HOVERING CRAFT & HYDROFOIL

THE INTERNATIONAL REVIEW OF AIR CUSHION VEHICLES AND HYDROFOILS

Volume 1 Number 10

JULY 1962

KALERGHI - McLEAVY PUBLICATIONS

Another World's "First" on Castrol!

WESTLAND CHOOSE CASTROL

for the world's first commercial hovercraft – the SRN2

Castrol
MOTOR OIL

Castrol has been associated with more "firsts" on land and water and in the air than all other oils put together. Now, once again, Castrol is chosen for another sensational "first" . . . the world's first passenger carrying hovercraft, the Westland SR N2 which is equipped with four 815 h.p. Bristol Siddeley Nimbus engines, all of which are lubricated with Castrol. The SR N2 is built by Saunders-Roe, a division of Westland Aircraft Ltd. and is intended for regular services.

ALWAYS ASK FOR CASTROL BY NAME

The Rt. Hon. H. Macmillan, Britain's Prime Minister, on board the ACD-1 at Luton Hoo in Bedfordshire. The ACD-1 represents a new approach to air riding vehicles. Further details concerning the craft appear on pages 30-31 of this issue.

HOVERING CRAFT
& HYDROFOIL

First Hovering Craft & Hydrofoil Monthly in the World

THE INTERNATIONAL REVIEW OF
AIR CUSHION VEHICLES AND HYDROFOILS

HOVERCRAFT MARKET SURVEY

HARLEY, MULLION and Co. Ltd., the 64-year-old City of London shipping brokers, have recently distributed to their clients outline details of Hovercraft intended for commercial service.

Eric F. Greenfield, a director, told *Hovering Craft and Hydrofoil* that his company feels that Hovercraft have reached the commercial stage and that they are now doing everything to promote their use. The company is currently arranging a number of visits by shipowners to Hovercraft manufacturers.

From the survey distributed by the company we have extracted the following items concerning the current situation in development, basic prices and anticipated delivery dates.

Saunders-Roe SR.N 2. At present the craft is not for sale. It is to be used to gain experience under varying conditions and by the late summer, should trials prove satisfactory, a sub-charter may be arranged. A comparable craft to the SR.N2 would have a basic price of £317,000. It would take 9-12 months to build.

Saunders-Roe SR.N2, Mk. 2. In this developed commercial form the SR.N2 will have increased length and all-up weight. Cost to run per passenger mile will be 6d. as opposed to 9d. for the Mk. 1. Basic price is expected to be £433,000, and delivery within 12-15 months.

Vickers VA-2. First of these utility 4-5 seaters should be ready this month. Capable of 40 knots it will be suitable for fast executive transport work over sheltered and inland waters or over difficult terrain where existing vehicles cannot operate. Power is provided by two Continental horizontally-opposed engines — a 133 s.h.p. 0-300 for lift, and a 230 s.h.p. 0-470L, driving a reversible pitch 2-blade airscrew, for propulsion.

Denny Hovercraft. The D.2 Hoverbus is expected to start its trials this month. The craft is 83 ft. long, 19 ft. 3 in. wide and will carry 88 passengers or about six tons of cargo. The first four built will seat 70 passengers. Two caterpillar turbo-charged diesels will provide lift, and two propulsion. Dry weight will be 25 tons and top speed is 25 knots. Range is 100 miles. Should trials prove successful, sister craft will be built. No price has been quoted for the type.

Cushioncraft Ltd. The second CC-2 is due for completion by the end of the month and will be put through extensive endurance and running tests on the Solent. Delivery of production craft will start in January, 1963. Price will be £25,000. Approximate cost to run per passenger mile is 7d.

COVER PICTURE: Lieutenant-Commander P. M. Lamb, Chief Test Pilot of the Saunders-Roe Division of Westland Aircraft about to board the SR.N2. A paper presented by Lieut-Commander Lamb to the Institute of Navigation appears on page ?? of this issue.

