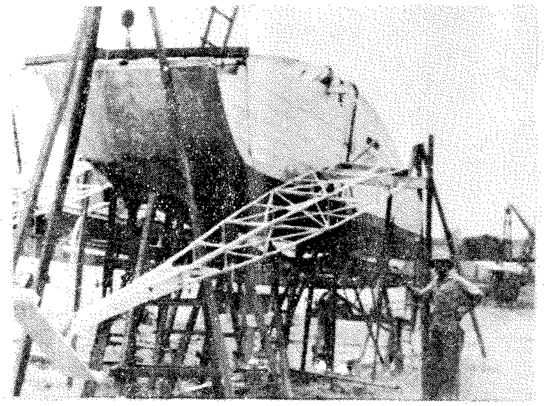


Figure 43

As will be seen from the diagram shown in Fig 45, a fixed foil is supported, together with tiller-operated rudders, from the stern of the craft. A cross beam and vertical struts support pivotally mounted lift foils at the bow. An arm, pivoted to the cross beam, carries control floats arranged to skim along the surface of the water, and is also rigidly connected to a front extension of the lift foil, thereby establishing a positioning relationship between the control and lift foils.

Hook suggested that in addition to mechanical power units, sails or wind-driven propellers may be used to propel such a craft and this appears to be the first time that such a combination had been suggested.

Experiments showed that, in small waves, craft of the above type tended to follow too closely the wave contour and it was proved that in certain wave forms the lift foils were liable to surface between the crests. To overcome this condition, Hook proposed to retard the downward movement of the control float, and in December 1944 he applied for his British Patent 588,733. A dash pot device installed between the foil support strut and the pivoted arm carrying the control float restricts downward movement by the arm. Resistance of the dash pot device can be adjusted by the pilot to suit prevailing sea conditions.

A further development of November 1945 was the incorporation of a trimming gear, enabling the angle of incidence of the lift foils to be trimmed in accordance with sea conditions without affecting the action of the control

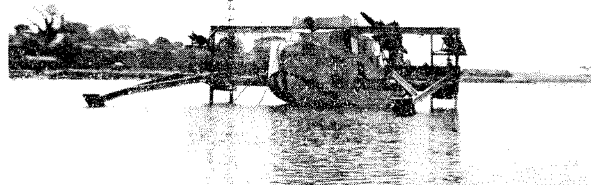
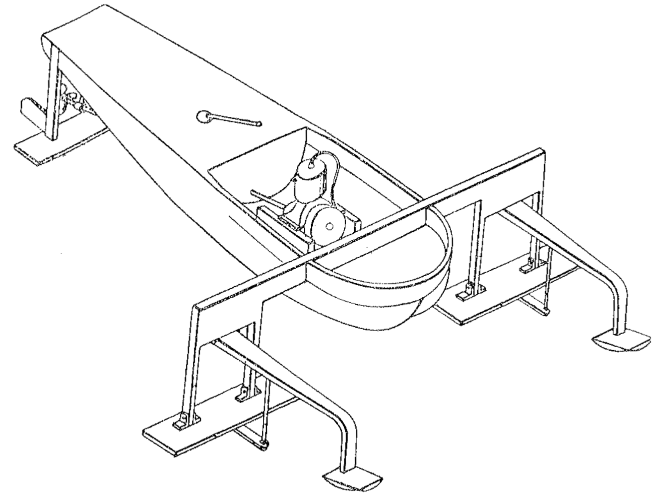


Figure 44



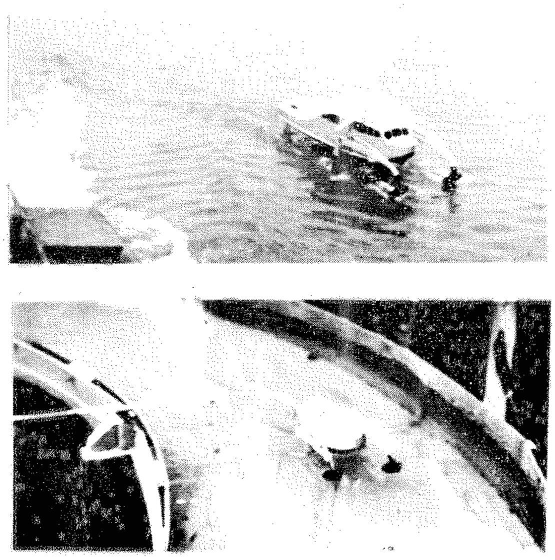
C. HOOK. 1943.

Figure 45

floats. This proposal is the subject of British Patent 591,933.

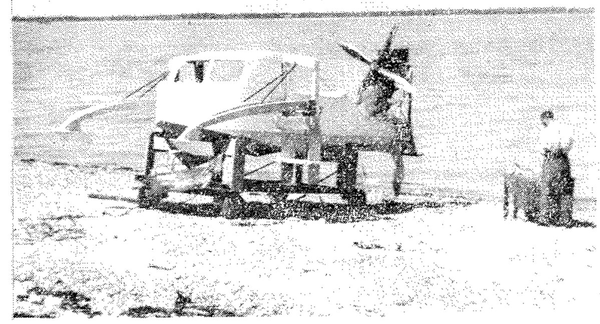
In 1945 Hook returned to England and set up a small research establishment at Cowes. Model tests in open water and in his circular test tank, Fig 46, were actively pursued, these tests resulting in the building of HN.4 at Cowes in 1947 (Fig 47).

Due to lack of interest and support from British sources, Hook decided in 1950 to exploit his inventions in the United States. He exhibited a small one-person craft at the New York Boat Show of January 1951, and with help from an American partner, C. P. Holt, he carried out many demonstrations in New York, Long Island Sound, Washington and Annapolis. Moving to Miami, Hook and his partner Holt built and sold a small number of conversion kits (Fig 48) for attachment to sporting type craft (Fig 49). They also worked as consultants on a hydrofoil craft being designed and built for the United States Navy.



C.HOOK. 1945.

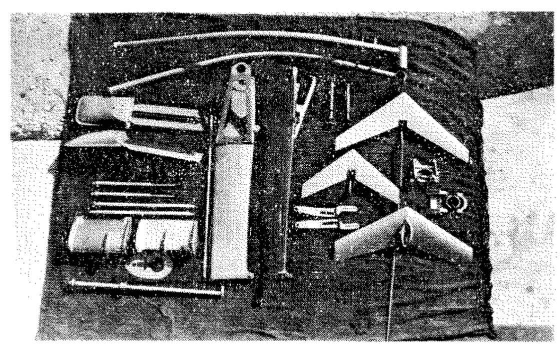
Figure 46



H.N. 4. COWES. 1947. C.HOOK.

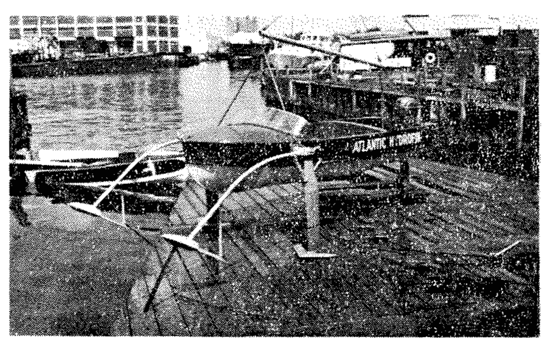
Figure 47

Further work by Christopher Hook resulted in United States Patent 2,708,894 dated March 6th, 1952, British Patent 738,333 dated April 1953, and United States Patent 2,795,202 dated August 18th, 1954. All these patents relate to various developments or use of control floats and arrangements for varying the ratio between the angular movement of the control float arms and the lift foils.



CONVERSION KIT PARTS.
C. HOOK.

Figure 48



CONVERSION KIT ON SPORTS-BOAT. C.HOOK.

Figure 49

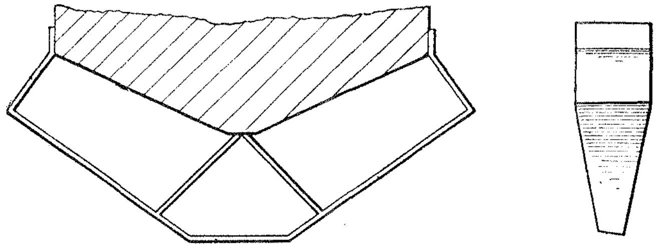
Craft utilising Hook proposals have been built in many countries.

It is believed that the first record of hydrofoil craft being used on military operations can be claimed by the Canadian Navy, who operated small smoke-laying craft in the Dutch estuaries during World War II. The craft, of which little appears to be known, were designed by Baldwin and Rhodes and closely followed design patterns set by Alexander G. Bell. Underwater screws were used instead of air propellers.

In January 1944 A. M. Hamilton, a British subject, proposed a craft having various forms of "box kite" type foils, two types being shown in Fig 50. The foils, tapering in width and thickness, are arranged to be rotated through an angle of 90° to lay beneath the hull as required. Alternatively the foils can be retracted along the side of the craft. Shock absorber devices deaden impact loads between the foils and the hull. Hamilton suggested that his designs could be incorporated in flying-boats and seaplanes.

A collaboration between Geoffry Cromwell, James Dalziel and Peter Macpherson, all British subjects, resulted in the issue of British Patents 582,985 and 588,315, applied for in July 1944 and January 1946, respectively. A Tietjens type foil, transversely disposed beneath the hull, is attached to the hull by a re-entrant bracket of foil section, as shown in Fig 51. The angle of incidence and the chord dimensions increase from the centre position towards the outer extremities. For strength and stability, centre struts are provided between the main foil and the base of the hull. With the arrangement shown, the foil attachment brackets and the centre struts all contribute to the total lift effect.

British Patent 588,315 relates to an improvement of the above foil system, the foil being given a variable convex surface along the length of the upper surface. The lower surface is convex or plane at the mid-point, plane at an intermediate section and concave at the outer extremities. It is suggested that foils of this type, Fig 52, designed for a predetermined velocity, compromise between lift/drag ratio and result in obtaining the most efficient lift at all stages of foil immersion.

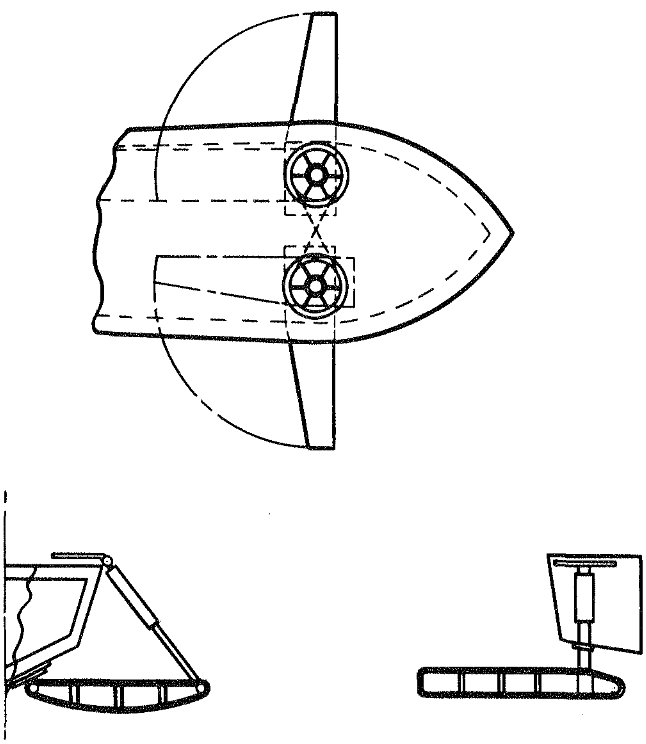


G. HAMPDEN, J. DALZIEL. & P. MACPHERSON. 1944.

Figure 51

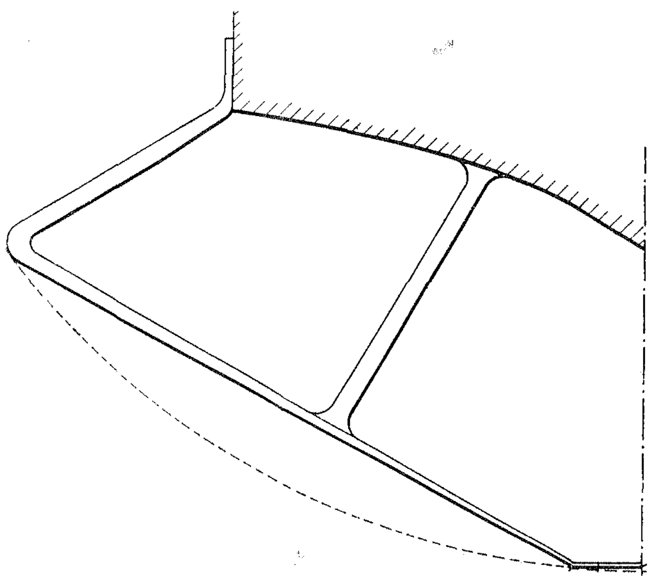
It is known that a 20 ft craft designed by Hampden and Macpherson was built by Camper Nicholson and tested in Portsmouth Harbour during 1947. A speed of 38 knots was achieved.

Leslie Morgan of Northampton was granted British Patent 587,317, having an application date of September 1944. Morgan's proposal relates to a hydrofoil pleasure craft. The body of the craft is in the form of a small flying-boat, a single fully submerged foil being mounted on the base of a vertical keel member. An engine installed in the hull drives contra-rotating propellers mounted on a pod to the rear of the lift foil.



A. M. HAMILTON. 1944.

Figure 50



G. HAMPDEN, J. DALZIEL. & P. MACPHERSON. 1945.

Figure 52

A further proposal that falls somewhat in the realms of fantasy is the subject of British Patent 597,570 of March 1944, granted to Henry Pearson of New Jersey, USA. A large flat-bottomed hull has longitudinally extending side walls of considerable depth. Hydrofoils located at the base of the side walls span the space between them and continue to extend a considerable distance exterior of the side walls. Rudders are provided at the rear of both side walls and marine type propellers mounted within the side walls provide propulsion. Flaps extending along the rear of the foils provide incidence control. Pearson claims his craft would travel at great speed and rather hopefully suggests that a torpedo would pass between the side walls without inflicting any substantial damage!

A pivoted hydrofoil mounted on the stern of flying-boats was proposed by Thomas Slate of Washington, DC, in October 1941. It is suggested that such an arrangement could be used to assist landing of flying-boats and seaplanes. As the tail of the craft enters the water the foil is moved to maximum braking position and automatic or manual control is used to progressively adjust the angle of the foil until the craft is at rest. It is also suggested that the foil would prevent the craft from nosing-over on landing.

An unusual adaptation of hydrofoils is disclosed in US Patent 2,491,744 and US Patent 2,493,482, which refer to seaborne flight simulators. An aircraft cockpit complete with normal controls and supported by buoyant pontoons is fitted to the top of a vertical column. At the base of the column is a waterproof chamber containing an engine for driving a marine propeller. Attached to the outside of the chamber is a fully submerged foil system very similar in design to an aircraft wing and tail structure. When in motion, the pontoons are lifted clear of the water and the craft is supported on the hydrofoils, operation of the "flight" controls producing a response identical to that of a conventional aircraft.

(To be continued)

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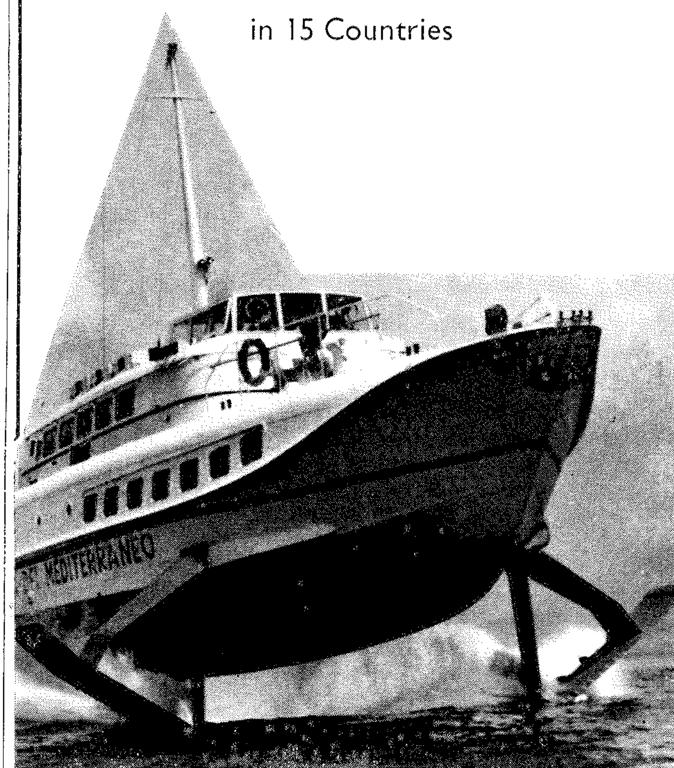

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The History of Hydrofoils

(Part V)

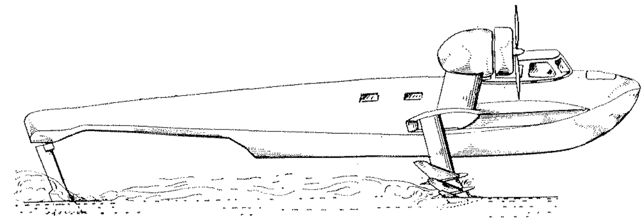

Figure 53

by Leslie Hayward

PRIOR to the Second World War, Russian interest in hydrofoils appears to have been restricted largely to theoretical and model work.

At the end of the war the Russians took over most of the completed and partially completed craft of the German Navy and instituted a large development programme on them in addition to their own studies. In the early fifties four small craft powered with automobile engines were built to test positioning and design of various types of foil configurations. Some of the development was carried out at the Sormovo Shipyards on the Volga, near the city of Gorky, under the direction of Rotislav Alekseyev. The first Russian passenger-carrying craft was launched in 1957.

Although a considerable amount of private research and development was carried out in the United States of America prior to the Second World War, official support from Government departments did not become available until 1947, when the Naval Department instigated a research programme.

John Gordon Baker of Evansville, Wisconsin, USA, developed a number of small high-speed craft employing three retractable "V" type foils which eliminated the necessity of immersed supporting struts. All underwater surfaces except for the propulsion unit are lifting surfaces, resulting in minimum drag. United States Patents 2,856,877, 2,856,878 and 2,856,879 disclose details of Baker designs. Vol 1 No 1 of *Hovering Craft & Hydrofoil* gave details of the hydrofoil sailboat *Monitor* designed by the Baker Manufacturing Co.

As a commercial proposition *Monitor* proved to be too expensive and Baker turned to the development of a hydrofoil system for 14 ft motorboats, development being completed just before the Korean War. On the strength of the performance of these boats — they carried four men at 27 mph with a 10 hp engine — the US Navy awarded the company a contract to build two hydrofoil research craft. The first, *High Pockets*, 23 ft long, 10½ ft beam, with four V-shaped piercing foils in a tandem arrangement, displaced 6,000 lb and reached a speed of 35 knots with a 125 hp engine. The second craft, *High Tail*, employed a fully submerged foil system consisting of three angle-controllable foils.

Other early American experimenters include R. Gilruth of NACA. Gilruth started experimental work with hydrofoils as a hobby in 1938. His first craft was a 12 ft sail-powered catamaran which became foilborne at 5 knots and reached 12 knots. This work resulted in US Patent No 2,703,063, which relates to a hydrofoil yacht with a submerged foil system. Application of Gilruth's work to high-speed configurations formed the basis of the first research proposal to the US Office of Naval Research in 1947.

A theoretical and experimental research programme was undertaken in America in the period 1947-55 by W. P. Carl & Sons. Based on Gilruth's work, and with his help, a 12 ft model was built and tested. As a result of these tests a 53 ft craft was built. This craft, the XCH-4, exceeded its design speed of 65 mph by a wide margin and its stability was excellent. Powered by two 300 hp engines, XCH-4 displaced 16,500 lb, had a top speed of 75 knots and was completed in 1955. US Patent 2,914,014 granted on November 4th, 1959, and GB Patent 907,711 granted on October 10th, 1962, show design details.

Two forward, "V" type ladder foils carry the major portion of the weight and a single fully submerged foil is used at the stern. The engines are mounted on support struts well clear of the main body of the craft and are arranged to drive conventional type air propellers.

A further US Navy test craft, the HC-4 or *Lantern*, was 36 ft long and 22 ft wide and had a speed of 18 knots with

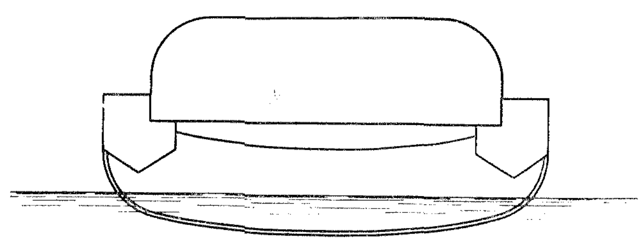

Figure 54

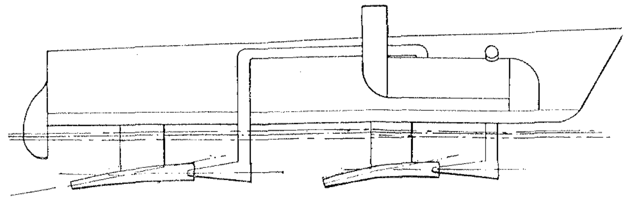

Figure 55

a displacement of 22,200 lb. A fully submerged foil system having automatic control of angle of attack was used. The craft was developed under the direction of Dr Vannevar Bush, who had earlier built a small boat having hydraulically controlled foils.