IN THIS ISSUE

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HYDROSKIMMER HIGHLIGHTS

Details of Bell's XHS-4

BELL AEROSYSTEMS CO., whose early experiments with air cushion craft were described in our October *1961* issue, have released further details of their model 2073 Hydroskimmer. Fabrication started at Buffalo, New York, in April and the craft is expected to be ready for test runs on Lake Erie by mid-1963.

Award of a design and construction contract for the 2073 by the U.S. Navy Bureau of Ships — reportedly for $2,040,000 — was announced on November 28th, 1961.

As a project the design is significant in several senses. It will be the first big air-rider built in the United States; it has been envisaged as a system able to test the suitability of these craft in a number of different operational roles, and it employs the Hovercraft principle.

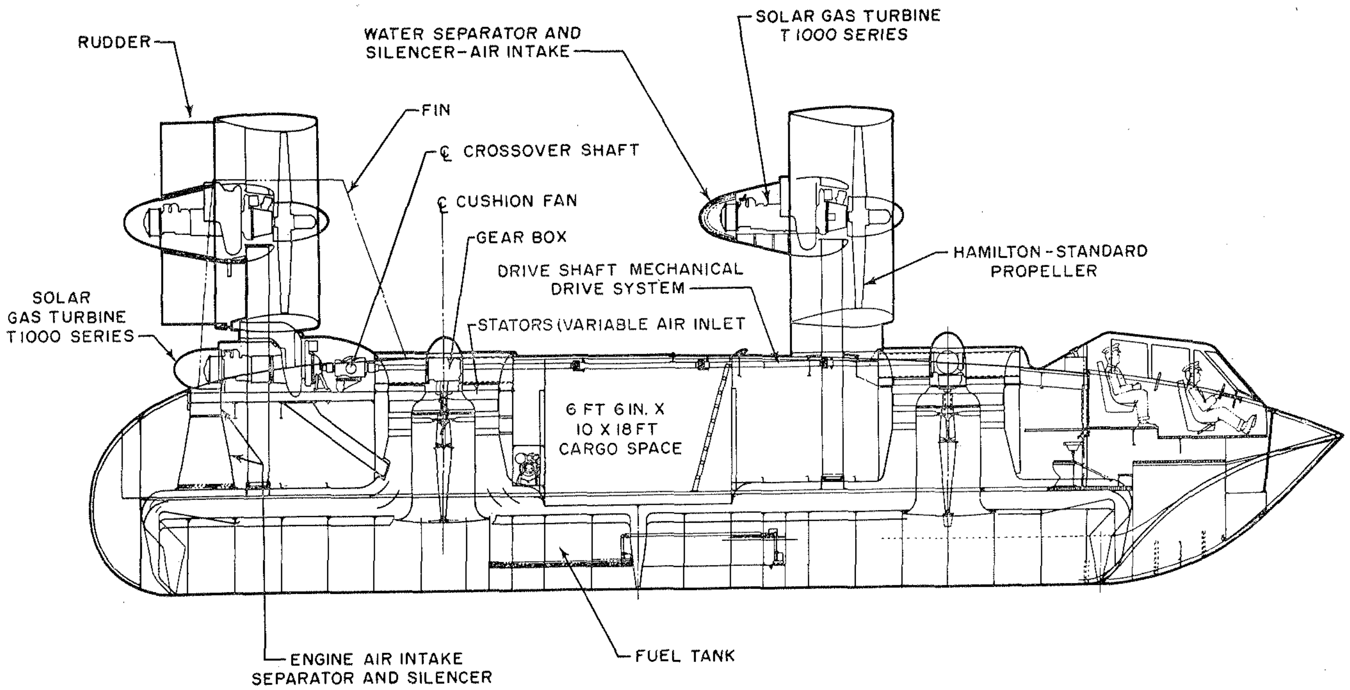
Recognising the basic problems and importance of the Hydroskimmer, Bell, the Electric Boat Division of General Dynamics and Hovercraft Development Limited, have all pooled their various resources to help develop the craft. The parts to be played by the three organisations are shown in a co-ordinated development plan printed on a later page.

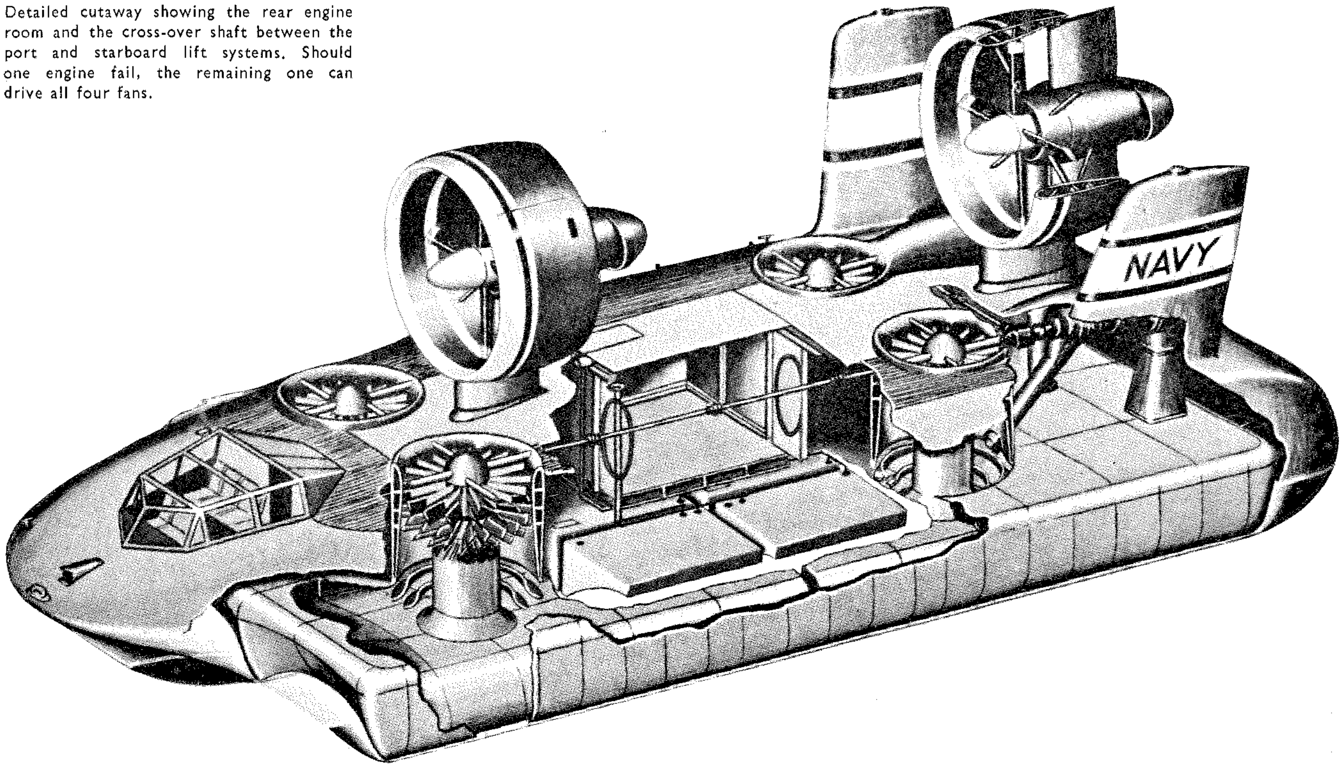
The project itself comes under the direction of E. Liberatore. Technical Director of the project at Bell Aerosystems, and A. Mirti, Programme Director. An advisory board for the programme comprises Christopher Cockerell, Hovercraft Development Ltd., V. Paxhia, Bell Aerosystems, J. V. Harrington, Electric Boat Division, J. Sawyer, General Turbine Corporation, and a member of the Bureau of Ships.