On June 7th, 1955, US Patent 2,709,979 and on June 12th, 1956, US Patent 2,749,869, both relating to pressure-activated hydraulic control systems for submerged foils, were granted to Bush and The Hydrofoil Corporation of Washington, DC.

Further British contributions to the general art were made in November 1947 and July 1948 by N. W. Gardiner and Robert Bull Ltd of London. The angle of attack of a hydrofoil is varied by fitting an electrical predictor device associated with pivotal predictor arms located in front of the main lifting foils. Signals to the predictor device result in a change of foil incidence to maintain lateral stability. Details of the device are given in British Patent 643,682. Designs using a rearward-facing foil, located at the end of forward-facing sensor arms, to mechanically activate or control the incidence of the main foil system are disclosed in British Patent 643,697 and US Patent 2,603,179.

In April 1950, Allyn Hayard of Albuquerque, New Mexico, USA, designed a small high-speed craft having a manually operated control system for fully submerged foils. Hayard set out to provide an inexpensive craft, simple to construct and easy to maintain. He also suggested that his foil and control systems could be easily attached to conventional small boats and that outboard motors or air-propeller drive may be used. Foils attached to bell-crank levers housed within tubular struts attached to the boat hull are interconnected via cables and pulleys to a joy-stick type control column. It is believed that a number of these small craft were built and used for sporting purposes.

B. K. L. Almqvist and B. O. Elgström of Alvsjo, Sweden, persevered with development of the Grunberg foil system and in 1948 they proposed a new form of front stabilising foil. The new foil, formed from two surfaces connected together and to the hull by upwardly and inwardly inclined plates, is also joined to the hull by support tubes as shown in US Patent 2,597,048. Further development, the subject of US Patent 2,791,195, resulted in a foil system as shown in Fig 55. The foil, fitted at the centre of gravity of the craft, supports the major part of its weight. A front planning surface and an automatically operated rear stabiliser foil are used. The main lifting foil extends under the hull from the outer surfaces of longitudinally arranged "V" bottomed floats which are raised above the water when the craft is operational.

In July 1946, H. C. Harris and C. S. Harris of Cirencester, Gloucestershire, England, proposed a large streamlined tubular-hulled craft supported on hydrofoils located at and depending from the underside of the front and rear portions of the hull. A feature of the design is the inclusion of controllable flaps or ailerons in the front hydrofoils and the use of tiltable foils at the rear of the craft.

Louis Corlieu of Paris, France, appears to be the first person to suggest foils formed with a rigid leading edge and a very flexible trailing edge. His design of September 1947 shows such a hydrofoil in which the surface has a progressive flexibility towards its trailing edge. Corlieu suggests his design of foil could be used in the fully submerged form on large craft.

An interesting development was proposed by W. D. Cooke of Iver, Buckinghamshire, England, in January 1951. As shown in Fig 55, the hull of the craft is carried above the water by struts connecting with downwardly curved convergent lifting nozzles, open fore-and-aft. A convergent steam nozzle, fed from a boiler in the hull, projects into the lifting nozzle, the steam condensing and forcing the water through the lifting nozzle at high velocity. Increase in water momentum drives the craft forward and due to the remitant downward component provides the necessary lift force to maintain the hull above the water line.

United States Patent 2,703,063 granted to Robert R. Gilruth of Seaford, Virginia, USA, discloses a craft having catamaran-type hull supporting a mast and fully rigged sail. At the nose of the craft support struts extending downwards from the inner walls of the two hulls connect with a fully submerged dihedral hydrofoil of high aspect ratio and low profile drag. Depending struts at the rear of the twin hulls support a fully submerged hydrofoil having a manually controlled elevator flap mounted in its trailing edge. A rudder is provided on one of the rear struts. Operation of the elevator flap counteracts fluctuations in pitching moment from change in wind or tack.

A design of craft intended to be used as a landing craft by the Armed Services was proposed by M. H. Vavra of Glen Burnie, Maryland, USA, in October 1951. The craft, powered by two 90 hp engines, having a gross weight of approximately 6 tons and capable of carrying twenty-two men, was expected to have a top speed of 25 knots. The hull is supported via struts on a main lift foil made up from a fixed centre span and a pair of independently adjustable outer spans each carrying a propeller unit. The support struts are pivotally mounted and the complete foil assembly can be retracted to lie flush with the underside of the hull, the propellers still being available for water propulsion. Fully submerged stability foils are arranged at the bow of the vessel; these foils are also retractable within recesses in the underside of the hull. Auxiliary foils, also fully retractable, may be fitted in front of the main lifting foil.

In 1953 the US Navy instigated an investigation into the use of hydrofoils on landing craft. The Navy showed interest in the use of retractable foils, intended to increase the approach speed of the craft to approximately 35 knots. The first craft had retractable submerged foils, the front foils being controlled by forward-facing feeler arms. The craft was 20 ft long, $5\frac{1}{2}$ ft wide and displaced 2,600 lb; it had a top speed of 23 knots. A non-amphibious craft was also developed. Designated LCVP, it was developed from the LCPs of the Second World War. Supported by four surface-piercing foils, three times the speed of conventional craft was attained on tests over a period of several years.

As a result of these tests the design and construction of two larger amphibious landing craft was undertaken. The *Halobates* was completed and tested in 1957; 45 ft 9 in long and 12 ft wide, it displaced 31,000 lb and was powered by a 630 hp engine. Originally the front foils were controlled by mechanical feeler arms, but these were later replaced by an electrical system. The craft met with limited success. Details of the second craft are not available.

Two more amphibious craft have also been completed. Designated LVHX-1 and LVHX-2, they are of identical size and performance; 38 ft long with aluminium hulls, both have a foilborne speed of about 35 knots. A 5 ton payload is carried. The former has a fully submerged foil system and the latter a surface-piercing main foil and a submerged rear foil, obviating the necessity for incorporation of an automatic control system. A hydrofin landing craft working on Hook's principle has also been built and tested. A further development, using a turbine-powered DUKW of the Second World War, was first tested in 1959. The use of turbines on hydrofoils increased the speed of the DUKW from 6 to 35 mph. Avco Corporation's Lycoming Division has been responsible for a considerable amount of research and development work on hydrofoil landing craft.

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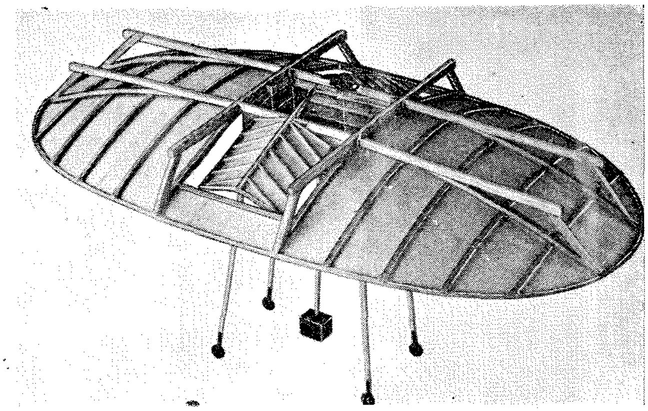
Applications are invited from suitably qualified graduates for the post of Research Fellow in the Department of Aeronautics and Astronautics for work in Fluid Mechanics applied to Hovercraft. The salary will be based on the qualifications and previous experience of the candidate but would be in the region of £1,200 p.a.

Applications (in duplicate) giving details of qualifications and experience, together with the names of two referees, should be sent to the Deputy Secretary, The University, Southampton, before 15 November, 1965.



THE HISTORY OF AIR CUSHION VEHICLES

LESLIE HAYWARD

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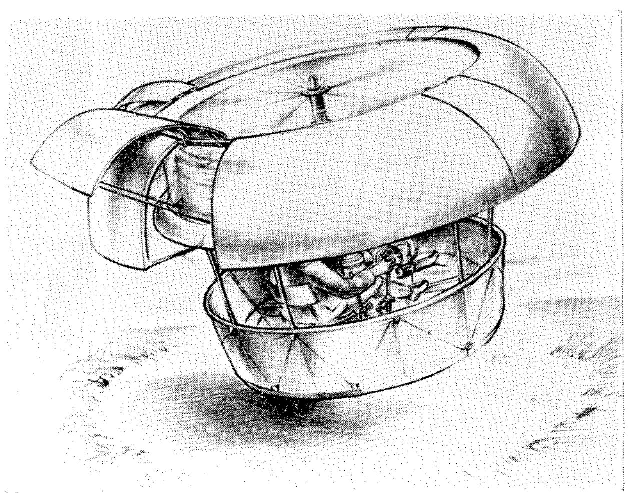


The History of Hydrofoils

(Part VI)

by

Leslie Hayward

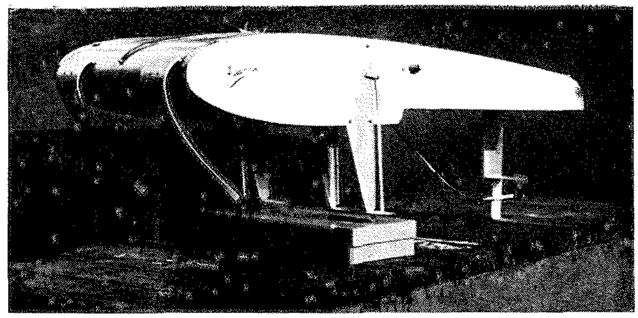


Figure 56

Hydrofoil craft which use some form of float, skimming along the surface of the water, to control the position or angle of the main lifting foils require the skimming foil to undergo a very wide range of movement as it passes from a wave through to a wavecrest, and in addition, the control movements follow rapidly one upon the other, when the craft is operating in a short sea.

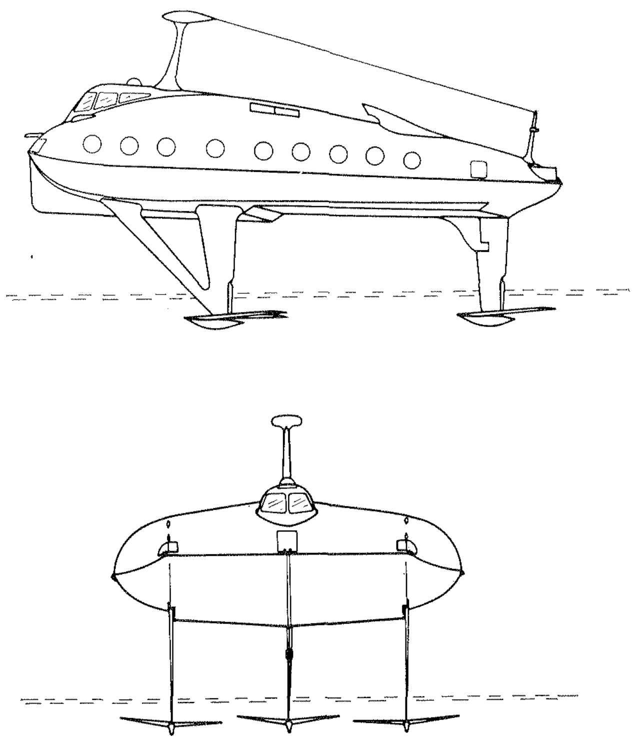
Stephen W. Hobday of Sycamore Road, Farnborough, Hants, England set out, in 1947 to provide a control device which while being responsive to water surface irregularities is subjected to a master control arranged to average out the irregularities of the water surface and therefore give a relatively smooth control responsive to general conditions, rather than the instantaneous conditions in the vicinity of the control device.

As will be seen from Fig 56 a fixed foil is mounted on the rear strut which also carries the propeller. Two pairs of struts depending from the hull carry variable pitch hydrofoils. Curved control vanes suspended from the front of the hull are pivoted so as to trail about an axis transverse to the hull. Each control vane is tapered throughout its length and hangs trailing and immersed in the water due to gravity or alternatively, its position is controlled by a spring or mechanical device, water pressure deflecting the vane back towards the rear of the hull. A linkage embodying lost motion and a damping arrangement transmits movement of the vane to the main foils. Details of the linkage mechanism are given in British Patent 713,730 and US Patent 2,722,189. Modifications suggested in October 1947 and forming the subject matter of British Patent 713,943 and US Patent 2,890,671 made use of electronic apparatus, for measuring variable signals which are in turn used to operate a mechanical lever system to adjust the main foil angle.

As reported in *Hovering Craft & Hydrofoil* for July 1964 the Grumman Aircraft Engineering Corporation have been granted an exclusive licence to use the electronic sonar system covered by the above two patents.

It may be of interest to record that the model shown in Fig 56 was demonstrated to the late Dr J. E. Allen in the National Physical Laboratories Tank at Teddington in 1950.

In May 1951 Stephen Hobday submitted a design brochure and proposals for the 48 ft craft shown in Fig 57 to the United States Navy Department. Use of turbo jets to eliminate screws and shafts resulted in a very good hydrodynamic layout and the swept back plan form of the hydrofoils greatly assists in the automatic removal of weed or flotsam. The centre of pressure for each foil is brought close to its pivot point and the chord tapers from



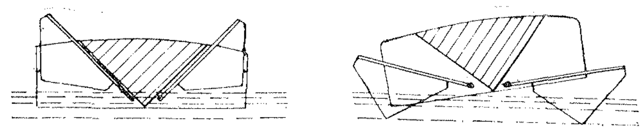
S.W. HOBDAY. 1950.

Figure 57

3 ft at the centre to 2 ft at the outer extremities. The outer half of each forward foil has a four degree dihedral angle and the rear foil has a symmetrical dihedral of similar amount. One important feature of the design is that as the trailing edges of the centre sections of the foils are all ahead of the struts on which they are supported, air passing down the trailing edge of the strut is unable to move forward through the high pressure region to the low pressure area at the rear of the foil to cause break-down of flow.

This craft, which bears a striking resemblance to the "Lantern" built by the Hydrofoil Corporation of Annapolis considerably after Stephen Hobday's design proposals were submitted to the US Navy, was probably the world's most advanced and fully streamline design of its time. The power plants suggested were two Rolls-Royce Derwent Gas turbines giving a maximum thrust of approximately 7,200 lb and a cruising range of 1,000 miles. Alternative proposals for a propeller driven version of the craft were also made.

Mr Hobday has kindly supplied the following details. Length 48 ft; beam 24 ft; height 32 ft 9 in overall; volume excluding cabin 9,680 cubic ft; all-up weight 40,000 lb; disposable load 25,000 lb; static displacement 640 cubic ft; hull draught 1 ft 2 in; forward foils 8 ft length; area of forward foils 48 sq ft; loading of forward foils 666 lb per sq ft; loading of rear foils 333 lb per sq ft; max. speed 60 mph; cruising speed 30-40 mph; take-off distance 150 ft; Electronic sonar control system which appears from *Hovering Craft & Hydrofoil* of February 1962 to have been subsequently used in the Gibbs and Cox "Sea Legs" was incorporated in both designs.



J. HERZ. 1952.

Figure 58

A control foil directly connected to, and controlling the pitch angle of the main foil, having a mechanism which can adjust the phase relationship between the two foils for varying the general height of the craft above the water was proposed by David Z. Bailey of Charlestown, USA, in January 1952. The control foil is attached to the leading edge of a vertically moveable strut so that movement of the strut operates a system of cables and pulleys to relay a positioning signal to the main lift foil. The phase relationship is manually or automatically adjustable.

To obviate the necessity of having cantilever structures projecting from the sides of a hull J. Herz of Berlin-Spandau, Germany, suggested a craft having side-by-side retractable V-type foils arranged in tandem, the foils being pivotally mounted under the hull, adjacent the longitudinal axis of the craft as shown in Fig 58 US Patent 2,713,317 discloses details of this design.

Fritz Vertens of Schleswig, Germany, who has built a class of runabouts and thirty foot cruisers more or less based on Tietjens designs obviously came up against cavitation problems, as in February 1954 he proposed several surface piercing foil assembly designs in which the incidence angle of the foil progressively varies between the upper and lower portions of the foil. Many different conceptions of V and hoop foil systems are illustrated in the Vertens patents.

An unusual adaptation of water skis and hydrofoils is found in US Patent 2,751,612 issued to H. Shepard of Auburn, New York, for a scheme proposed in March 1954. Hydrofoils fitted below water skis enable a person being towed over the surface of the water to be lifted above the water surface.

A mechanically propelled water sport sea sled equipped with a tandem type ladder foil system was the brain child of C. J. Kregall of Chicago during January 1955. Extensible pontoons support the sea sled when boating.

Harold Boericke, of Washington D.C. undertook considerable research and development studies on surface piercing foils, angle of attack control, foil retraction and cavitation during the period 1955-1957. One of the foil configurations investigated became known as the "diamond-shaped" hydrofoil and comprised an upper inverted V and a lower V connected at the horizontal corners by a bracing structure also serving as a lift foil. The chords of both of the V foil sections may vary from one another to improve lift-depth characteristics and the camber of both of these sections may vary from one another to provide a combination of low drag at high speed and

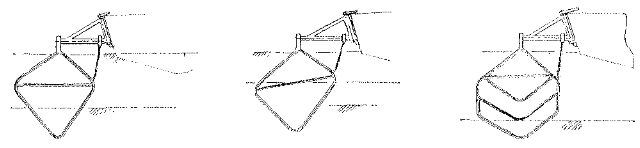


Figure 59

low take-off speed. A strut attached to the apex of the inverted V and a further strut attached to the inboard section are pivotally supported from mounting brackets in turn pivotally attached to the hull of the craft. This arrangement permits the foils to be retracted about a horizontal axis or turned about a vertical axis for steering. The support line for the foil assembly is forward of their leading edge so that lift forces on the foils tend to rotate the assembly forward to assist in counterbalancing drag forces and obtain hydrodynamic balance.

Applications of the above type of foil configurations, shown in Fig 59 in combination with interconnected hydraulic mechanisms for steering, controlling and indicating angle of attack and for retracting foil assemblies mounted on the sides of a hull are disclosed in US Patents 2,887,028 and 2,887,081 applied for in August 1956.

During the early part of 1957 Boericke proposed that his various foil and strut sections should be so shaped and chosen relative to each other and to the speed of the craft that they should be free of destructive cavitation at speeds when they would normally be submerged. For instance, at speeds up to 45 knots all sections could be submerged, no cavitation taking place, at speeds up to 55 knots the top section would be out of the water no

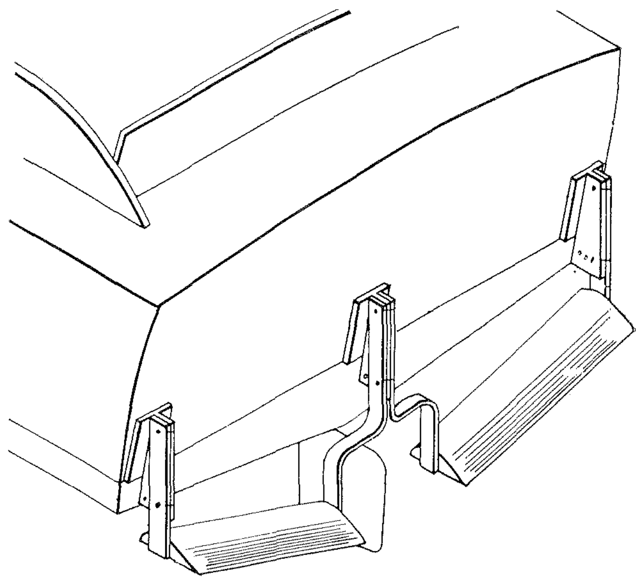


Figure 60

cavitation taking place on the remaining submerged sections, up to speeds of 65 knots when only the lower non-cavitating section of the foil assembly would remain under the water. US Patent 2,890,672 gives details of these proposals.

John Bader, a co-inventor with Boericke in US Patent 2,887,082 also proposed his own form of mechanism for steering by simultaneous fore and aft movement of transversely arranged, independent foil systems. He was also responsible for considerable detail design work in connection with retracting and folding, diamond type foil assemblies against the side of the hull. In 1959 Bader proposed various schemes for retracting V-shaped, surface piercing foils, in which the angle of the V may be varied to suit operational requirements, against the keel form of a high-speed craft. The mechanism for retracting the foils being used to vary the angle of the V and also to adjust the angle of attack.

Further developments concerned the retraction of foils extending transversely across the underside of the keel, the foils carrying propulsion propellers, and, designs for a craft wherein the propeller struts act as after foils. These proposals are described in detail in US Patents 2,991,747, 2,984,197 and 3,031,999.

Aeronautical Boat Shop Inc and Joseph Lyman of Halesite, New York, USA, proposed a design of sailing craft having a vertical keel with horizontally extending fixed submerged hydrofoil surfaces in the early part of 1955. The hull of the craft is said to have been "rocket shaped" and a deep keel incorporating a rudder is known to have been proposed.