The craft, which has the U.S.N. designation XHS-4, has tandem, swivelling propellers for propulsion and control. The air cushion is generated by four vertical-shaft fans set in a rectangular pattern in the deck. The base geometry consists of a peripheral jet with stabilizing cross jets. For maximum seaworthiness the Hydroskimmer has a trimaran hull.

Power is provided by four Solar Saturn shaft turbines, each developing 1,120 hp at 1,200 rpm each. The two propulsion engines are pylon-mounted and set in ducted nacelles above the deck and the two for the cushion fan system are horizontally mounted at the rear of the hull. Each of these drives two modified mixed-flow fans, and should either engine fail, a cross-over shaft between the starboard and port systems permits the remaining engine to drive all four fans.

The hull is built in aluminium alloy.



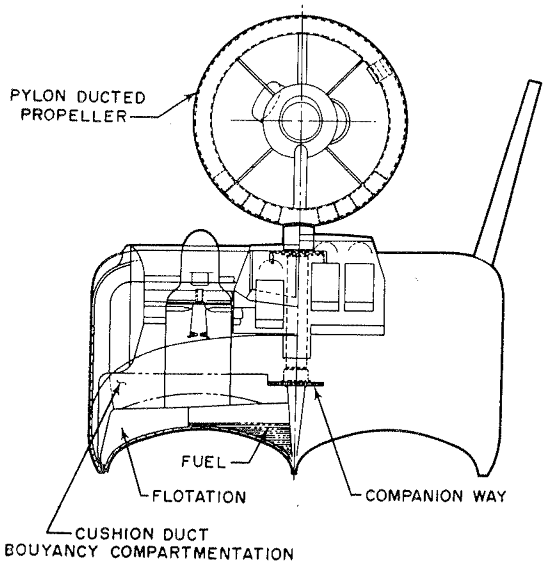


Detailed cutaway showing the rear engine room and the cross-over shaft between the port and starboard lift systems. Should one engine fail, the remaining one can drive all four fans.

Principal Specifications

Dimensions

Length (overall): 67 ft. 6 in.
Beam (hull): 22 ft.
Beam (maximum at fin tips): 26 ft.
Height (overall): 24 ft. 9 in.
Total Cushion Area: 1,000 sq. ft.



Cross section showing the siting of the mixed-flow fans and the unusual trimaran hull.

Weights

Gross Weight: 45,000 lb.
Empty Weight (light displacement): 37,280 lb.
Overload Gross Weight: 55,000 lb.

Power Plants

4 Solar Saturn shaft turbines, 1,120 h.p. at 1,200 r.p.m. each.

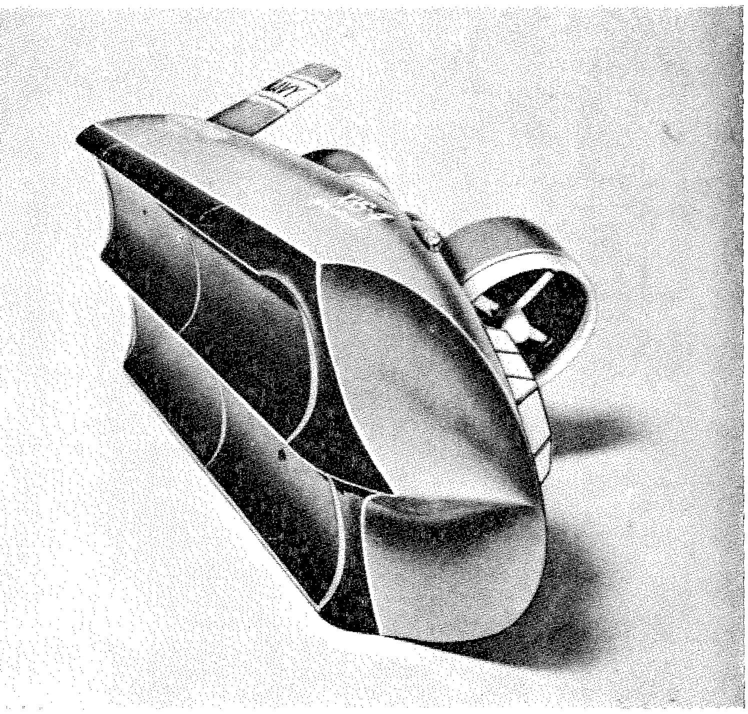
Fans

Lift Fan: 4.
Diameter: 5.94 ft.
Blades: 15.
R.P.M.: 1,200.
Propeller: 2.
Diameter (ducted): 9.5 ft.
Blades: 4.
R.P.M.: 1,800.

Crew :—3

Performance

Operational Speed at
Gross Weight and at
6 in. Height of
Skeg above water: 70 knots.
Maximum speed: 93.5 knots.
Hover Height (solid surface)
45,000 lb: 6.5 in.
55,000 lb.: 3 in.
Turn diameter at 70 knots: 3,250 ft.
Endurance at 70 knots and 45,000 lb. weight: 3.1 hrs.
Range at 70 knots and 45,000 lb. weight: 225 nautical miles.



The Hydroskimmer's Trimaran hull and curtain geometry are shown by this model. The curtain has side, end and central stabilizing jets and pressure taps.

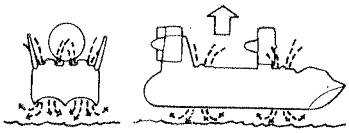
Structure

The aluminium alloy hull is similar in construction to an aircraft fuselage. Naval architectural practice is observed, especially with regard to the bow structure where large impact loads at high speed are expected. The hull is divided into twelve watertight compartments. In the secondary structure, fibreglass and waterproof plywood are used where advantageous.

HYDROSKIMMER HIGHLIGHTS . . .

Control System

The control system consists of variable inlet vanes on the cushion fans to decrease or increase airflow on swivelling ducted propellers, the aft one of which has a rudder and reversible pitch, used for changes in thrust and forward speed, braking and backing.

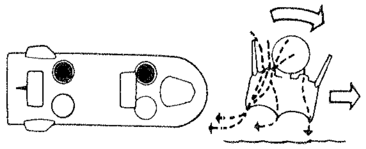


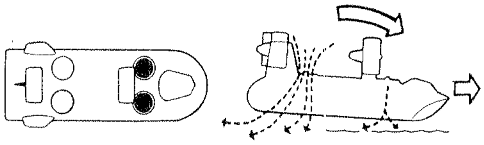
Cushion Lift Control

The hovering height is obtained and controlled by varying the r.p.m. of the four cushion fans which varies the airflow at the nozzles.

Roll Control

Operation of the inlet vanes on the port or starboard pair of cushion fans decreases the airflow to that corresponding side of the craft which produces a roll and thrust in that direction.



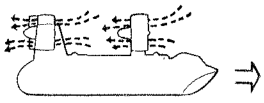


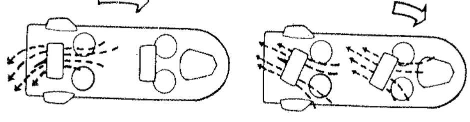
Pitch Control

Operation of the inlet vanes on the forward or aft pair of fans decreases air flow, causing pitch and thrust.

Fore and Aft Control

Two four-bladed ducted propellers are located on fore and aft mounted pylons. R.P.M. can be set and propeller pitch varied for changes in thrust and forward speed. The propellers are reversible for braking and backing.





Turns

In forward flight the rudder, mounted on the aft ducted propeller, provides the yaw force required for normal turns. For tight turns, further motion of the control wheel swivels the ducted propellers, providing the increased side force which is required.

HYDROSKIMMER HIGHLIGHTS . . .