A British contribution to the combination of water based aircraft and hydrofoils was made by F. E. and S. Hanning-Lee of London during June 1954. A high wing monoplane is fitted with a pair of hydrofoils, the outer ends being attached to the wings and extending downwards and inwards from the point of attachment to a point beneath the centre line of the hull and in front of the centre of gravity of the aircraft. Foils may also be fitted in similar manner to the tail plane. In both cases the foils form a large V suitably braced to the aircraft structure. These proposals are shown in US Patent 2,942,810.

Two brothers, D. A. and P. V. Elyosius, of Hartford, Connecticut, USA, applied for US Patent 2,832,304 in August 1955. Their designs provided a dihedrally arranged hydrofoil of high lift to drag ratio supported by struts on the stern of a waterborne hull. This device shown in Fig 60 was expected to improve the performance of vessels which have an excessively elevated bow and deeply depressed stern. The foil element, angularly adjustable, remains constantly submerged, the lifting force being confined to a single transverse vertical plane well aft of the centre of gravity. It is known that a number of successful experiments were carried out using this proposal.

A German design contribution was made in November 1954, by F. H. Wendel. A high speed craft has an elongated hull with supporting struts depending downwardly to carry an elongated structure supporting adjustable hydrofoils. Wendel claims that his submerged structure contributes to the lift generated from the hydrofoils.

The History of Hydrofoils

(Part VII)

by

Leslie Hayward

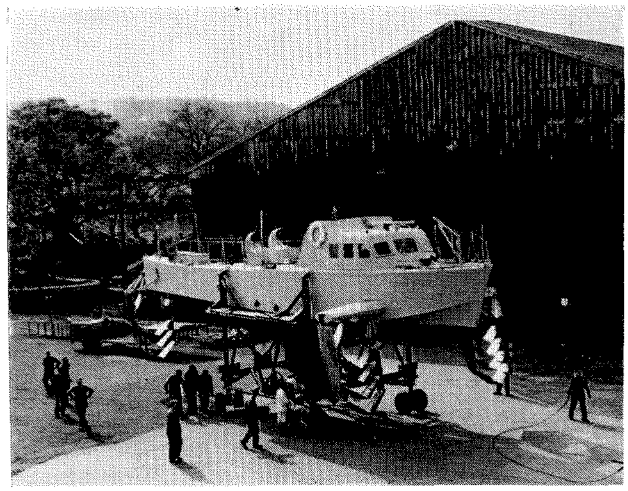


Figure 61. Saunders-Roe Anglesey. Bras D'Or

PHILLIP RHODES, who was associated with many of the early designs of the Bell-Baldwin team, designed the Canadian craft known as R-100, subsequently called *Massawippi* after the Canadian lake where early tests and development trials were carried out. This craft was sponsored by Commander D. Hodgson, RCN, and was initially conceived for an attempt on a water speed record. Forty-five feet long and having an all-up weight of approximately 12,000 lb, it was engined with a Rolls-Royce Merlin developing 1,200 hp and fitted with surface-piercing hydrofoil units similar in design to those used by Bell and Baldwin. The Defense Research Board of Canada expressed considerable interest in this craft and with Commander Hodgson acting as project engineer they implemented a redesign and rebuild of the original craft. The modified craft, known as the NRE R-100 *Massawippi*, had a new foil system designed for a displacement of approximately 16,000 lb. Tests with this craft evoked sufficient interest in Canadian Navy circles to cause an order to be placed by the Defense Research Board of Canada with Saunders-Roe Ltd of Cowes, Isle of Wight, to design and build the R-103 17 ton craft shown in Fig 61 and known as the *Bras d'Or*.

Models of the *Massawippi* were tested to prove and develop the foil system, and a radio-controlled, quarter-scale model of *Bras d'Or* was used for tests to be carried out in the open sea. The scale model was propelled with a motor-cycle type power plant and was fitted with recording gear enabling propeller torque, accelerations, speed, rate of turn, trim and roll to be logged when the model was under radio control.

The *Bras d'Or*, 75 ft in length and powered by two 1,500 hp Rolls-Royce Marine Griffon engines, was launched at Beaumaris on April 29th, 1957, by Mrs Hartley Zimmerman, wife of the Chairman of the Canadian Defense Research Board. Many details of construction and performance of this craft are still secret.

British Patent Specification 814,173 in the name of Saunders-Roe Ltd and dated June 1955 discloses the foil assembly shown in Fig 62.

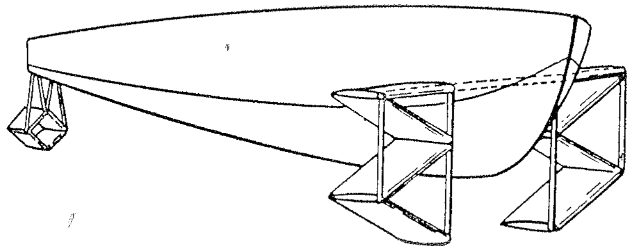


Figure 62. Saunders-Roe Ltd.

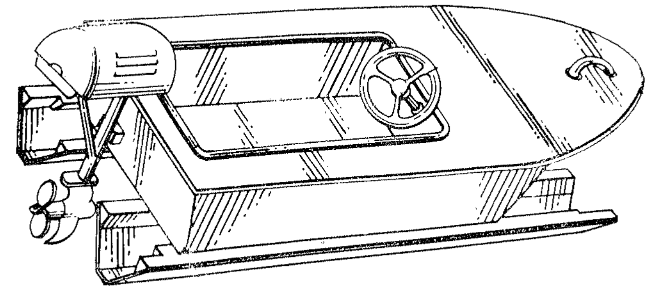


Figure 64. Ecroyd

The years 1956 and 1957 appear to be the period of the sporting enthusiasts. H. E. Follett of Wilmington, Delaware, USA, proposed a type of foil which incorporated the features and effects of the water ski. US Patent Specification 2,972,974 shows many details of Follett's proposals, but the basic design relates to a hydrofoil which is below the water-line at low speeds and above the water-line at high speed. A hydroski surface, below and at the rear of the foil, supports the craft at high speeds.

Surfboards equipped with hydrofoils which automatically move to an inoperative position against the bottom of the board when a tow rope is released were designed by Otto L. Kuchn of Hartland, Wisconsin, USA, in November 1956. A hydrofoil "water bike" having a submerged foil system and powered by an outboard motor was patented in the USA by O. R. Palmer and R. H. Olson in April 1957. Handle-bar type controls are used for steering the front foil and for changing its angle of incidence.

Another sporting device of 1957, a small towed raft fitted with a main and secondary hydrofoil, was designed by H. I. Flomenhoft of Massapequa Park, NY, USA. Stabilisers extending outwardly and upwardly from the main hydrofoil to the raft structure are arranged to provide stability against roll and pitch and serve to deflect spray away from the occupant of the raft while being towed at high speed.

Collaboration between A. Korganoff, a Frenchman, and H. Schlung, a German, resulted in a design for the application of hydrofoils to submarine vessels. In an attempt to attain the advantages of both spheres of operation the vessel was designed to act as a normal submarine when proceeding below the water surface and as a hydrofoil craft when the hull is lifted clear of the water. Ladder type sets of hydrofoils are made transversely retractable, enabling them to be stowed in chambers within the hull. In addition to the foils having a variable angle of attack, the space between individual foils is variable to assist manoeuvrability.

Patrick Leehey, US Navy, carried out a series of experiments at the David Taylor Model Basin in the early part of 1957. Two models were used, one having tandem "V" foils of 45° dihedral equally spaced fore and aft of the craft centre of gravity, the other model having a forward "V" foil of 45° dihedral and a fully submerged flat foil at the rear. As a result of the tests Leehey proposed a type of foil to improve the performance of area-stabilised configurations in following waves. As shown in Fig 63, three equally spaced transverse foils, mounted in tandem on the hull, each have a vertical stability strut. As the centre foil assembly is used for stability rather than lift, the foil has little, if any, angle of incidence. Both the front and rear 45° dihedral foils have suitable angles of incidence.

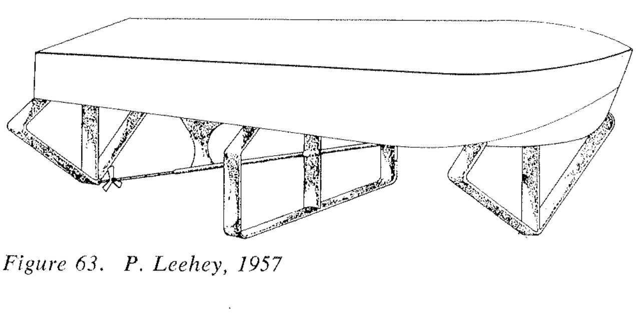


Figure 63. P. Leehey, 1957

United States development of the Gibbs and Cox *Sealegs*, 29 ft long, 8 ft beam, with a displacement of 11,000 lb, is well known. This craft, powered by two 210 hp engines, reached a top speed of 31 knots and had a rearwardly mounted, controllable, submerged foil and a forward located pitch control foil.

The period 1958 to 1961 appears to have been one of considerable activity in many countries. To describe or refer to each development or proposed design is beyond the scope of this history, but it is intended to list all such known developments or designs in the final summary.

In May 1958, Bush, Scherer and Meyer of the USA applied for US Patent 3,141,437 relating to a constant lift system. Variations of flow over a fixed hydrofoil surface have the effect of increasing or decreasing the effective angle of attack and therefore the lift force produced by the foil. Variations in relative velocity between fluid and foil also affect lift forces. This proposal incorporates a linkage mechanism which adjusts the foil for variations in flow so that lift produced will remain substantially constant.

A "V" shaped foil capable of being attached to the keels of power boats, the angle of attack being variable to suit local conditions, was produced by K. Unger of Chicago in August 1958.

Dracone Developments Ltd of London, England, broke new territory with a proposal made in May 1958 to fit hydrofoils to power-operated or towed flexible barges. At certain speeds, depending upon the type and density of the cargo being transported, porpoising may occur. To counteract the tendency of the towed vessel to dive, surface-piercing hydrofoils are attached near the bow of the barge, the foils exerting sufficient lift force to prevent the barge from assuming a diving attitude.

In December 1959, Grumman Aircraft Engineering Corporation applied for patents on a hydrofoil having a concave bottom surface and a sharp leading edge. A leading edge flap pivoted to the upper surface of the foil may be extended to induce cavity flow around the foil. With this arrangement the vapour bubbles do not collapse on the upper surface but are carried aft of the trailing edge to

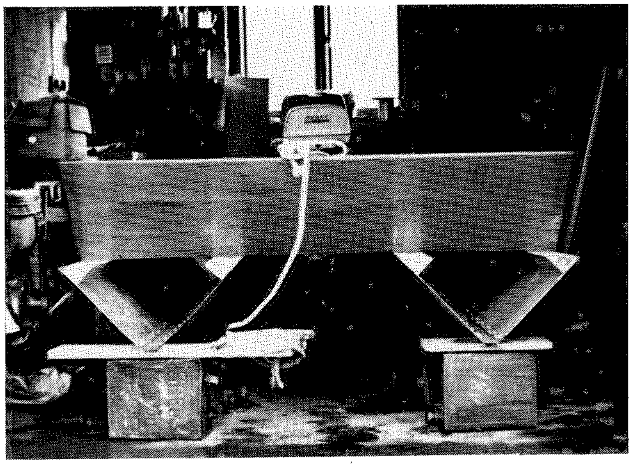


Figure 65. Ecroyd

collapse in the water to the rear of the foil.

Super-cavitating hydrofoils are discussed in detail in US Patent 3,065,723 in the name of Marshall P. Tulin.

Built in England in 1960, a craft had a novel type of foil. In June of 1961, John W. Ecroyd of Aldermary Road, Chorlton-cum-Hardy, Manchester, England, and his associate, Derek J. Lodge, proposed a form of high-speed boat which they have termed "longfoil craft". As will be seen from Fig 64, "V" section channels spaced apart and longitudinally disposed are fitted to the underside of a flat-bottomed craft. Under normal flotation conditions the channels are fully submerged, but as the front of the craft becomes elevated at speed, the front of the channels rises above the water-line so that water beating against the prow will travel through the hollow channels and so reduce the wave shock forces on the craft. As forward speed and hence the angle of inclination increases, ram air passing between the channel sections forms a pressure cushion acting between the water and the underside of the craft, and reduces frictional resistance.

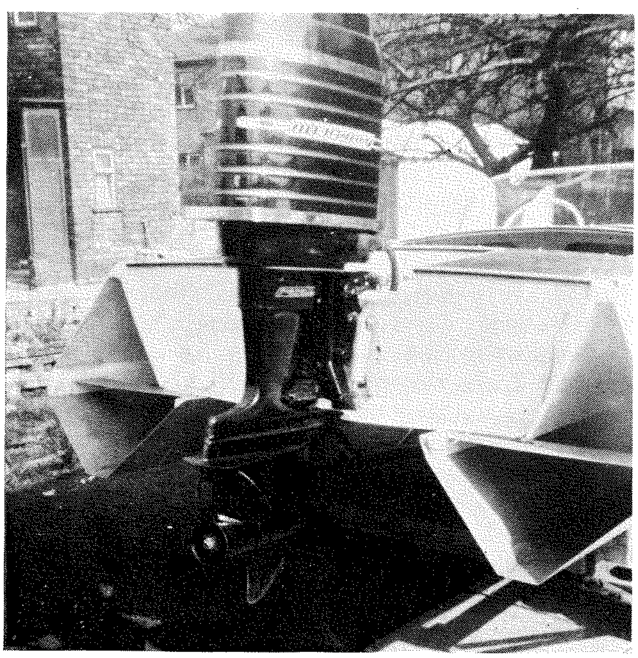


Figure 66. Ecroyd

Original work started in 1960, when a 12 in model was used for test purposes. The first full-scale craft, LF-1, was constructed during 1961 and consisted of a box-like structure, 12 ft by 5 ft, fitted with a Scott 40 hp outboard motor. The channel sections shown in Fig 65, 10 in deep, 1 ft 9 in wide at the top and a flat section of 2 in at the "V" root, were attached to the underside of the structure. Tests carried out on this craft up to speeds of 27 mph led to the construction of LF-2 in 1961. This craft was 10 ft in length and 4 ft in width. The flat sections of the channel were widened to $4\frac{1}{2}$ in. Speeds up to 42 mph were attained with a Scott 40 hp outboard motor. Tests carried out during July of 1962 in rough water off Deganwy and Bangor proved this craft to be stable and manoeuvrable and it was sold in June 1963.

LF-3, built during 1962, was converted from a standard runabout type craft. As shown in Fig 66, in addition to the channel foils an inverted "V" section was added to the sides of the hull. Powered by a Mercury 100 engine, the craft was sold in 1963.

LF-4 (Fig 67) was the first single-channel foil craft constructed. A considerable number of tests involving various engine installations proved the success of the foil design. Speeds of 30 mph were attained with a Mercury 22 hp engine.

LF-5, a two-berth cabin craft, 20 ft by 10 ft, powered by two Johnson 75 engines, was first tested in October 1964, and both LF-4 and LF-5 are undergoing development and a re-engine programme.

British Patent 23,169/61, US Patent 3,111,924 and Italian Patent 670,774 cover the proposals embodied in these craft.

(To be continued)

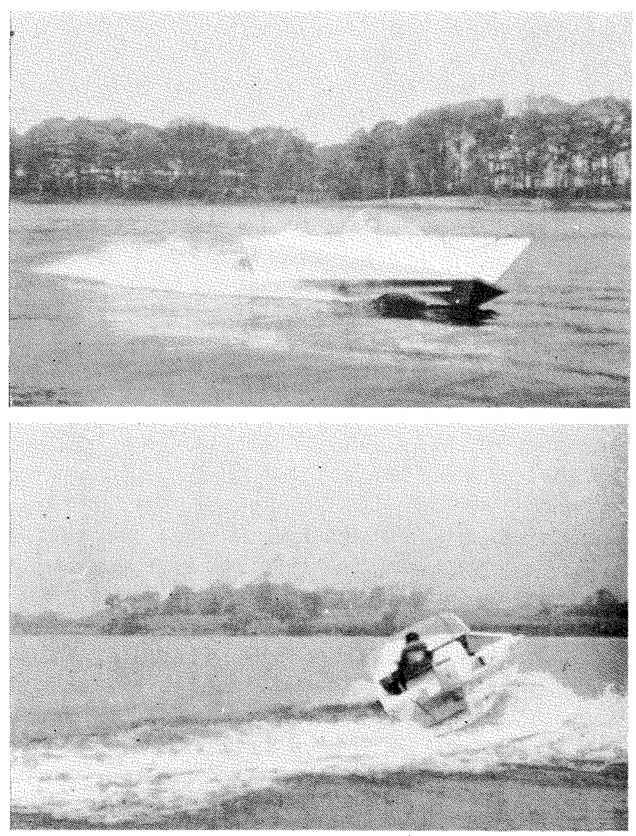


Figure 67. Ecroyd

The History of Hydrofoils

(Part VIII)

by

Leslie Hayward

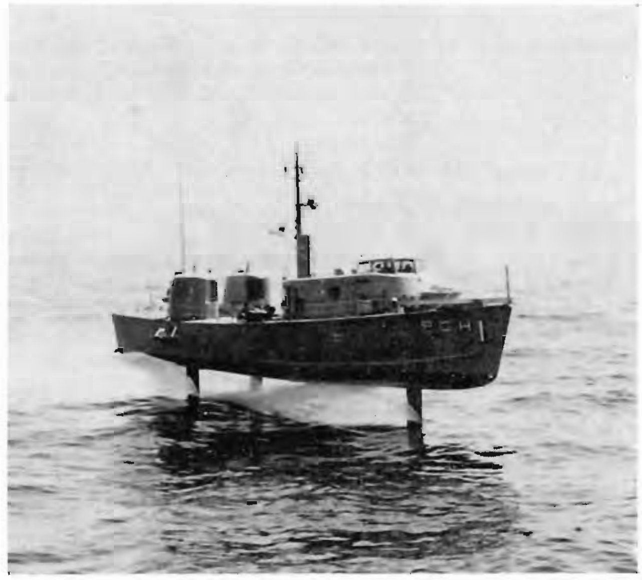


Figure 68. High Point

In June 1960 the United States Navy awarded a $2,000,000 contract to The Boeing Company for construction of a hydrofoil craft for chasing submarines. This craft, projected by the US Navy and designed PC(H)-1 (Patrol craft, hydrofoil), was the first operational military hydrofoil craft built for the United States Navy. Ultimately called *USS High Point*, after the city in North Carolina, the craft was launched in August 1962 and entered Navy service in September 1963. *High Point*, designed to operate either on the foils or on the hull, shown in Fig 68, is 115 ft long, 31 ft in the beam and displaces 110 tons.

Except for steel foils, aluminium is used throughout in its construction. Hullborne operation at speeds up to 14 mph is provided by a 600 hp diesel engine, the propeller being retracted at "take-off" to reduce drag. Two Bristol-Siddeley Proteus gas turbines, each rated at 3,100 hp, provide power for foilborne operation. Two propeller nacelles are coupled to the turbines through the rear foil struts and through two right-angle drives. Propellers are located at each end of the nacelles, giving a total of four for foilborne operation at speeds of the order of 40 knots. A flat, fully submerged, fully retractable canard foil system is used on *High Point* and stability while foilborne is provided by aileron-like control surfaces on the foils. An electronic control system sends signals to the control surfaces and they are arranged to maintain foil depth and an even translational movement. Foils are subcavitating and have been designed to operate with a smooth flow of water over both top and bottom surfaces.

During December 1960 The Boeing Company announced that tests on high-speed watercraft would take place on Seattle's Lake Washington and that jet-propelled boat would be used as a floating test laboratory.

Figure 69. *Aqua-Jet*

Figure 70. *Fresh-1*

The *Aqua-Jet*, an 11,600 lb displacement Boeing jet-propelled research hydroplane, was first put into operation during June 1961. Powered by a 4,600 lb thrust, Allison J-33 turbo-jet engine, mounted well above the waterline and aft of the c of g, the craft is capable of speeds of up to 100 knots! As will be seen in Fig 69, the 38 ft lobster-shaped craft has provision for placing hydrofoil models and other marine shapes in the water between the arms of the claws. Tests are normally carried out on quiet water during daylight hours. The starboard cockpit carries the driver, and the port cockpit the test observer.

Detailed design of the *Aqua-Jet*, constructed primarily of mahogany plywood, was done under Boeing contract by Phillip F. Spaulding & Associates, Seattle naval architects and marine engineers. The hull was constructed by Blanchard Boat Co of Seattle.

May 1963 saw the first full-scale tests of the 15 tons jet-propelled test craft *FRESH-1* (Foil Research Supercavitating Hydrofoil), designed and built by The Boeing Company under a contract from the US Navy's Bureau of Ships. *FRESH-1*, shown in Fig 70 during a test run on Puget Sound, near Seattle, is designed to exceed a speed of 100 mph. The craft is designed and constructed so that varying types of foils may be mounted on it in differing arrangements. Used as a test bed, the craft has provided considerable detailed information on the performance of foils in high-speed operation.

The twin hulls of this very unconventional 53 ft craft are connected by tubular trusses which support the cabin and the Pratt & Whitney turbo-fan engine rated at 17,000 lb thrust. Construction of the hulls and cabin was carried out at the J. M. Martinac Shipbuilding Corporation yards at Tacoma, Washington, the component parts being brought to Seattle for assembly and outfitting of the complete craft at Boeing's Missile Production Centre on the Duwamish Waterway. Two 75 hp outboard engines provide hullborne operation. *FRESH-1* has a fully submerged foil system with electronically operated control surfaces. Boeing designed and built the electronic control system, which makes wide use of solid-state components and etched circuitry. It is divided into modules, each enclosed in plastic. Various modules can be exchanged to control different foil systems. A data recording system built in the craft provides continuous and complete information during test runs.

The 50 mph Boeing pump-jet hydrofoil craft, known as *Little Squirt* and shown in Fig 71, is a 2¼ ton vessel with a water-jet propulsion system. Designed as a research craft by the Advanced Marine Systems organisation of Boeing's Aero-Space Division, the 20 ft craft has supplied valuable research information on a variety of operational characteristics and by October 1964 more than 150 hours' operation had been carried out. Fully submerged foils having typical airfoil sections of the NACA 16 series providing uniform pressure distribution to avoid the development of cavitation at the design lift coefficient are used. Movable foil surfaces provide stability and depth control. The angle of attack of the foils is variable and is automatically controlled through a system which senses and controls the

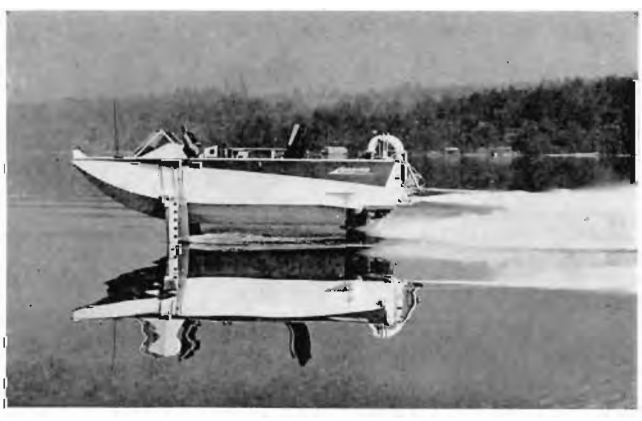


Figure 71. *Little Squirt*

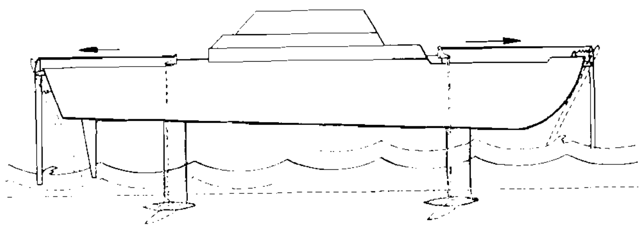


Figure 72. Boeing. R. Vogt. 1963

height of the craft above the water. The same system also controls pitch, roll and heave. *Little Squirt* is propelled by a stream of water taken in through an intake integral with the rear strut. Water travels up the strut and passes to a centrifugal pump operated by a Boeing 520 gas turbine producing 500 shaft hp. Water is then pumped out of a propulsion nozzle to atmosphere at the rear of the craft. The water pump operating at 2,900 rpm is capable of moving 3,500 gallons of water per minute. Plywood construction is used for the hull, and the foils are of stainless steel.

In March 1963 Richard Vogt and Boeing applied for US Patent 3,149,602 which relates to a hydrofoil craft having one or two controllable foils connected to an automatically operated boat position sensing device. As will be seen from Fig 72, a downwardly extending vane type spring, normally clear of the water when the craft is operating at sufficient height to clear the waves, will make contact with the water when the craft has sunk below a predetermined operating height and transmit a control signal via a linkage mechanism to the pivotal foils. A second and similar vane type spring provides a signal for lowering the foils out of the cavitation area when the craft is operating over a predetermined height. Breaking or distortion of the vane springs upon contact with floating debris is prevented by the incorporation of safety devices and they are preferably mounted to the rear of a protection or foil supporting strut. With the arrangement shown, various combinations of control may be achieved.

A load-alleviating hydrofoil unit was proposed by W. R. Wiberg of Boeing in October 1964. Hydrofoils, whether of the surface-piercing or submerged type, experience incremental lift forces when operating in certain sea states. To combat such forces a unit for alleviating loads on the foil is attached to the hull of the craft in such a manner that it provides a change in the foil incidence in response to incremental loads on the lifting surfaces. The arrangement shown in Fig 73 utilises a pivotally mounted hydrofoil unit

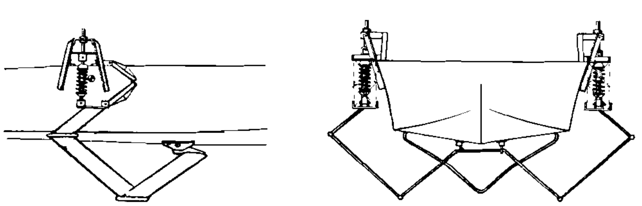


Figure 73. Boeing. W. R. Wiberg. 1964

in which the surface-piercing lifting surfaces are balanced so that when lift loads are applied they do not shift longitudinally depending upon the depth of immersion of the lifting surfaces. An arm projecting inwardly from the outer lifting surface is connected to any convenient form of rigidly mounted reaction unit and to a stabiliser unit, pivotally mounted to the hull. In operation, movement of the foil surface about the pivot mounting on the underside of the hull results in an incidence change and decreased lift. The reaction unit tends to restore the incidence angle to its correct operational position and maintains the craft at a predetermined level above the water surface. A fully detailed description of the entire system together with alternative embodiments are given in US Patent Specification 3,199,484.

A considerable increase in activity in the hydrofoil field appears to have taken place during 1960. Thomas Lang of Arcadia, California, was concerned with base ventilated foils; V. E. Johnson of NACA carried out theoretical and design studies on a non-supercavitating foil for use at speeds up to 100 mph; and S. L. Morel of Miami, Florida, proposed various arrangements of hydroski assemblies which incorporated hydrofoils.

Delta-shaped hydrofoils have been investigated by R. T. Headrick of La Canada, California. One detail design of such a foil has longitudinal and transverse convex upper surfaces while the lower surface may be flat, convex or concave as desired. The incidence angle is automatically controllable over a relatively wide range. Air may be fed to the space immediately to the rear of the trailing edge of the foil by passing it down the support strut. In a modification Headrick suggests that transverse support struts may be rotated to adjust the angle of attack and that the undersides of the foils are provided with concave channels running from the front of the foils to the trailing edge. These channels increase the velocity of water flowing under the lower surface and provide additional lift. Details of these proposals are given in US Patents 3,085,537 and 3,114,343, and British Patent 992,375.

R. Lopez and Aqua-Flite Hydrofoil Corporation of New York produced a simple and inexpensive hydrofoil for attaching to the hull of a relatively small craft. The method of attachment enabled the foils to be retracted clear of the water and also provided simple but effective mechanism for changing the angle of attack of the foils. The front foils, built up by welding three aluminium castings as shown in Fig 74, are pivotally attached to partly rotatable reinforcing blocks fitted to the hull of the craft. The rear foil, of uniform chord-wise dimensions, is pivotally mounted for retraction and for adjustment of the angle of attack.

United States Patent 3,081,728 granted to M. W. Wilterdink, T. F. Hursen and The Bullard Company of Bridgeport, Conn, relates to a hydrofoil system which includes pivotally mounted, retractable struts, releasably fastened to the hull of the craft so that the strut loading is taken by hull structural members, none of the stress being taken on the pivot points. The hydrofoil system proposed includes totally submerged foils for use at high speeds in combination with surface-piercing foils giving self-stabilising characteristics. The front struts, mounted near the bow of the craft, are retracted by power-operated gearing. An

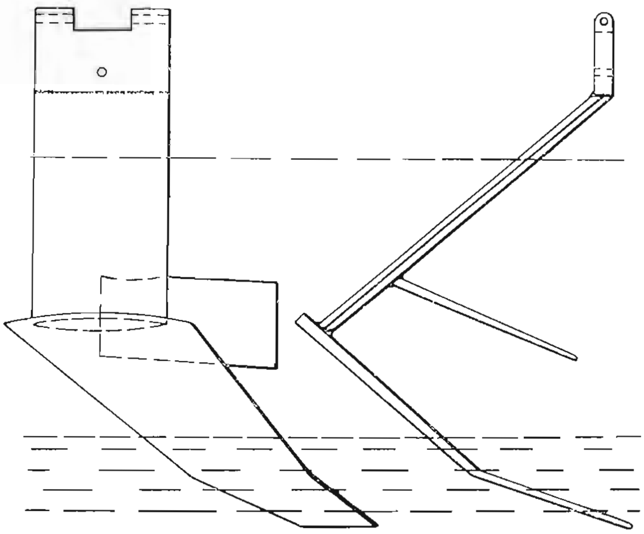


Figure 74. Aqua-Flite Hydrofoil Corp., Lopez. 1960

hydraulically operated locking device operates in both the extended and retracted positions.

A retractable, single, rear strut carried a propeller and is steerable as required. It is suggested that the angle of attack of the fully submerged foils may be adjusted by rotation of the foils, or, alternatively, movable control surfaces may be incorporated in the foils. Various alternative foil arrangements and design details are disclosed in the Patent Specification.

In July 1960 a small outboard motor driven craft was provided with a rearwardly extending hydrofoil supported platform, for supporting purposes, by Jack Diamond of Washington, DC.

Outboard motor boats are not particularly suitable for trolling and due to their light weight it is difficult to support outrigger deck extensions. A hydrofoil supported platform, attached to the rear of the hull, fitted with buoyancy floats to maintain the platform sufficiently above the water when the craft is stationary, provides an extension of sufficiently useful area without requiring much extra propulsive effort.

(To be continued)

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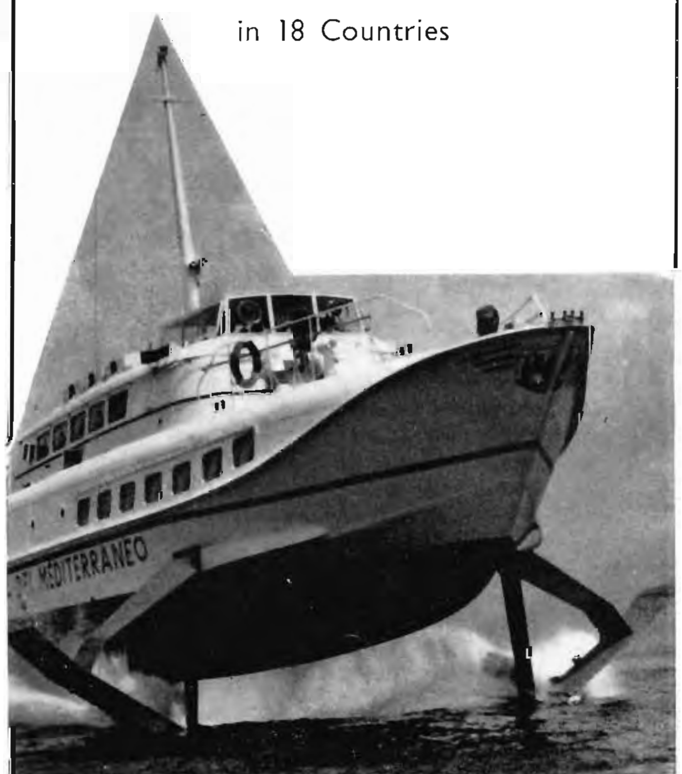

ANY KIND
of
SHIP REPAIRS

The History of Hydrofoils

(Part IX)

by

Leslie Hayward

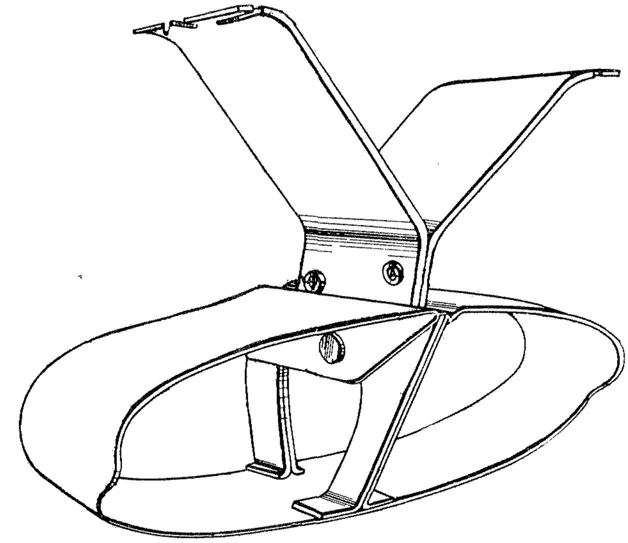

Figure 75. F. B. S. Grimston, 1961.

NINETEEN-SIXTY-ONE to date has been a period of intense research and development in various types of hydrofoil craft in many countries. Many hundreds of patents have been granted throughout this period.

Some of the more important or interesting patents are now described.

In February 1961 F. B. S. Grimston proposed the oval-shaped foil and stabilising device shown in Fig 75, the upper portion of the foil being utilised for sensing and for controlling the angle of attack of the lower foil. Stops limit the range of movement to approximately 20° between the normal operating position of the support foil and its maximum lift position.

As the craft gains speed with the stabiliser submerged, pressure on the sensing foil adjusts the angle of attack of the stabiliser to lift the bow of the craft out of the water. When the sensing hydrofoil is clear of the water surface, the centre of pressure moves behind the pivot point so that the angle of inclination of the support foil decreases to approximately 5° to the horizontal and planes on the water surface. The sensing foil tilts the stabiliser and increases the angle of inclination of the supporting foil when a wave is encountered.

An automatic altitude control for hydrofoil craft, proposed during February 1961, is the subject of United States Patent 3,175,526 granted to North American Aviation Inc. A hull-less type of foil-sustained sailing craft was proposed by B. Smith of China Lake, California, in June 1961. A mast mounted at the centre of three struts arranged at 120° spacings supports a sail. Two pivotable, rearwardly sloping, delta-shaped foils are mounted on each of the leading struts, the trailing strut being arranged to plane along the surface of the water.

Minneapolis-Honeywell Regular Company of Delaware carried out a series of investigations during 1961 on a system of control capable of collectively varying the incidence of two or more foils and in addition providing a differential incidence between the foils for directional control.

Development of the jet engine with its excellent power/weight ratio for powering hydrofoil craft brought many new problems to the designer and builder. Due to the high exhaust velocity and relatively small exhaust area, such power plants are generally inefficient at speeds much below 400 knots.

One proposal put forward by Bell Aerospace Corporation of Wheatfield, New York, during September 1961, United States Patent 3,055,331, was that the velocity of the exhaust gases leaving the jet engine is decreased by arranging the

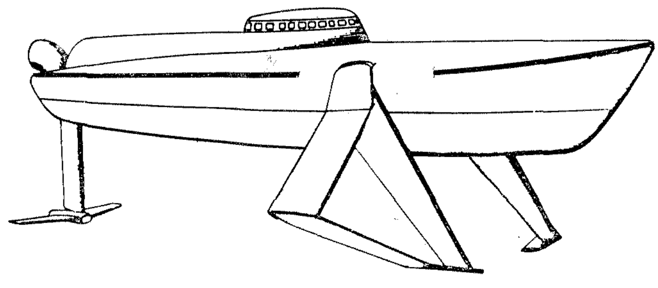

Figure 76. Bell Aerospace Corporation, 1961

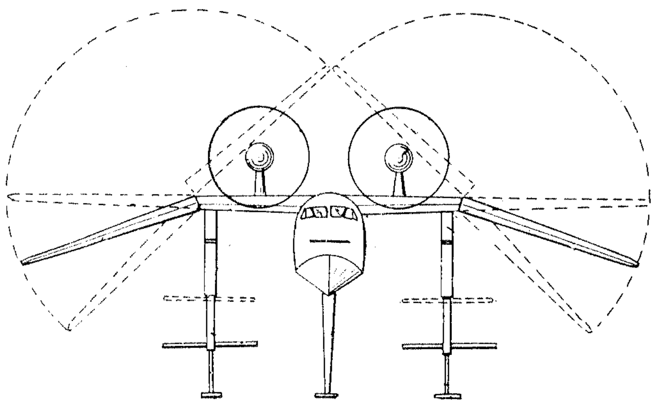

Figure 77. Fairchild Stratos Corporation, 1961

gases to drive an auxiliary exhaust turbine before issuing to atmosphere through an enlarged gas exit duct. The turbine is coupled to an underwater propulsion system. Ducts around the exhaust gas exit permit additional atmospheric air to be drawn in and mixed with the gases as they pass to atmosphere. This arrangement also assists in cooling the exhaust turbine. The general type of craft is shown in Fig 76.

D. Cardwell and A. F. Graf Von Soden of San Diego, California, proposed possibly the most imaginative craft of all time in September 1961. Reference to United States Patent 3,082,975 discloses a craft supposedly capable of operating as a submarine, a surface vessel, a hydrofoil-supported vessel and in addition a heavier-than-air flying machine. Telescopic foils and propellers, retractable struts, folding and extending wings, ballast tanks, etc, all add to the constructor's nightmare!

A much more practical combination of airfoil and hydrofoil was made by the Fairchild Stratos Corporation of Maryland, USA, in December 1961. As shown in Fig 77, a wing positioned near the centre of gravity of the craft and extending laterally on both sides is arranged to supply most of the lift when the craft is travelling at high speed, giving a high lift/drag ratio. Struts depending from the wings support a series of foil units including both sub-cavitating and supercavitating foils; the sub-cavitating foils may be moved to an inoperative position as required. An automatic pilot control is used to maintain the craft at its desired height to prevent the supercavitating foils leaving the water when the craft is moving at speed. The wings are hinged so that the tips can be drooped or raised to suit various operating conditions.

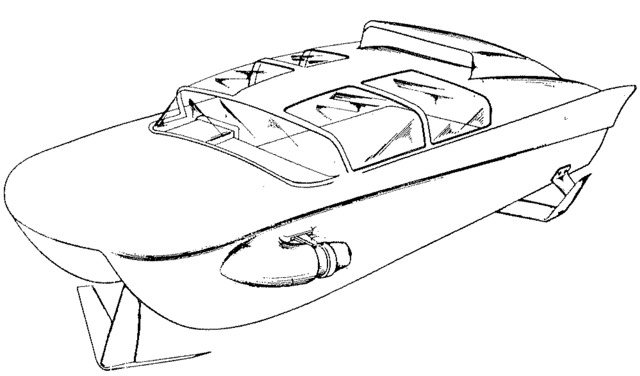

Figure 78. Lockheed Aircraft Corporation, 1961

December 1961 appears to have been the date when a number of design proposals put forward by J. Traksel of the Lockheed Aircraft Corporation were finalised. United States Patent 3,106,179 relates to a water propulsion system for hydrofoils. Water is taken in at the front of selective foils and pumped out through propulsion nozzles by turbine-driven pumps. British Patent 956,617 and United States Patent 3,149,600 disclose combined propulsion and directional control devices for the type of craft shown in Fig 78.

During 1962 considerable inventive ingenuity was applied to various types of foil control systems; some widely differing examples are disclosed in United States Patent 3,137,260, Sperry Rand Corporation of Great Neck, New York; US Patent 3,149,601, Raytheon Company of Lexington, Massachusetts; US Patent 3,092,062, D. Savitsky of Jackson Heights, New York; US Patent 3,130,702, Melchior International Corporation of New York; and US Patent 3,156,209, United Aircraft Corporation of East Hartford, Connecticut.

A further example of combined role craft is disclosed in United States Patent 3,183,871 in the name of Weser Flugzeugbau GmbH of Bremen, Germany. Fig 79 shows the craft in both operational roles, as a foil-supported vessel and as a submarine craft.

Developments in retractable foils were patented by the Aqua-Flite Hydrofoil Corporation of New York towards the end of 1962, US Patents 3,164,117 and 3,164,118; and General Dynamics Corporation of San Diego, California, ended the year with a further proposal for automatically stabilising high-speed hydrofoil craft, United States Patent 3,110,280.