Fans

Four modified mix-flow fans (MMF) are used for cushion air supply. The fans, designed and fabricated by Electric Boat, are arranged in a rectangular pattern with inlets on the deck. Controllable inlet guide-vanes permit the operator to vary the airflow through the fans and to each quadrant of the base. In the event of power loss or failure of one engine, a cross over shaft between the starboard and port fan systems provides for drive to all four fans from the remaining engine.

Propulsion

The propulsion system consists of two ducted four-bladed, constant speed air propellers designed and manufactured by Hamilton Standard Division of United Aircraft Corporation. Each propeller is driven by a Solar Saturn engine. R.P.M. and pitch can be selected by the operator to attain desired thrust at maximum efficiency. The propellers are reversible to provide control for hovering manoeuvres, backing and braking. Each complete power package is mounted on a swivelling pylon.

Missions

The Hydroskimmer will be used to test the operation suitability of air cushion vehicles in naval missions. Tests will enable a compilation of performance, payload and mission environment requirements, and provide realistic operations criteria for the development of other craft of this type.

Tests will cover the practicability of introducing Hydroskimmers in the following roles:

Ship-to-shore logistics over a wide range of natural obstables; ASW missions; as an instrument and weapons platform; for high-speed reconnaissance along enemy shores.

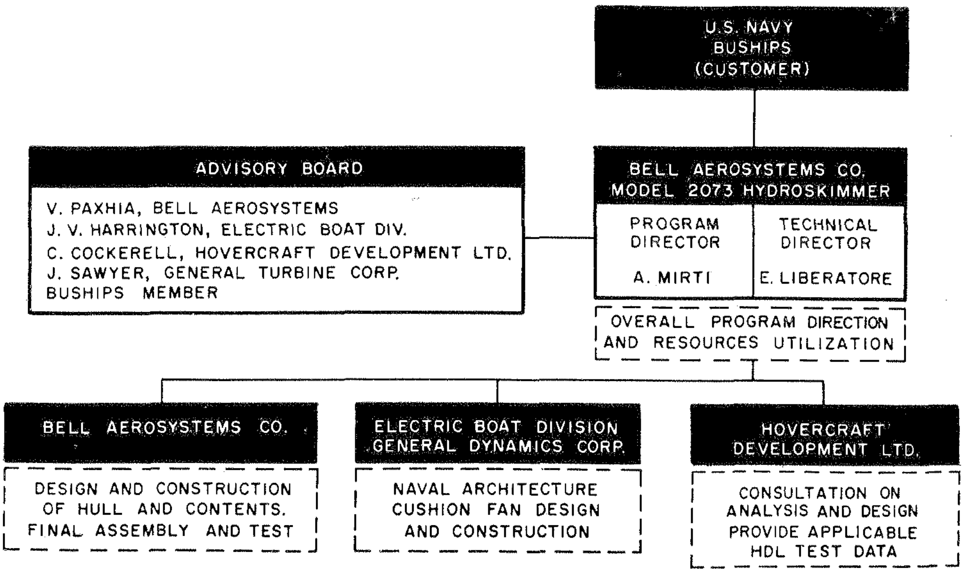
The data accumulated will enable the formulation of an operational evaluation test programme; the provision of improved definitions of the operational craft, and the direction of improved design enhancing the craft's operational suitability.

Management

Make-up of the organisation established by Bell, its associated contractor and Hovercraft Development to handle the programme, is seen in the accompanying diagram. The Advisory Board has been set up to work with the Programme and Technical Directors.

The personnel of the various groups report to the Programme Director who maintains a check on the contract from a budget, scheduling and business point of view.

Participating as a consultant, HDL will provide aerodynamic and hydrodynamic design data based on their experience. Their model test experience and association with practical high-speed operation in rough water with the SR-N1 and SR-N2 will help speed the development of the Hydroskimmer.