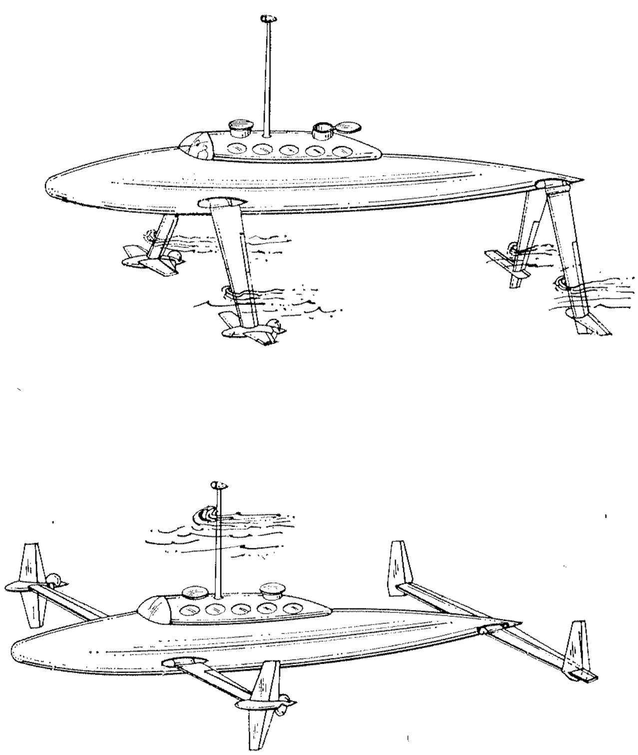

Figure 79. Weser Flugzeugbău, GmbH, 1962

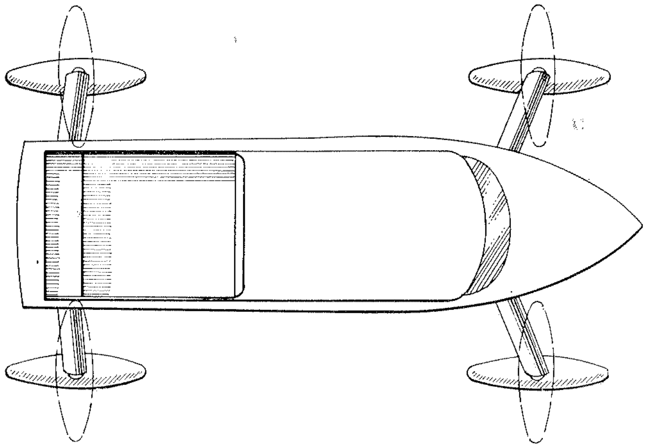

Figure 80. E. H. Handler, 1963

In February 1963 Eugene H. Handler of Kensington, Md, USA, was granted United States Patent 3,162,166. Handler's proposals covered a craft having variable sweep foils as can be seen from Fig 80. Symmetrically spaced support struts carry at their lower ends rotatably mounted foils which are aligned with the minimum chord fore-and-aft for the low-speed phase of the acceleration run or low-speed cruise.

In this configuration, the foil has maximum aspect ratio, a term which may be defined as the ratio of span to average chord. In addition, the low-speed position is specifically designed to have a sub-cavitating cross-section. As the hydrofoil boat speed is increased, the foil is rotated to a position giving the desired chord/thickness ratio and sweep. The angle of rotation in the simplest case is 90°, giving maximum aspect ratio and chord/thickness ratio for low speed and minimum aspect ratio and chord/thickness.

A variable sweep arrangement of hydrofoils is disclosed in United States Patent 3,195,495, dated March 13th, 1963, and issued to Thurston Erlandsen Corporation, Sandford, Maine, USA. The movable hydrofoils may be swept back at high speeds, extended transversely at low speeds, and made to assume a variety of intermediate positions in order to have the best sweep angle at intermediate speeds for maximum operational efficiency.

During 1963 a number of patents were granted. On April 24th, 1963, British Patent 924,374 was granted to M. Trasenster, who proposed a hydrofoil system controlled by drag elements. This was followed on August 14th, 1963, by British Patent 934,094, granted to North American Aviation Inc (who were working under contract to the US Government to study automatic control systems for hydrofoils) for an automatic height control system. Another control system was proposed in British Patent 937,046, granted to the German firm V. E. B. Flugzengwerke, Dresden, who proposed a pressure-activated control system incorporated in the body of airfoils or hydrofoils to control the movement flaps.

(To be continued)

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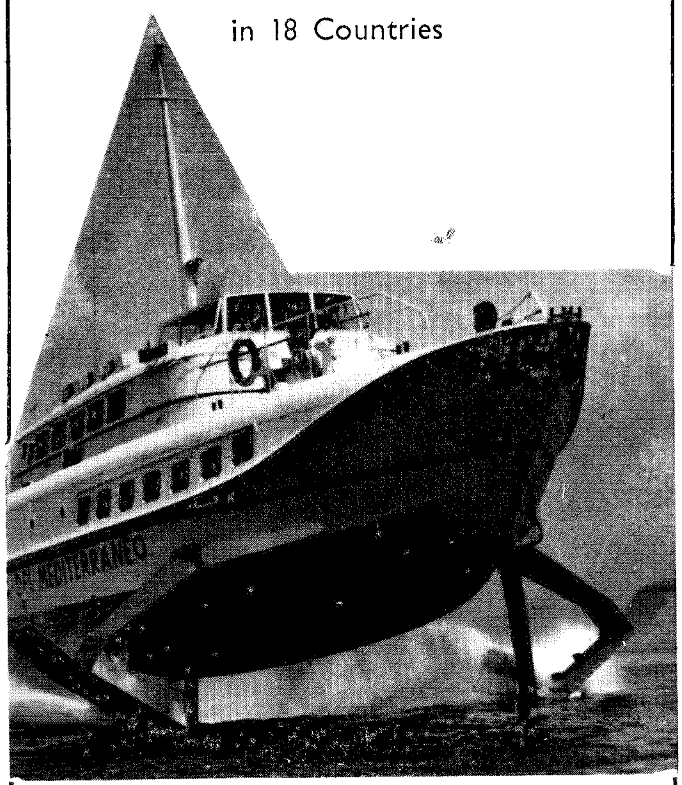

ANY KIND
of
SHIP REPAIRS

The History of Hydrofoils

(Part X)

by

Leslie Hayward

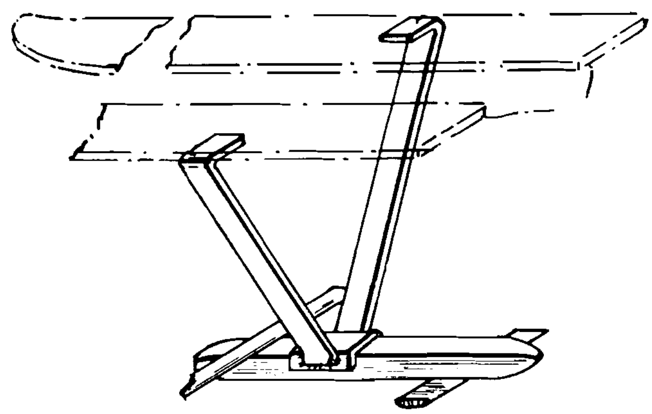

Figure 81. Cosmos Dynamics Inc

ON March 26th, 1963, Cosmos Dynamics Inc of Newton Upper Falls, Massachusetts, USA, applied for US Patent 3,164,119, which relates to transversely arranged foils connected to the structure of the craft in spaced parallel relationship.

As shown in Fig 81, water skis, which may be used in conjunction with marine craft, water-based aircraft, etc, support a V-shaped strut carrying a boom structure which in turn carries front and rear foils. The front foil, attached to the upper side of the boom, has a positive lift effect, and the rear foil, attached to the underside of the boom, has a negative lift effect. Various types of foils and carrying struts may be used.

It will be remembered from prior disclosures that attempts have already been made to improve the performance of hydrofoils under cavitating conditions by "ventilating" the foils. United States Patent 3,221,698 in the name of James Turner discloses a system for controlling the operational depth of hydrofoils using a somewhat similar principle. As shown in Fig 82, the foils have a number of spoiler apertures in the upper surfaces so that when air under pressure is passed through the apertures a cavitation bubble is formed. Air is supplied from a fan having a gas discharge rate at a preselected fan speed related to the submerged depth of the foil and to the load response characteristic of the fan. In operation, the pressure of the air source is set for the desired depth of operation of the foil. An increasing amount of air is discharged through the apertures as the hydrofoil depth decreases due to the decrease in external pressure, and a decrease in the amount of air being discharged takes place when the depth of hydrofoil increases. Details are given in the patent specification of a number of alternative embodiments of various types of apertures in various locations.

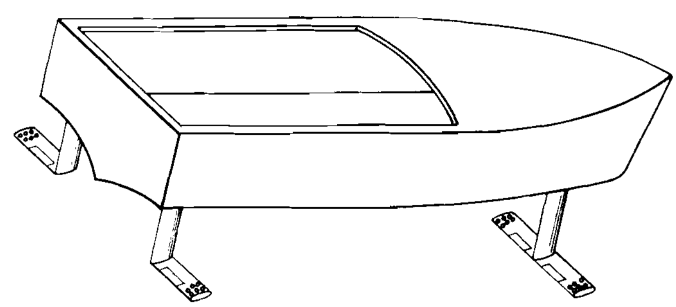

Figure 82. James Turner

Richard Barkley of Palo Alto, California, obtained the grant of US Patent 3,213,818 for proposals put forward in November 1963. Tandem-type foils are supported on front and rear pairs of struts. A fixed foil is supported between a pair of struts, the foil set at some predetermined angle. Dihedral foils, movable from a position parallel with the main foil to a raised position, are pivotally mounted to the lower ends of the support struts. It is claimed that this type of foil arrangement has increased roll stability over the conventional aileron-type control hydrofoils. By independent or simultaneous control in opposite directions—decreasing the dihedral of one foil while increasing the dihedral of the opposite foil—roll control is attained. Vertical lift provided by the movable foils may also be controlled. The control mechanism, extending through the foil supports, may be operated hydraulically, pneumatically or electrically.

R. E. Bowles of Silver Springs, Maryland, filed a specification, US Patent 3,209,714, on October 14th, 1963, for a fluid control system for foils in which a minimum number of moving parts are required. Pressures are directly monitored to effect foil lift, thereby eliminating the conversion of pressure to electrical signals which have to be reconverted by servo systems to alter the angle of attack of the foils.

The system senses foil lift conditions relevant to the local dynamic conditions of the water and the static pressure at foil level relative to depth. The static pressure is damped and averaged to eliminate high-frequency pressure fluctuations due to choppy water. The static and dynamic fluid pressure signals are combined with a fluid pressure related to a required depth selected on a control and the resultant pressures are amplified to produce an output which operates directly on the foil by action or reaction to adjust its position and maintain a constant depth and lift. The control system can also add in a signal derived from a fluid gyroscope and related to pitch and roll to improve stability.

Fig 83 shows a hydrofoil craft employing three independently servoed hydrofoils, and Fig 84 illustrates diagramatically a pure fluid computing and amplifying system incorporated in a foil which produces reactive and pressure effects to alter the position of the foil.

A static sensor projects from the foil support and a dynamic or lift sensor extends forward from the foil. The dynamic sensor contains pure fluid amplifiers which send amplified signals into a summation amplifier which adds in signals from the static sensor, the depth selector and a pitch and roll transducer. The resultant is amplified to produce maximum gain of fluid flow, and the fluid issues from ports above and below the rear of the foil, causing a reaction which in turn corrects the angle of the foil.

The specification gives many variations and modifications of the control system and details are given of the construction and operation of the fluid amplifiers, which do not include any moving parts.

It is known that considerable experimental work has been carried out by Bowles on this type of apparatus on behalf of the United States Navy.

Retractable, resiliently-mounted, variable angle, steerable foils of submersible or ladder type form a part of the

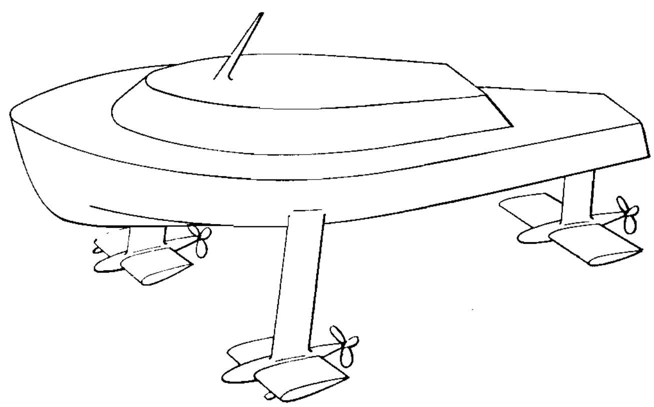

Figure 83. R. E. Bowles

description of US Patent Specification 3,241,511 in the name of Otto Drtina of Cleveland, Ohio.

A surface-piercing, concave-disc type of hydrofoil has been proposed by the Sturgeon Brothers of Seattle, Washington, and is the subject of US Patent 3,237,582, which was issued on March 1st, 1966. It is suggested that this type of foil automatically sheds itself of debris, to a great extent overcomes the problem of skin friction, and eliminates cavitation. A bearing assembly inside the housing supporting the foil shaft is suspended from the hull of the craft by swinging links and a shock absorber assembly. A foil disc mounted on the base of the outwardly inclined shaft has a concave lower surface. The axis of rotation of the disc converges upwardly and rearwardly in relation to the hull of the craft so that the wetted surfaces of the disc move in rotation with the flow of water to reduce skin friction.

Considerable hydrofoil development has been carried out by the Russians. In 1957 work was completed on their first multi-seat passenger hydrofoil, the 90 ft long *Raketa*. This single-screw craft, capable of carrying sixty-six passengers at a speed of 45 mph, has a displacement draught of 6 ft and a foilborne draught of 3½ ft. The *Raketa* was initially powered by an 800 hp diesel, but this has been changed to a more economical 1,000 hp diesel.

Upon completion of the *Raketa*, Alekseyev's team designed and built the *Meteor*. This craft made its first public appearance in Moscow during the summer of 1960. The *Meteor*, 112 ft long and displacing 52 tons, has a foilborne draught of 4 ft and is capable of carrying 150 passengers at a speed of 50 mph, power being provided by two 850 hp diesels turning twin screws. The control cabin,

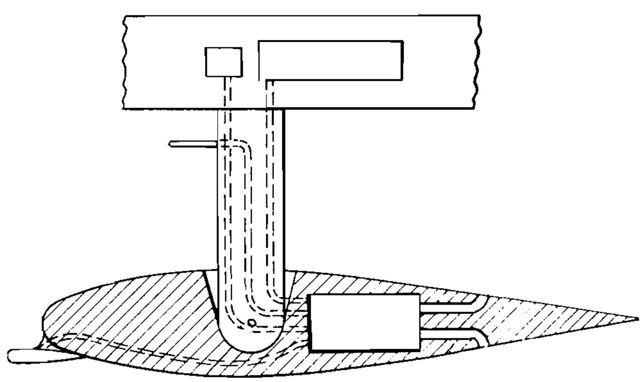

Figure 84. R. E. Bowles

set well forward for good visibility, is equipped with an automated control system enabling the craft to be piloted by one person.

In November 1961 the *Sputnik*, a still larger craft capable of carrying 300 passengers, made its appearance. *Sputnik* is 165 ft long and displaces 100 tons. Power is provided from 750 hp diesels driving four propellers and gives the craft a top speed of 50 mph. The hull is of alloy construction and the hydrofoils are of stainless steel. Passengers are accommodated in three saloons, and facilities aboard include a promenade deck and a restaurant.

It has been stated that the running costs of this craft are fourteen times lower than the best ship of the Volga Shipping Line.

The smallest Russian hydrofoil, *Molnia*, is a six-seater pleasure craft fitted with a 90 hp engine that provides a speed of 40 mph.

One of the most recent Russian hydrofoils to go on scheduled service is the *Chaika*. Intended for commuter and pleasure services, it has a range of 310 miles. Power is supplied from a 1,200 hp diesel engine arranged to drive a two-stage pump providing water jet propulsion. Thirty passengers can be carried at a top speed of 60 knots. The hull of this 86 ft craft, displacing 14¼ tons, is built in three sections divided by companionways; the bow section is occupied by the control cabin, the centre section provides the passenger compartment and the stern section houses the engine. The water jet system, besides providing propulsion, can also be used in conjunction with bow and stern rudders for manoeuvring, and by using a deflector plate across the water jet nozzle, a zero turning circle can be attained. Originally the hull, struts and foils were built of light alloy but this was later almost entirely replaced with stainless steel to improve reliability and endurance.

Motor ship *Mir* was launched in the autumn of 1961. Provided with stainless steel V foils and a lighter alloy hull, this open-sea craft has a cruising speed of 45 mph.

Autumn 1961 also saw the launching of the seagoing *Kometa* (or *Comet*), the largest seagoing hydrofoil craft of its time. The *Kometa*'s foils, like those of the *Mir*, are similar in shape to the wings of a sea bird. The *Kometa* has a speed of 45 mph and carries 150 passengers. Other seagoing Russian hydrofoils are the *Strela*, carrying ninety-two passengers; the *Dolphin*, a small turbojet craft; the *Vikhr*, a 300-passenger craft; and the *Cosmos*.

Russian *Raketa* hydrofoils have done service in Hungary but a Hungarian-designed craft, *Fecske* (*Swallow*), similar to the *Raketa* and carrying sixty passengers, is now known to be in service.

The Japanese, one of the latest entrants into the hydrofoil field, already produce the largest range of hydrofoil craft in the world.

The decision to manufacture hydrofoils was taken in 1960, and since then the rate of development has been quite remarkable. Hydrofoils are now in regular use in nine major areas in Japan: Nagasaki, Kagoshima, Beppu, Setonaikai, Kobe, Lake Biva, Tokyo and Matsushima.

To interest ship operators in hydrofoils, six main manufacturers joined forces to publish a sales brochure laying out details of areas where services were, or were to be, provided, and also the types of craft available and the advantages of hydrofoils over conventional craft. The manufacturers concerned were: Hitachi, Ishikawajima-Harima, Mitsubishi, Shina Mitsubishi, Shin Meiwa and Uraga.

Japanese manufacturers build many different hydrofoil craft including the PT-3, PT-20, PT-35 and PT-50, constructed by Hitachi under licence from Supramar.

Mitsubishi build the MH-60, a 95 ft craft powered by two 1,500 hp diesels and capable of carrying 168 passengers. They also build the MH-30, an eighty-passenger craft powered by a 1,500 hp diesel giving 40 knots, and the MH-3, powered by a 280 hp engine and capable of carrying twenty-one passengers at 40 knots.

Ishikawajima-Harima build a smaller range of craft, the largest being the 1HF-8, powered by two 280 hp diesels and capable of carrying thirty-four passengers at 65 knots, as well as the 1HF-3, carrying thirteen passengers, and the 1HI Runabout 16, a small pleasure craft.

Shin Meiwa build three different versions of the fourteen-passenger SF-30.

Uraga produce the Sea Bird, a four-seater powered by a 75 hp engine giving 55 knots; and Shin Mitsubishi produce the MHF-4, a six-seater craft capable of 65 knots.

The Small Hydrofoil Prototype to the Stryela

Translation from Russian of an article in the May 1966 number of the Soviet monthly magazine Sudostroyeniye *(No 5), organ of the Ministry of the Shipbuilding Industry of the USSR, and the A. N. Krylov Scientific and Technical Society of the Shipbuilding Industry, (pp 57-59) by Commander Edgar P. Young, RN (retd).*

by E. A. Aframeyev

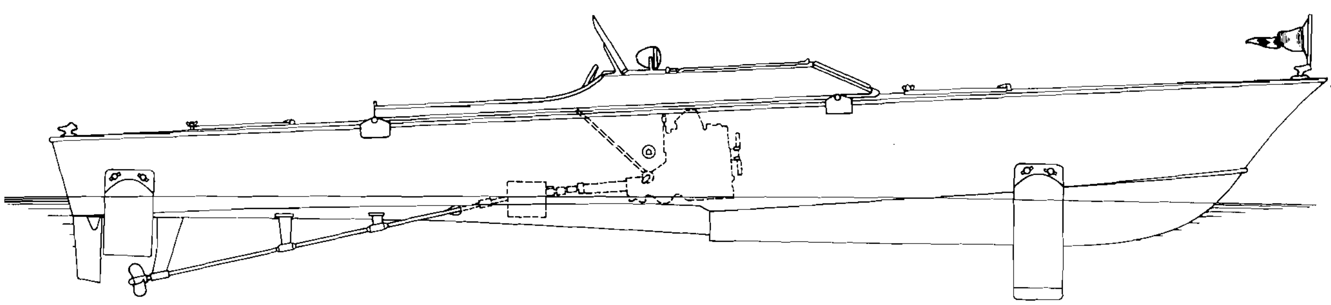

Figure 1. General view of the motorboat from the side

PRINCIPAL PARTICULARS, ETC

Length overall	9.60 m	(31 ft 6 in)
Length between perpendiculars	8.70 m	(28 ft 6½ in)
Maximum breadth (at forward bilge)	1.67 m	(5 ft 5¾ in)
Height of side (freeboard):		
Stem	1.34 m	(4 ft 4¾ in)
Transom	0.77 m	(2 ft 6¼ in)
Draught at rest:		
Hull	0.35 m	(1 ft 1¾ in)
Foils	0.65 m	(2 ft 1⅝ in)
Propellers	0.78 m	(2 ft 6¾ in)
Draught under way (propellers)	0.35 m	(1 ft 1¾ in)
Displacement (without crew or passengers)	1,650 kg	(3,638 lb — about 1½ tons)
Crew	Four	
Maximum speed	50 km/h	(about 31 knots)

THE hull is of wood, and has two continuous bulkheads which separate the forward and after parts from the passenger and engine compartments. Over the engine compartment there is a removable hatch, to facilitate access to the engines, and two ventilating cowls run up through the raised deck there, one on each side. The petrol tanks are situated in the forward compartment, some distance from the engines, to reduce fire risk.

The boat is controlled and steered from the port side of the front of the passenger compartment, each motor being separately controlled. There are the same indicators of cooling-water temperature and lubricating oil pressure as in a motor car, but in addition to these there is an electric tachometer with two needles, to indicate the number of revolutions, and the position of the rudder is indicated on the steering wheel. All excepting the last of these are mounted on a dashboard in front of the coxswain.

The middle part of the boat is designed to take the coxswain and three passengers, but an overload of up to two more persons is permissible.

The hull is typical of a sports boat: a sharp bow; fine frames forward, broadening out aft; maximum width in the middle; and a transom stern. Spray-shields with angular profiles are mounted along the sides of the fore part. The fineness of the forward frames reduces the effect of wave shock, while the sharp lines of the hull reduce the resistance when the boat is becoming foilborne. The lines and the relative proportions which have been selected ensure satisfactory trim when running at speed and great lateral stability when becoming foilborne.

The foil system is made of an alloy AMr5B.

The load on the forward and after foils is approximately equal.

Several types of forward foil have been tried with the same after foil, the one described here being the simplest for plotting curves to show good characteristics for resistance and for stability.

Both the forward and the after foils are fitted with inclined stabilisers, as shown in Figs 1 and 2 and these provide considerably increased lateral stability when the boat is becoming foilborne and when she is foilborne.

The forward foil system includes two intermediate inclined planes running along the sides of the boat which enter the water directly the stream of water over the main lifting surface is interrupted and limit the sinkage of the foil by providing additional lift.

It takes the boat 20-25 sec to become foilborne from rest, the hull becoming completely clear of the water at a speed of 30-32 km/h (18.6-19.9 knots). (See Fig 3.)

The foil system guarantees stability at a speed of 40 km/h (24.8 knots) on all courses with waves of 0.5-0.7 m (1 ft 7⅝ in-2 ft 3⅝ in) in height and excellent manoeuvrability, almost with any heel. The turning circle is reduced by fitting two small fins on the forward foil, just below the flat part where it joins the stabilisers.

The propellers are three-bladed, with a diameter of 0.24 m

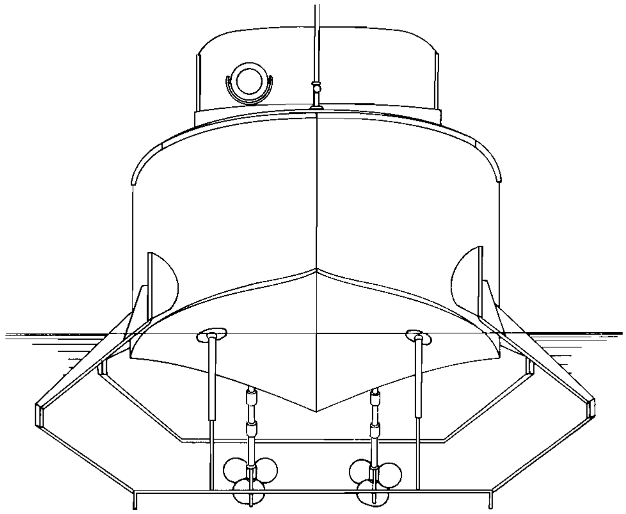

Figure 2. View of the motorboat from ahead

(9½ in), and are situated under the after foil so as to avoid the possibility of their drawing in air from the atmosphere. The propeller shafts are held in position by three single-stayed brackets streamlined with pressed Goodrich rubber.

In order to prevent air being sucked into the propellers, the brackets are fitted with thin washers, and similar washers on the rudders prevent interruption of the stream and ensure that there is sufficient submerged surface when the boat is foilborne.

In order to reduce the resistance produced by the propeller-shaft brackets, the middle stays of the after foil and of the rudder are placed one behind the other, but are not made into a single structure, so as to ensure that it is possible to change the position of the foil. For it must be taken into account, when building any boat, that one may have to change the foil system, because it is impossible in practice to determine by calculation the correct angle of attack taking into account all the constructional peculiarities of this or that boat.

The foil systems of the EK-4 are secured to the hull by bolts running into the curved seams of the flanges of the side brackets, and to the stays, by semi-flush large-diameter screws which serve also as the rotating axis of the entire foil. This system of securing facilitates making changes of the angle of attack of the foils while testing and perfecting them.

The EK-4 boat has stood up to hard testing conditions and may be recommended as a reliable and very seaworthy high-speed craft.

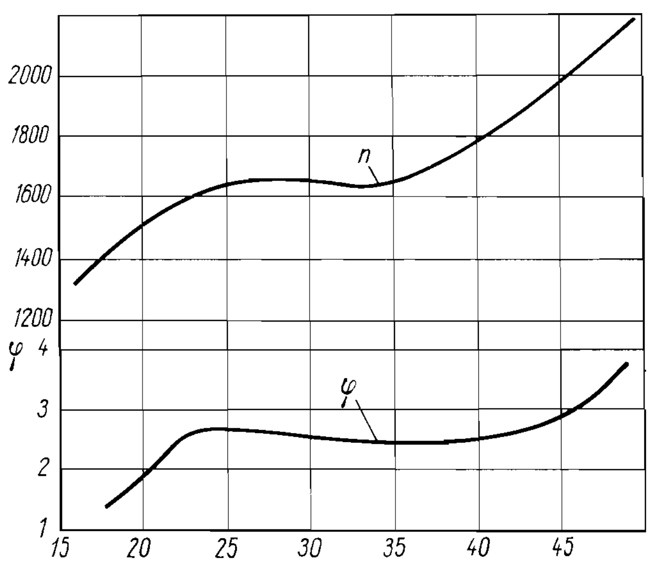

Figure 3. Running characteristics of the boat: n_B — No of revolutions per minute of the propeller shafts; φ — Trim of the boat; v—Speed

The History of Hydrofoils

(Part XI)

by

Leslie Hayward

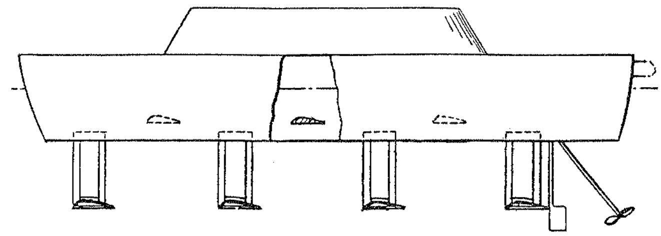

Figure 85. Yoichiro Kanbe

Two recent catamaran hull type of hydrofoil vehicles are described in British Patent 1,007,567 and US Patent 3,227,123. The British patent granted to Yoichiro Kanbe of Sokashi, Saitamaken, Japan, illustrates a design in which twin hulls are spaced apart and rigidly joined together by surface decking. A series of hydrofoils, each foil being longer than the beam of the craft, are supported from the hull structures. Part of the support structure acting as one leg of a "V" type foil. The tip portions of the foils are retractable within the main foils to facilitate docking.

Auxiliary foils rigidly attached to the hull beneath the water line are arranged in staggered relationship with the main foils. Propulsion is achieved by screw propellers or hydraulic jets.

United States Patent 3,227,123 issued to Hellmut R. Voigt of Sun Valley, California, relates to a catamaran type craft suitable for towing on an automobile trailer for transportation purposes. A main surface piercing dihedral foil, located near the centre of gravity of the craft, is rigidly connected to the hull and a totally submerged foil is pivotally attached to the stern. The angle of attack of the rear foil is automatically adjusted with respect to speed, load and water surface conditions by a mechanically acting sensing device which follows the water surface in front of the craft. A manual control over-rides the automatic control as necessary.

The American firm of Grumman entered the hydrofoil field about 12 years ago and acquired the research organisation of Dynamic Developments Inc. during 1956. The first craft produced was the XCH-4, built for the Office of Naval Research in 1955. Powered by two aircraft engines with air propellers and fitted with ladder type foils, this eight-ton craft reached a speed of seventy-eight knots and established a new world speed record for hydrofoil craft. The XCH-6, a small research craft, also built for the Office of Naval Research during 1958, and fitted with supercavitating foils and a supercavitating propeller, attained a speed of sixty knots powered by a marine turbine engine.

Hydrofoil kits suitable for "do-it-yourself" installations on fourteen to sixteen foot outboard runabouts were marketed during 1958 and enabled speeds up to thirty-five knots to be attained. These kits were manufactured from aluminium and it is known that more than 200 were sold to the general public.

In 1960 the United States Marine Administration awarded a contract to Grumman for the design and construction of the hydrofoil ship *Denison*. The craft, an eighty-ton ocean research vessel, was launched in June 1962 and has operated at speeds in excess of sixty knots. A 320-ton 212-foot craft has recently been commissioned for the US Navy.

The *Dolphin*, built of special corrosion resistant alloys, is a 75 ft craft designed for the commercial operator. Having gross tonnage of approximately eighty-three tons, the *Dolphin* is designed to carry ninety passengers or 19,000 lbs of cargo and a crew of four, over routes extending to 200 nautical miles at a cruising speed of fifty knots. Power is supplied by either a single or twin gas turbine engine and twin diesels are installed for hullborne operations at speeds up to ten knots. The two fully submerged forward foils providing 70% of the lift are hydraulically retractable and may be stowed in the overhead position. The single rear foil is combined with the rudder and propeller pod.

A recent British venture which merits considerable interest is the design put forward by Southern Hydrofoils Limited of Southampton. *Sea Ranger* having a displacement of 7¼ tons, provides a high performance craft using fully submerged foils controlled by mechanically operated predictor arms. Glass reinforced plastic is used for the

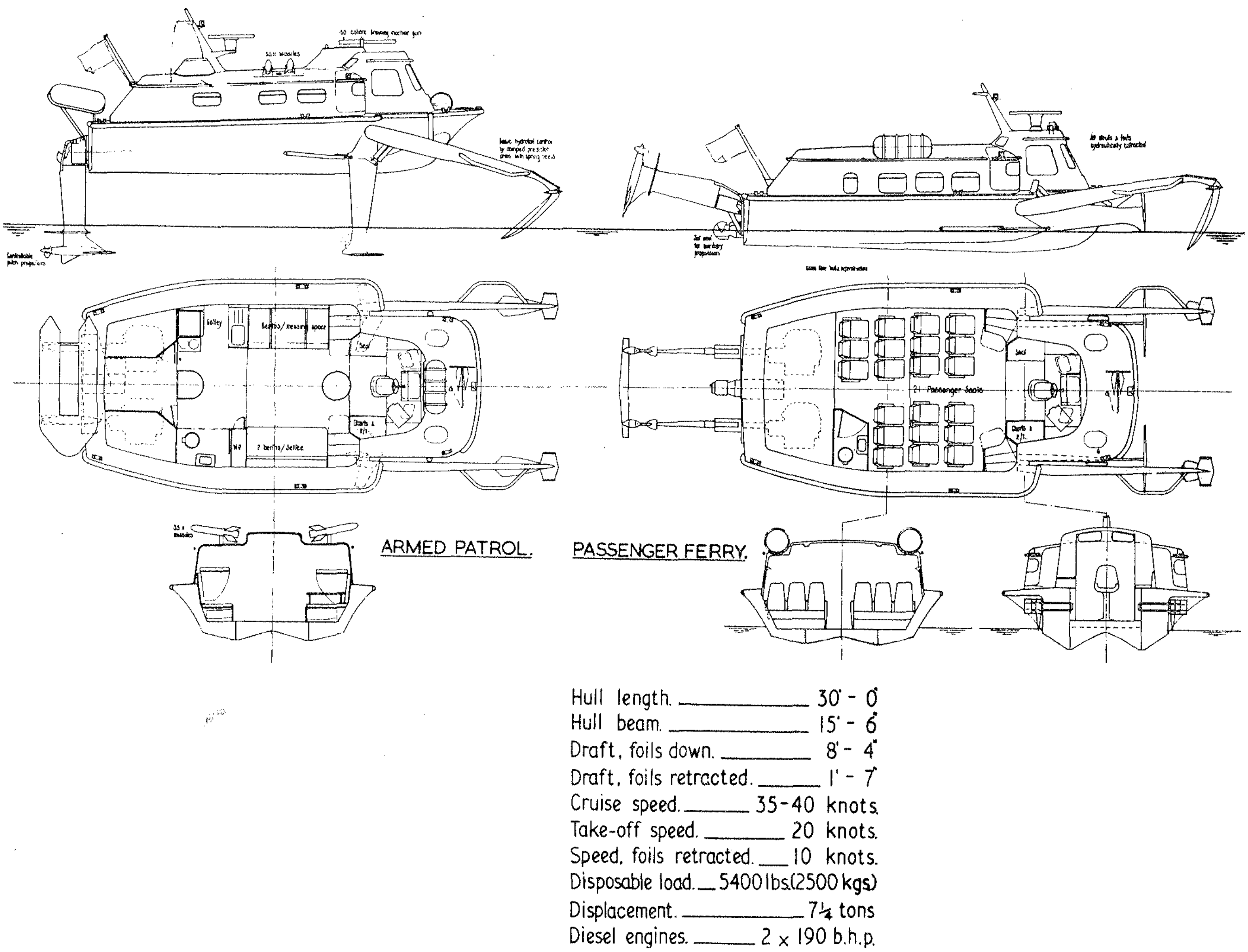

Figure 86. Sea Ranger

hull and superstructure, giving freedom from corrosion, low maintenance requirements and ease of repair. The stern gear of the *Sea Ranger* utilises "Z-drive" units which permit the use of propellers giving direct rather than angled thrust which delays the onset of erosive cavitation conditions. The propellers have two pitch positions, one for take-off and one for cruise, thus permitting the best possible use of available power. All struts and foils are hydraulically retractable, but in the down position all the foils are within the beam of the craft, enabling docking to be accomplished without fear of danger to the underwater units.

Fully submerged foil systems require accurate and sensitive controls to maintain level flight in the narrowly restricted zone above the water in which the hull they support must travel. Modern electronic aids can provide such controls, but they tend to be costly to install and to maintain. Southern Hydrofoils' solution to the control problem is to use the water surface itself to provide both altitude and wave height-and-shape data, and also the motive power for foil incidence change. Predictor arms, travelling ahead of the craft, "measure" the waves, and their movements are transmitted, mechanically, to the main foils. So that the craft does not react to small waves, over which the boat can fly level, filter heels maintain the predictor arms at some height above the water; movements of these heels have no effect on the heavily-damped arms.

Through a mechanical-hydraulic linkage, the pilot can intervene in this automatic system to regulate flying height, to bank for turns, and to effect take-off.

The predictor arms serve another useful function, not provided for in electronically activated systems. In the case of rapid flight over confused seas, there is always a danger of the momentary surfacing or near-surfacing of a foil, and consequent loss of lift (a "sea crash"). The *Sea Ranger's* predictor arms carry foils which provide emergency lift in such circumstances, and tests have shown that, on nearly every occasion, they re-establish level flight before the hull touches the water.

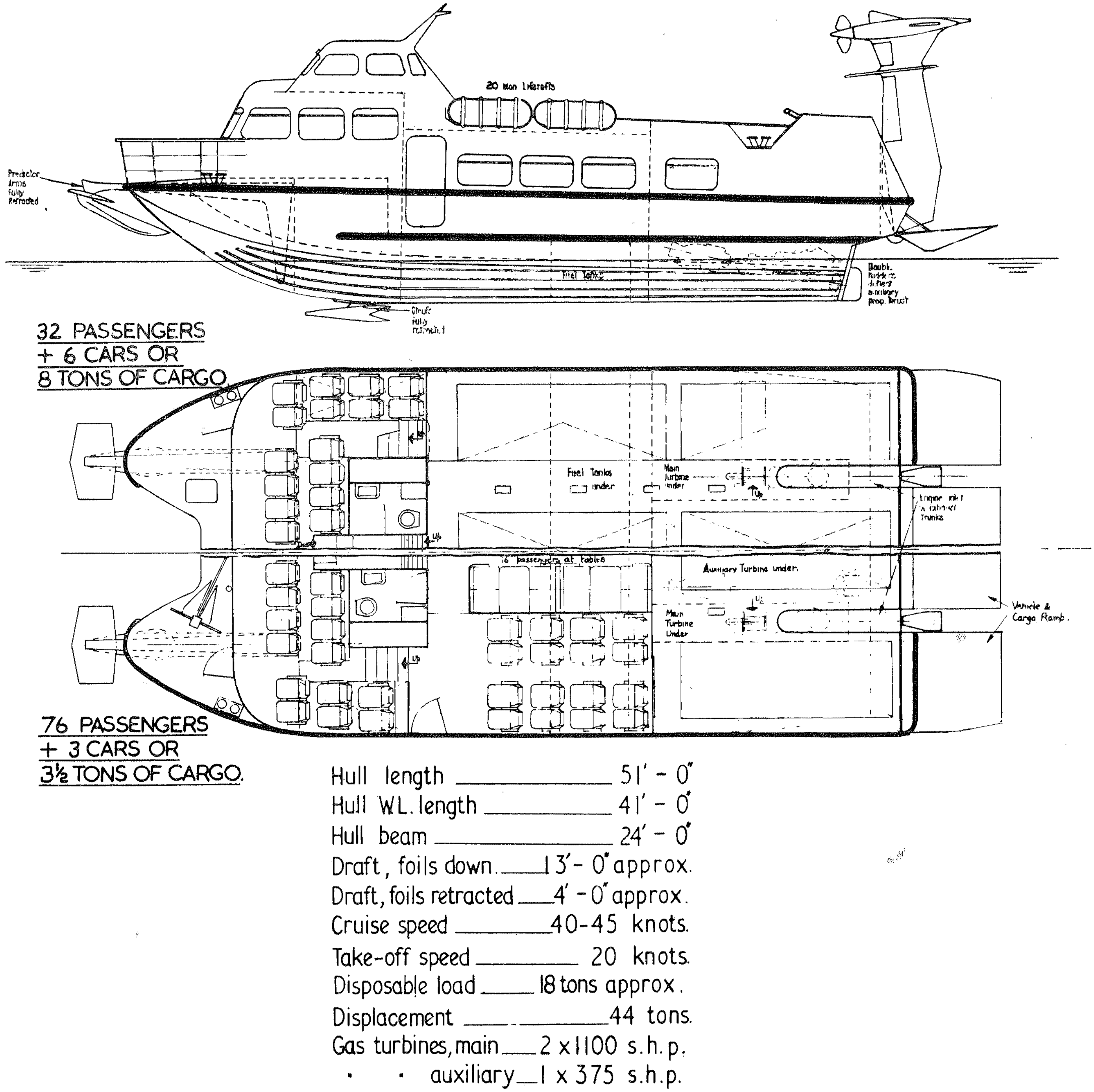

Figure 87. Ocean Ranger

The *Sea Ranger* has been designed to be as versatile as possible, for use in a great variety of duties, and wide variations of passengers and cargo loads (and also of operating range) can be obtained within the vessel's overall disposable load of 4,200 lb (2,000 kg). The "standard" version is a 21-seat passenger boat, equipped with roomy comfortable seats, generous luggage space, and toilet facilities. The "tourist" version has greatly extended window area, transparent roof panels, and seats for 25 passengers. A crew-and-equipment-transportation version provides simpler, removable seating, large rear entry and space for cargo. In addition, Southern Hydrofoils have designed specialised patrol boat versions (armed and unarmed) and an emergency vessel, designed to assist in routine and emergency ambulance and sea rescue work, equipped with medical facilities, including stretcher beds and emergency operating equipment, and also with standard rescue and fire-fighting apparatus.

Powered by two General Motors 6.V.53 diesels, *Sea Ranger* is expected to have a cruising speed of forty knots

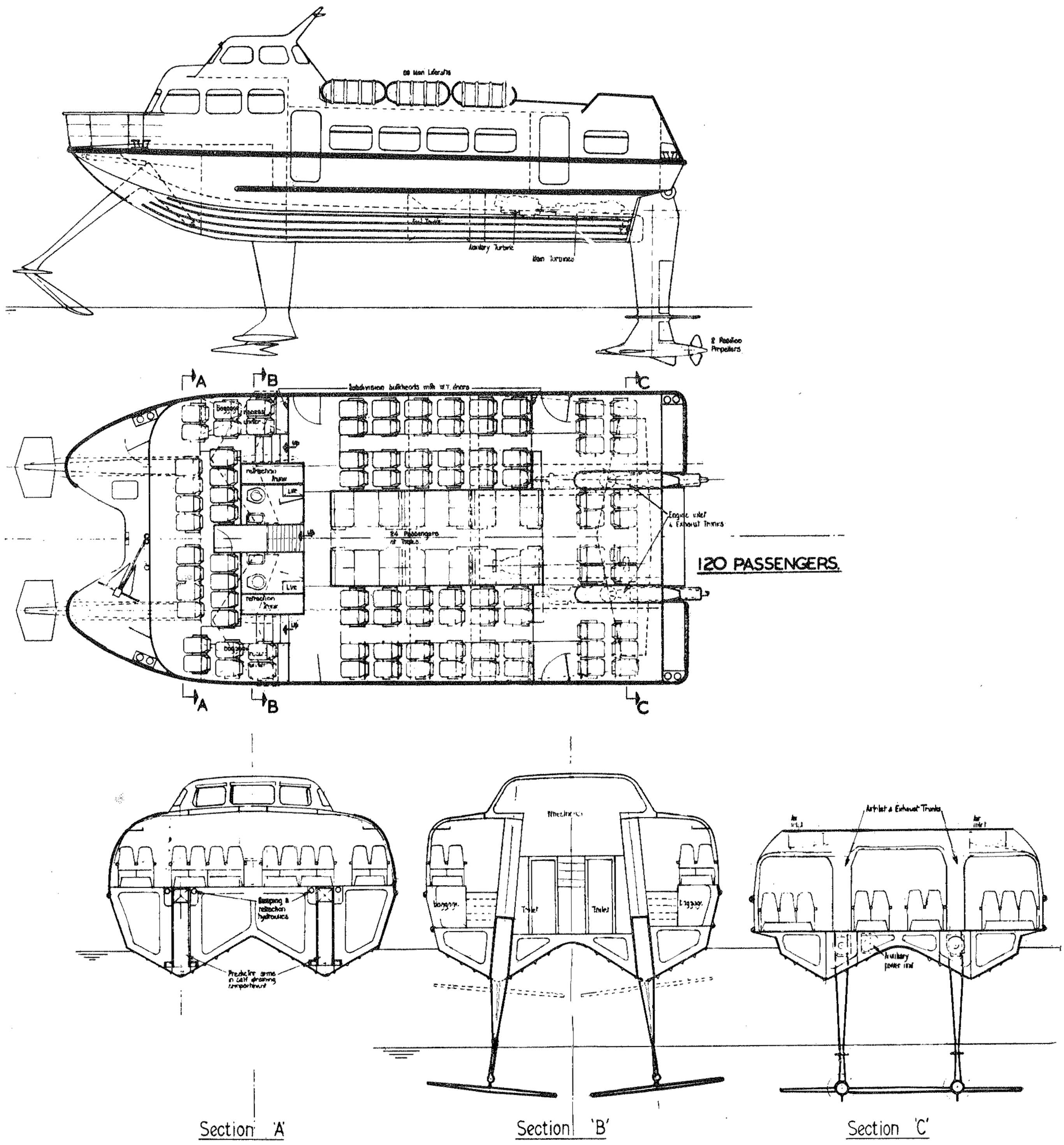

Figure 88. Ocean Ranger

in the fully loaded condition. A Dowty jet pump unit is installed for auxiliary displacement conditions and for shallow draft operation when the struts are retracted. The three fully submerged foils are of swept-wing plan form and are constituted of solid aluminium alloy, protected by a plaster coating.

Ocean Ranger is of similar design to *Sea Ranger* but has a hull length of 51 ft and a displacement of forty-four tons. Projected power units are Solar Saturn 1,100 shp turboprops.

Let us hope that sufficient backing and interest will be forthcoming to enable the first British passenger carrying hydrofoil craft to go into production.

The History of Hydrofoils

(Part XII)

by Leslie Hayward

Technical Contribution of Hans von Schertel

IN July 1934, Hans von Schertel proposed the design disclosed in British Patent Specification 493,176 and US Patent 2,257,405. Von Schertel investigated many different hull forms and discovered that the early hydrofoil craft, having foil systems fitted to existing hulls, suffered many disadvantages which could be overcome if the hull was designed to have a co-operate relationship with the foils. For instance, when the early craft with orthodox hull forms hit waves at speed in a rough sea, the resistance to forward motion was so great that the speed of the craft dropped below that necessary for the foils to support the hull and consequently it dropped back into the water.

Von Schertel realised that if the hull was designed to assist the stabilising action of the foils, to add to the lift force when striking the water and to have a small resistance opposing the forward run, a much smoother, more stable and more efficient ride could be obtained.

The craft proposed has a transversely stepped hull forcing the flow off the bottom of the hull and only permitting wetting of the bottom surface where it is provided with gliding surfaces. These gliding surfaces, set obliquely relative to the axial direction of the craft and given stepped set-offs arranged transversely to the direction of motion, are spaced apart as far as possible, one being under the bow for longitudinal stabilisation and others at the stern for transverse stabilisation. Stepped surfaces may also be positioned amidships, but apart from these surfaces the hull is arched or positioned high up to avoid frictional resistance.

The foils are spaced from, and mounted directly underneath, the gliding surfaces which can add to the lift effect without displacing the combined lift resultant, the foil remaining in its correctly trimmed position. During operation of the craft the foils are positioned partly above and partly below the waterline and vary spanwise with regard to their shape, profile and angle of incidence relative to their height above the water surface.

Considerable design information and a large number of alternative hull and foil forms are given in the relevant patent specifications.

One of the problems associated with craft having front and rear transversely inclined foils is that when operating in heavy following seas, the front foil is apt to leave the wave crest when the rear foil lifts in tending to follow a wave contour. This condition results in a decrease in the angle of attack and affects the lift on the front foil, causing it to undercut the following wave and giving rise to unstable operation.

In April 1951, H. von Schertel proposed the solution shown in British Patent 715,850 and US Patent 2,917,016. Front and rear surface-piercing foils are designed in such a way that the rear foil is more sensitive to changes in the angle of attack than the front foil. Stabilising forces on the front foil result from changes in the depth of submersion, while stabilising forces on the rear foil result from changes in the angle of attack. Details of the foil designs are given in the above patent specifications.

Fig 89 relates to British Patent 745,821 and US Patent 2,720,180, applied for in October 1952. To enable the inci-

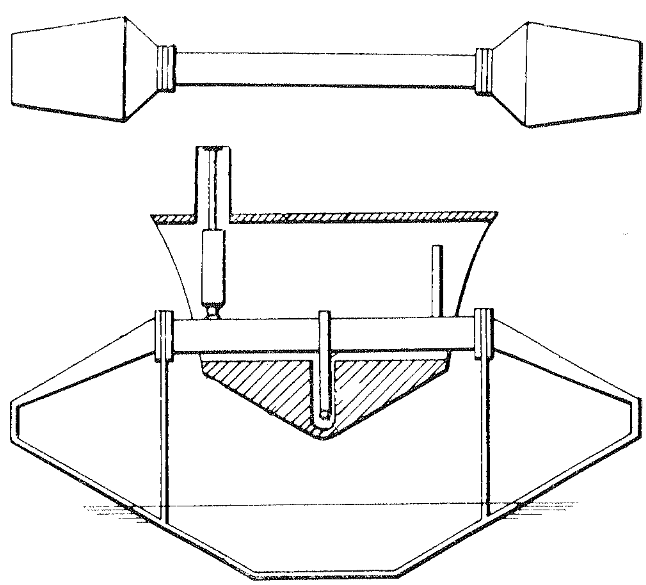

Figure 89

dence of foils to be adjustable when the craft is at rest, or in some cases under way, von Schertel proposed that a surface-piercing type of foil, together with associated support struts and load-carrying girder, should be combined in a single, self-contained framework. The framework is rotatably variable with respect to the hull and does not form any part of the hull structure. Lift-producing sections extending from the sides of the main support girder are linked with and gradually merge to the foil profile. Suitable spring-loaded or damped mechanism is provided for rotation of the entire assembly.

A proposal made in October 1951 relates to an automatic, rough sea, damping device for varying the lift force of surface-piercing foils. Power fluctuations arising from shocks encountered on entering and leaving a wave provide the motive power source. The foil lift force is transmitted through a damped resilient control device. The damping device ensures that small variations in lift force do not affect foil incidence while large changes in the lift force produce acceptable incidence changes. The delay periods of the damping device are manually or automatically adjustable. Details of this invention are given in US Patent 2,771,051.

During August 1955 another patent application was filed in Great Britain disclosing another arrangement for automatically controlling the hydrodynamic lift of surface-piercing foils. The foils are provided with mechanism which alters the lift by adjusting the incidence of the foils or by moving flaps at the trailing edge. The foils are arranged to move vertically against an elastic element when disturbed by waves so that they oscillate relative to the vessel's hull. The oscillations serve as control signals for adjusting the lift. The phase of the controlled alterations of lift of the foils is displaceable relatively to the phase of the transmitter of the adjusting mechanism according to the wave lengths of the sea. Displacement is 180° with the shortest waves, increasing to 360° with the longest waves, being automatically increased as a function of the wave length.

The foil is positioned at the foot of a double leg which, at the forward edges of its upper end, is pivoted to the shorter arms of pivotable horizontally extending levers. The longer arms of the levers are each attached to a vertically mounted spring unit. Another lever extends downwardly from a cross member secured between the top of the two elements forming the double leg and is pin jointed at its lower end to a hydraulic jack pivoted to the hull. A linkage interconnects between a slide valve on the jack and the longer arm of one of the horizontal levers, by way of a phase displacement control unit.

In operation, the foil is urged by action of the waves and by restraint of an inactive control unit to oscillate vertically relatively to the hull, the lifting forces being balanced by the spring unit. The oscillating movements are transmitted by the input portion of the linkage to the control unit which causes a delayed movement of the output portion to control actuation of the jack. Movement of the jack results in arcuate movement of the double legs and controls the pitch of the foil. Alternatively, the legs may be constrained to vertical oscillation only, and the foil arranged to pivot on the legs by direct action of a jack positioned in the bottom of a leg. The delay provided by the control unit responds to, and is regulated by, the wave length as indicated by the periods of oscillation.

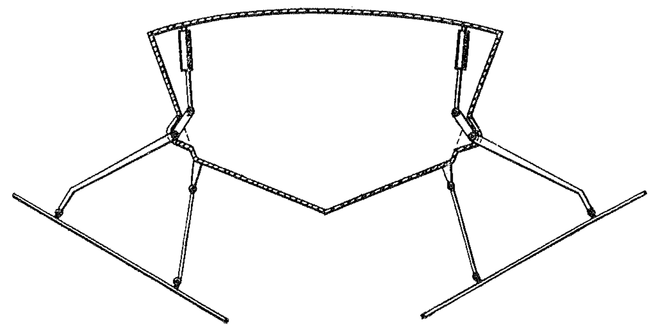

Figure 90

In January 1960, H. von Schertel proposed a retractable surface-piercing foil system which has a separate foil on each side of a conventional hull, the foils being angled upwards and mounted on two links arranged so that the lower link is shorter than the upper link, the inboard pivots being closer together than the outer pivots. This arrangement, shown in Fig 90, permits the foils to be folded closely against the side of the hull when not in use. The inboard pivots can be mounted on the ends of a transverse beam capable of being bodily rotated about its major axis to alter the angle of incidence of the foils. Various suggestions are made to hold the foils in the folded position. Details are given in US Patent 3,099,239.

Proposals made during the later part of 1960, relating to automatic stability controls, are disclosed in British Patent 934,882 and US Patent 3,103,197.

The first disclosure suggests an automatic lift force control for foils, using air collected through inlet ports in the foil support strut. Air flowing from the strut in response to movement of the craft controls the lift force of the foils by mixing with the flow or the cavitation bubble on the upper surface of the foils. This arrangement results in a reduction of the sub-pressure in proportion to the amount of air introduced. Air added to the flow prevents cavitation and therefore the thickness of the foil section can be increased, resulting in a reduction of stress at high speed. If partial cavitation occurs in front of the foils, air fed slightly to the rear prevents collapse of bubbles in the high-pressure region and prevents erosion of the foils. With fully cavitated foils, the bubbles being collapsed at the rear of the foil, sub-pressure is reduced in proportion to the air supplied and the lifting force is automatically controlled.

A continuous lift control is achieved by distributing air over the entire chord of the foil, when, with increasing velocity, the transition stage from sub-cavitation to cavitation is passed.

The further disclosure relates to a modified arrangement for achieving similar results but is operated by dynamic water forces created by movement of the craft. The control utilises adjustable flaps hinged to the trailing edge of the foil. The foil support strut carries a series of pitot tubes and the dynamic pressure of water through these tubes is arranged to operate mechanism, in turn, connected to the flaps pivoted on the trailing edge of the foil, to give adjustment required to suit varying speed and sea conditions.

Further developments of these types of control arrangements are disclosed in detail in US Patents 3,146,751 and 3,146,457.

The History of Hydrofoils

(Part XIII)

by Leslie Hayward

USSR

No country in the world is so rich in navigable rivers, lakes and waterways than Russia, therefore it is not surprising that Russian engineers have applied their skill and knowledge to the design and production of various types of commercially operable hydrofoil craft. Serious and logical development in the Soviet Union can be traced from the latter part of 1945 when an experimental design team, headed by Rostislav Yevgenievich Alexeyev based at the Krasnoye Sormovo shipyards at the river port of Gor'ki, on the Volga river, experimented with a small self-propelled raft-type launch fitted with varying arrangements and types of fully submerged foils. Four experimental craft were built and used for intensive development trials before work was started on the design of a large passenger carrying craft.

In June 1957 the Russians launched their first passenger carrying hydrofoil vessel, the *Raketa* (Rocket), the first trial service being operated along the Volga between Gor'ki, Cheboksary and Kazan on August 25th, 1957. As further craft became available, services were inaugurated on the Dnieper, Ob, Yenisei and Lena rivers. More recently a craft has been operating in Siberia between the industrial centres of Pavlodar and Omsk on the Irtysh river.

Raketa

Early versions of this double deck, aluminium hulled craft, built in the Sormovo shipyards to the designs of the Alexeyev team were powered by a 800 hp diesel engine, directly geared to a single propller, through a reversible clutch. Later versions are powered by 900 hp or 1,000 hp engines.

Length overall	88 ft 7 in (27 m)
Breadth overall	16 ft 5 in (5 m)
Maximum draught :	
Full displacement role ...	5 ft 11 in (1.8 m)
When on foils	3 ft 7 in (1.1 m)
Total displacement	24 tons
Useful load	6.5 tons
Maximum speed	40 knots
Cruising speed	33.5 knots
Passenger capacity	66 persons

With the engine developing 650 hp at 1,200 rpm, the cruising speed is 33.5 knots and the fuel consumption is approximately 63 gallons or 635 lb for 100 miles (170 kg per 100 km) and the range is 466 miles (750 km).

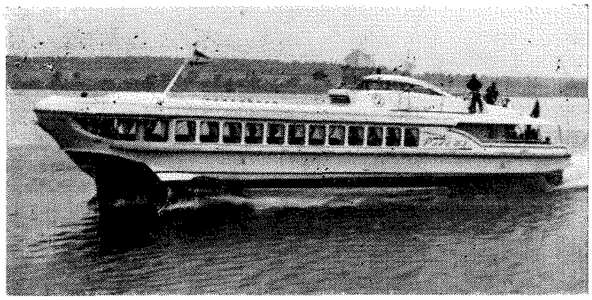

Figure 91. "Raketa"

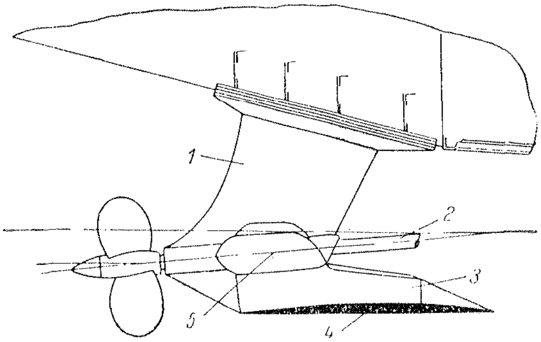

Figure 92. Construction of the after bracket after modification to the "Raketa"

During the latter part of 1959 considerable redesign was carried out on a Raketa craft to adapt it for use in waterways too shallow for the standard craft to operate. Major modifications included moving the propeller further aft and positioning it above the stern foil. Engine bearers were given a new angle necessitating a new rear bearing to accommodate the modified angle of inclination of the propeller shaft. The overall height of the rudder was reduced but its length was increased. As the propeller was not completely immersed its efficiency was somewhat reduced so the load draught was reduced, 48 passengers being carried instead of 66. The fuel load was also reduced.

The first trial run of the shallow-draught *Raketa* took place in November 1959 and was from Gomel to Kiev and back, a distance of 414 miles (668 km). The tests were not entirely satisfactory as it was found that the craft was difficult to steer at high speed. A high pressure, hydraulically operated servo system was installed to actuate the rudder, the pump being driven from the propeller shaft. This modification made considerable improvement in the steering of the craft as did the subsequent addition of a three fin rudder, but the central fin being in the pulsating stream produced by the propeller caused considerable vibration to be transmitted back through the hull structure. In the final design two separate rudders were fitted, each with its own hydraulically operated assister gear. A bow rudder was also fitted to the central support of the front foil. The draught of the finally modified *Raketa* is 3 ft 9 in (1.15 m) and the maximum draught when on foils is 20 in (0.5 m). Speed of the craft is reported to be 37.3 knots (60 km/hr).

Considerable numbers of both types of this craft are on regular scheduled services on many of the major Russian rivers. Regular services have also been established on the Danube between the Bulgarian ports of Rousse and Silistra and Rousse and Svishchov, and between Belgrade and Brahovo on the Yugoslav - Rumanian border. The Hungarian Navigation Company operate a service between Budapest and Vienna.

Meteor

The *Meteor*, another product of the Alexeyev design team made its first journey to Moscow from the shipyards at Gor'ki in the summer of 1960. In addition to scheduled services over this route many craft are now operating on major rivers in Russia.

Length overall	112 ft. 10 in (34.4 m)
Breadth overall	26 ft 9 in (8.0 m)
Maximum draught :	
Full displacement role ...	7 ft 6 in (2.3 m)
When on foils	3 ft 11 in (1.2 m)
Overall height above water when foilborne	22 ft 4 in (6.8 m)
Total displacement	53 tons
Maximum speed	49.7 knots
Cruising speed	43.5 knots
Passenger capacity	150 persons

Passenger accommodation is varied to suit the type of service provided. On suburban services, bench seats take 150 passengers but on long distance services, lightweight, aircraft-type seats take 130 passengers. The luxury of a bar, promenade deck, cabin air-conditioning and temperature control is present on both types of craft.

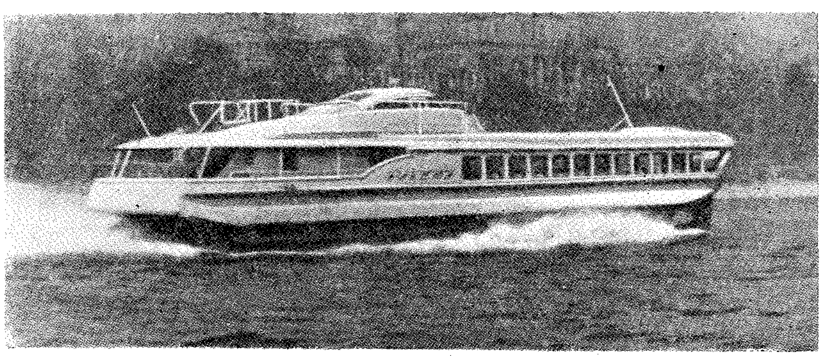

Figure 93. The modified "Raketa"

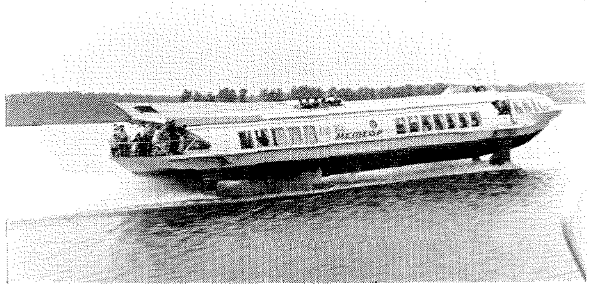

Figure 94. "Meteor"

Meteor is powered by two 900 hp, 12 cylinder, water cooled, supercharged "V"-type diesel engines. Each engine is arranged to drive its own propeller shaft and the twin screws contra-rotate to balance out torque. Apart from small, exposed fore and aft deck areas the hull and superstructure are built as an integral unit, the hull being framed on longitudinal and transverse formers. Steel construction members are welded together but the aluminium alloy skin structure is riveted in place.

Submerged horizontal foils, having convex cross sectional centre portions, are fitted at both the bow and stern and in addition two small subfoils project outwardly from the bow foil side supports, a central keel-type support is also used for the bow foils. The stern foils are attached to the hull by side supports only, the supports being provided with large inwardly directed flanges so that the incidence or angle of the foil may be changed to suit various operating conditions by insertion of wedge plates between the foil and the support flanges before they are bolted together.

On June 11th, 1962, Meteor craft established a regular service on the Moscow - Volga canal and other services are now operating on many lakes, rivers and waterways.

MIR

In the autumn of 1961, the first Russian built sea-going hydrofoil ship made its appearance. *MIR* a 92 passenger craft, built as a prototype of the later *Cosmos* craft, completed successful trials in the Black Sea during September 1961. The hull is of welded aluminium alloy and the surface piercing hydrofoils are made of high tensile stainless steel. This craft is said to have a speed of 46.6 knots.

Cosmos

Little is known about the *Cosmos* craft except that the engines are controlled from the wheelhouse and an automatic servo-operated helmsman has been installed to take care of emergencies. The foils are said to be of high tensile stainless steel and the craft is reported to have a top speed of 46.6 knots.

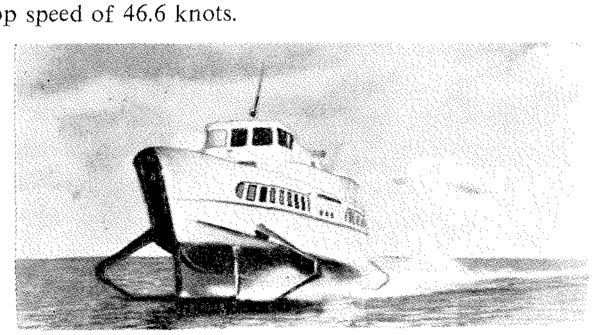

Figure 95. "Mir"

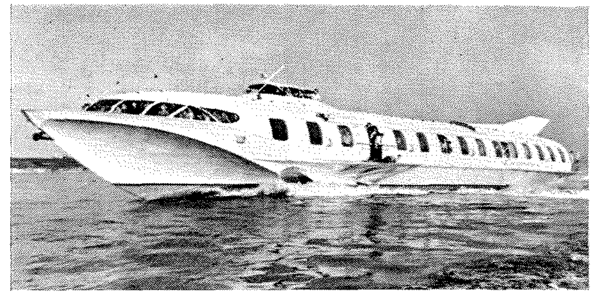

Figure 96. "Sputnik"

Sputnik

Built for operation on inland waterways and large lakes such as the Caspian Sea, Lake Baikal, etc, *Sputnik* made its maiden voyage during October 1961 covering the distance between Gor'ki and Moscow, approximately 560 miles, in 14 hours.

Length overall	157 ft 2 in (47.9 m)
Breadth overall	29 ft 6 in (9.0 m)
Maximum draught :	
Full displacement role ...	4 ft 2.5 in (1.28 m)
When on foils	2 ft 10 in (0.9 m)
Overall height above water when foilborne	
Total displacement	110 tons
Maximum speed	49.7 knots
Cruising speed	41.0 knots
Passenger capacity	260 to 300

Sputnik is fitted with four 900 hp diesel engines and has a cruising range of approximately 500 miles. An all-welded hull permits sectional construction to be employed and dispersed fabrication of various sections. This type of unit construction enables standard sections to be used on a variety of different craft. A considerable amount of plastic material is incorporated in the superstructure which, in addition to reducing the weight of the craft, has also solved some of the corrosion problems.

The passenger saloons, arranged as three separate compartments are insulated against heat and noise and fitted out with fire resisting materials. Accommodation for 68 passengers is provided in the fully glazed front saloon and for 96 passengers in both the central and rear saloons. By using bench-type seating, accommodation can be increased to 108 in each of these two saloons. Two cabins are provided for the crew. Overcoats, heavy luggage, etc, can be housed in a special compartment. A series of rotatable cowls, heated by a closed circuit hot water system, provide ventilation for all compartments. Approximately 85 gallons of drinking water is carried and suction pumps provide filtered sea water for other purposes. A well stocked buffet and store room caters for passengers' needs.

Safety precautions have been carefully planned. In addition to a mechanically driven pump capable of moving 235 cu ft of water per hour, an auxiliary hand pump can be used for pumping out the engine room. Fire extinguishers are fitted in the wheelhouse, passenger saloons and engine room. Two inflatable rubber dinghys are carried, and lifebelts are provided for all passengers and crew. Telephonic and loudspeaker communication is provided throughout the craft and radio telephones provide external communication.

Sputnik, navigated from a forward wheelhouse, has electro-hydraulically controlled engines and rudders. A 24 v electricity supply is produced from generators powered by the main engines. A diesel-engined auxiliary power unit produces an emergency supply of electricity, compressed air for starting the main engines, power for operating the bilge pumps, and many other services.

Fully submerged foils are supported by main struts depending from the hull structure. To give laterial stability, two auxiliary foils project outwardly from the front main support struts. At high speeds the auxiliary foils are normally clear of the water surface. Structural fairing, projecting from the side of the hull over the support struts, prevent the foils from damage when docking and also assist navigation by visually indicating the maximum width of the craft.

Figure 98. The engine, dashboard, seats and steering wheel on the Molnia are the same as those used for the "Volga"

Molnia

This six-seater, open cockpit, water-taxi and runabout pleasure craft, capable of speeds up to 42 knots and having a range of approximately 90 miles per hour, was exhibited at Earls Court in London during July 1961. Built at the Batoum and the Sormovo Shipyards, many hundreds of this type of craft are widely distributed throughout Russia. Lake Baikal in Siberia, now developed as a popular summer resort, is often the scene of much Molnia activity.

Length overall	27 ft 9 in (8.48 m)
Breadth overall	6 ft 5 in (1.65 m)
Maximum draught :	
Full displacement role ...	(2 ft 8 in (0.85 m)
When on Foils	1 ft 9 in (0.55 m)
Total displacement	1.75 tons
Maximum speed	42 knots
Cruising speed	35 knots
Passenger capacity	6

The light alloy hull of the craft is separated into three compartments by framed metal bulkheads. The front compartment is used for general stores, the central compartment forms the open cockpit with seating for six people, and the rear compartment houses a 77 bhp modified car engine and gearbox.

Life jackets are incorporated in the seat cushions and a lifebelt with lifeline is carried. Brooke Marine Ltd, of Lowestoft, Suffolk, have one of these craft in their shipyard. A contract has recently been signed between Sudoimport and the American Satra Corporation for the delivery of ten of these craft to the United States during 1967.

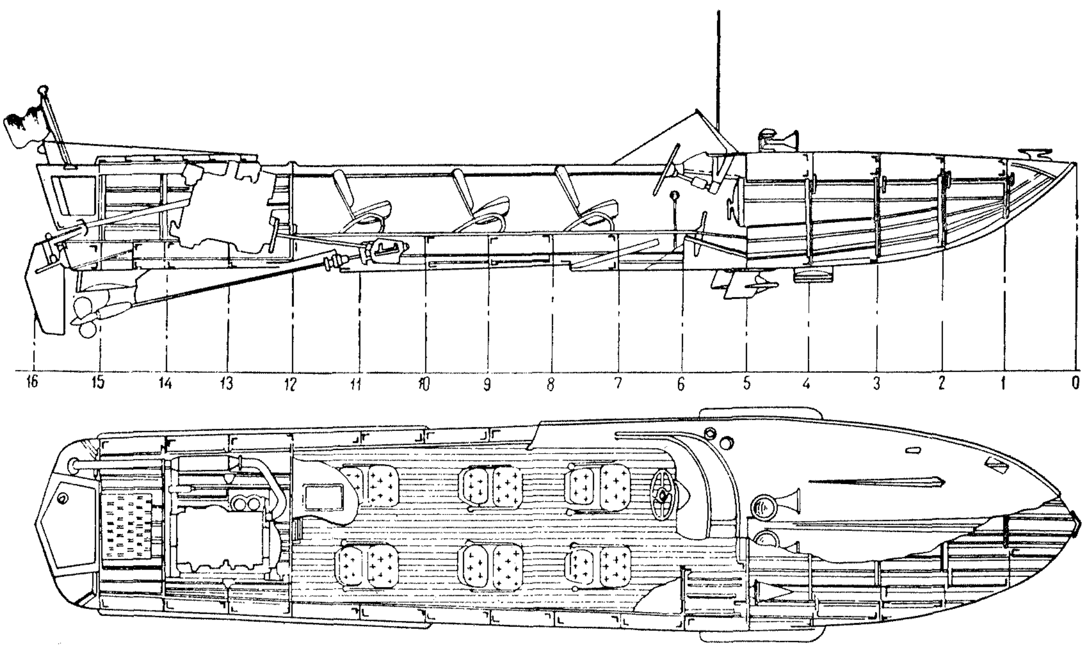

Figure 97. "Molnia"

The History of Hydrofoils

(Part XIV)

by Leslie Hayward

"Stryela"

THIS 92-passenger craft successfully completed its trials on the Black Sea in the autumn of 1961. Speeds up to 50 knots were attained. *Stryela* is similar in appearance to *Mir*, and unlike most of the Russian craft is fitted with surface-piercing foils. Twin diesels, collectively developing 2,400 hp, are arranged to drive twin screws. Fully automatic control systems are installed and an automatic helmsman may be locked in on long voyages.

In June 1962 this craft was put in service between Yalta and Sevastopol, the time taken by the normal ferry service of 6½ hours being cut to 1½ hours.

A second craft completed in October 1965 probably holds the world's record for a long-distance journey by hydrofoil. The journey from Yalta to Leningrad, a distance of 2,735 miles, was accomplished in 100 hours' operational time. The craft traversed the Black Sea to the Sea of Azov, the Volga-Don, the Volga and then through a series of interconnecting lakes at Tsimlyansk, Volgograd and Rybinsk to the new Volga-Balt canal, where it passed through Lakes Svir and Onyega to the River Neva.

In recent months *Stryela* craft have been operating on scheduled service between Tallinn and Leningrad.

"Delphin"

Acceptance trials of this 120-150-passenger craft were completed on the Volga during May 1964. Powered by turbo-jet engines, said to be similar to the power units of the TU.124 aircraft, *Delphin* is the first passenger-carrying, gas-turbine-engined hydrofoil craft produced in Russia.

The hull, of lightweight construction built up by welding, is very streamlined in shape. A system of water-jet reaction is used for propulsion instead of the orthodox propellers. Speed of the *Delphin* is reputed to be in the range of 68-70 knots.

"Kometa"

Very similar in construction and appearance to the *Meteor* craft, *Kometa* was launched in the late autumn of 1961. Extensive trials and minor modifications were carried out before this craft was put in regular service on the Black Sea in the spring of 1962.

Length overall	115 ft 0 in
Breadth overall	31 ft 6 in
Maximum draught:	
Full displacement role	10 ft 6 in
When on foils	4 ft 8 in
Total displacement	58 tons
Maximum speed	40 knots
Cruising speed	34 knots
Passenger capacity	150 persons

An anhedral type nose foil has been fitted to improve stability in open sea conditions. Ladder type foils are fitted both fore and aft, and a surface-skimming foil has been added amidships. Various passenger cabin arrangements have been adopted; the seagoing craft have sleeping cabins for 100-120 passengers, and the short-haul type carries up to 150 passengers. Two 1,100 hp diesel engines drive twin propellers. This craft was designed and developed by the shipyards at Sormova but the production craft are built at the Georgia yards on the Black Sea coast.

Two *Kometa* craft will be delivered to the USA by the Soviet Sudo-import Organisation during 1967. *Kometa* craft have already been exported to Western Germany and Bulgaria, and negotiations are proceeding on the sale of a craft to Greece.

"Fulgar"

The *Fulgar* is a single-seat research and development craft.

An interesting feature of this craft is the form of pneumatic insulation provided to deaden wave shock at the stern. Adjustable incidence, "V"-shaped arrow-like foils are fitted, the incidence angle being variable from the cockpit. *Fulgar* is reported to have reached speeds of 37 knots.

"Vikhr"

Probably the largest seagoing hydrofoil craft at present operating anywhere in the world, *Vikhr* appears to have been developed from the *Sputnik* class of craft.

Length overall	157 ft 0 in
Breadth overall	29 ft 6 in
Total displacement	110 tons
Maximum speed	25 knots
Cruising speed	43 knots
Passenger capacity	300 persons

Built at the Sormovo yards and launched during 1962, scheduled services have been carried out between Odessa and Crimea resorts and Odessa and Yalta. Four 1,200 hp diesel engines power four water propellers for propulsion, the propellers being supported by stern struts attached to the underside of the rear of the hull. The front and rear foils are of "V" shape and are also swept backwards. An amidships foil assists in attaining longitudinal stability.

"Chaika"

Developed by the Krasnoye Sormovo shipyards at Gorki, the experimental *Chaika* has been used to test a water-jet propulsion system likely to be used in larger Russian craft now under construction.

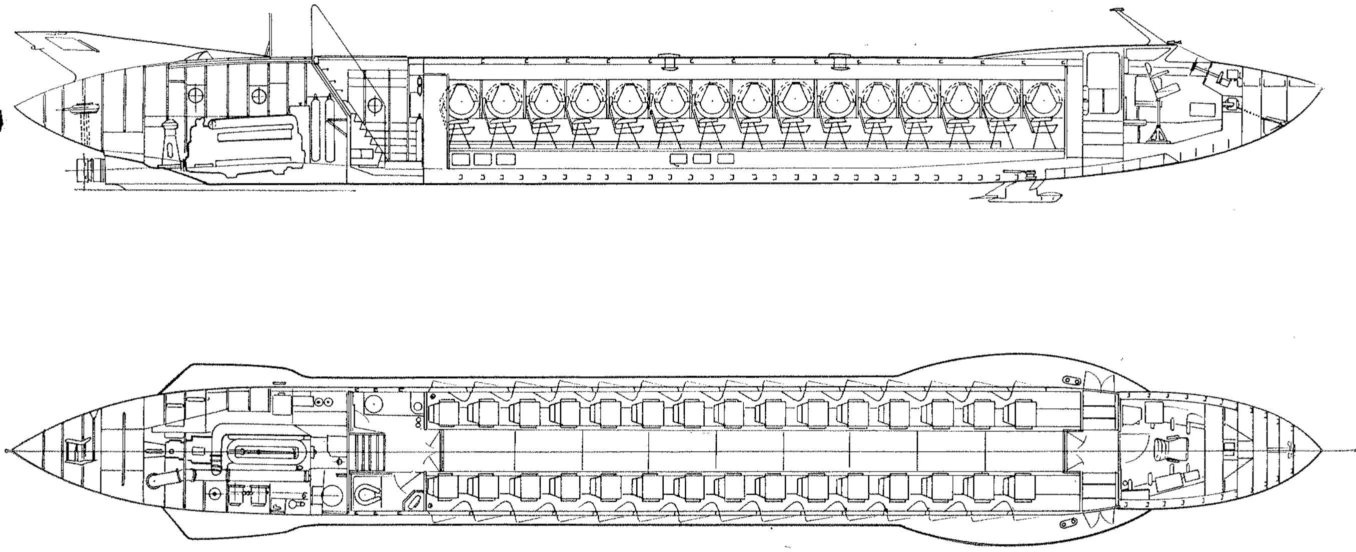

Figure 98. Sketch of the general layout of the "Chaika"

Length overall	86 ft 3 in
Breadth overall	12 ft 6 in
Maximum draught :	
Full displacement role ...	3 ft 10 in
When on foils	1 ft 0 in
Total displacement	14.3 tons
Maximum speed	60 knots
Cruising speed	46.5 knots
Passenger capacity	30 persons
Range	310 miles

A 1,200 hp diesel engine drives a two-stage pump providing water-jet propulsion. Rudders on each side of the water-jet nozzle provide directional control. Hull design and compartmentation are similar to that used for *Sputnik*. A full description of this craft was given in Vol 3 No 9 of *Hovering Craft & Hydrofoil*, June 1964.

"Burevestnik"

Claimed by the Russians as being technically and operationally in advance of any other hydrofoil craft in the world, *Burevestnik* was built at the Krasnoye Sormovo Shipyards and launched in April 1964. This craft is particularly suitable for operation in shallow waterways, having a foilborne draught of only 16 in. Water-jets provide propulsion, power being provided by two gas turbines of 4,000 shp. The water-jets can swing through 360° to assist manoeuvrability and docking operations. Variable incidence, fully submerged, titanium foils are fitted at the bows and stern, the foils being protected by outrigger platforms which also serve as service platforms.

Length overall	142 ft 0 in
Breadth overall	22 ft 0 in
Maximum draught :	
Full displacement role ...	5 ft 10 in
When on foils	1 ft 4 in
Total displacement	62 tons
Maximum speed	80 knots
Cruising speed	65 knots
Passenger capacity	150 persons

General

Considerable research activity on various types of hydrofoil craft is being undertaken in Russia. The National Patent Development Corporation of Park Avenue, New York, has recently secured the rights to license American manufacturers to build *Raketa*, *Meteor* and *Molnia* types of craft in the United States of America.

At least forty-five scheduled services are at present being operated in Russia and approximately 3,000,000 passengers are carried by these services during the course of one year.

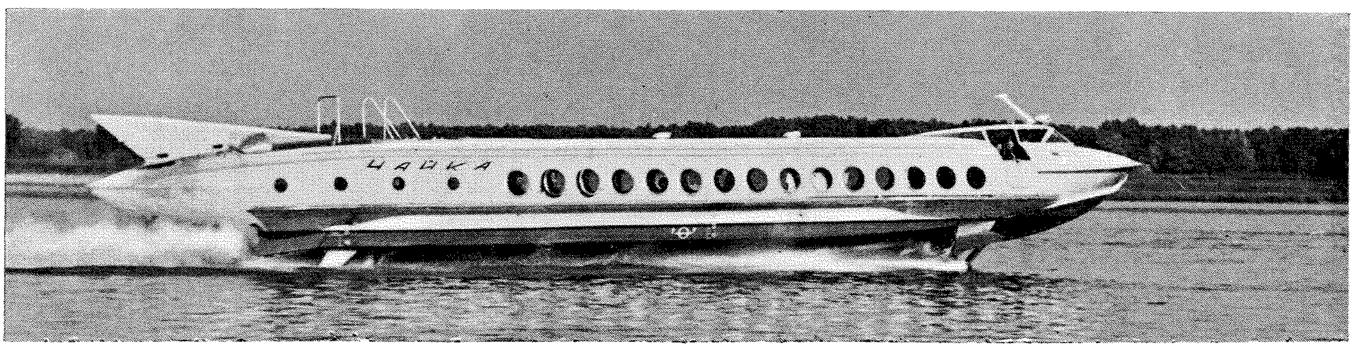

Figure 99. "Chaika"

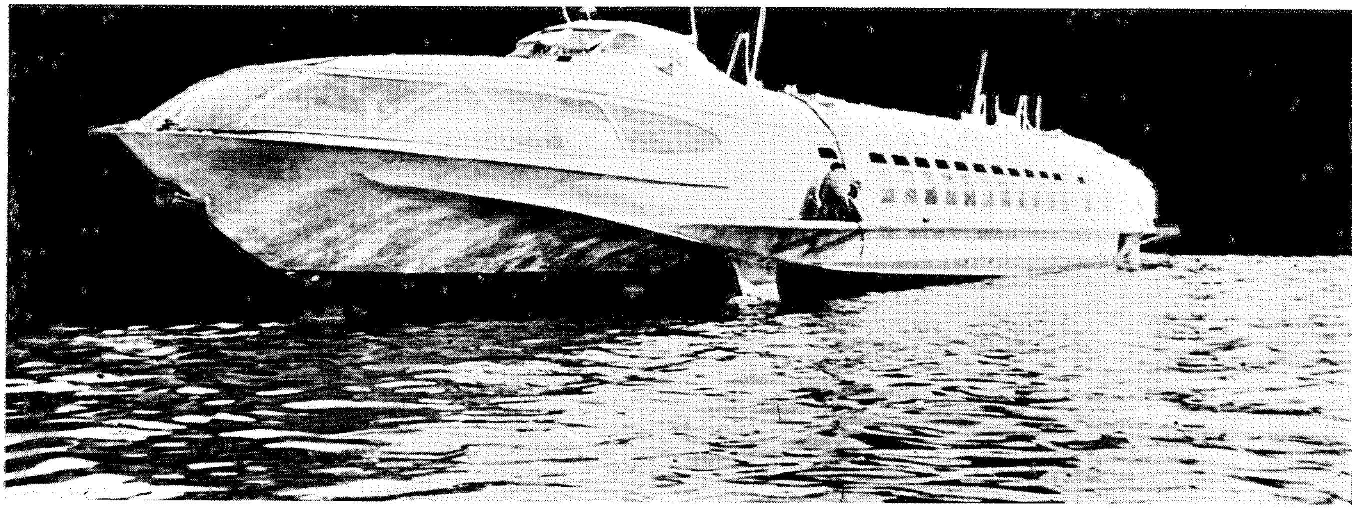

Figure 100. "Burevestnik"

POLAND

In 1961 the Department of Naval Architecture of the Gdansk Technical University was consulted by the Polish Central Board of Inland Navigation and River Shipyards concerning the design of a hydrofoil craft for operation in the Firth of Szczecin. The *Zryw* craft built during 1964-65 by Gdansk River Shipyard was the result of this collaboration.

Length overall	90 ft $6\frac{1}{2}$ in
Breadth overall	22 ft 0 in
Maximum draught :	
Full displacement role ...	6 ft 9 in
When on foils	4 ft 1 in
Total displacement	30.7 tons
Maximum speed	45 knots
Cruising speed	35 knots
Passenger capacity	76 persons

The *Zryw-1* has two shallow submerged stainless steel foils with a longitudinal and transverse dihedral in a tandem system. The front foil is of the surface-piercing type and the rear foil is fully submerged. The light alloy hull is of almost fully welded construction, riveting being applied only for the joints of the framings with the outer plating of the roof, partition walls and for joining steel and light alloy elements.

A Russian diesel engine of 1,200 hp is used to drive the three-blade water propeller. This craft has been in service on the Szczecin–Swinoujscie route, the forty-one miles being covered in approximately fifty-five minutes.

Figure 101. "Zryw-1"