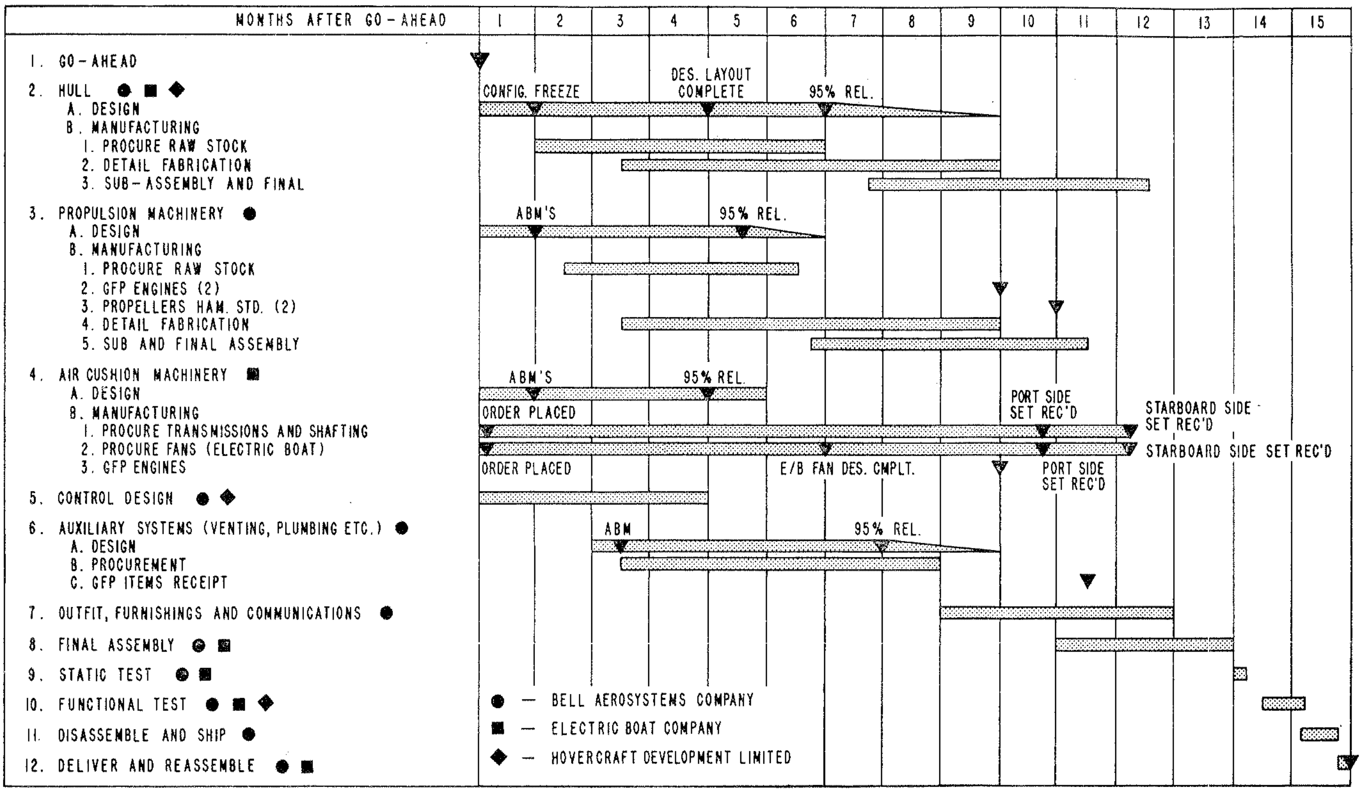


HYDROSKIMMER HIGHLIGHTS . . .

Development Plan

It is intended to deliver the Hydroskimmer to the U.S. Navy 15 months after the award of the contract. The design and manufacturing schedule below will interest many potential builders and operators of air cushion vehicles since it shows the completion target that can be set — and achieved — in developing new craft of this type under ideal conditions.

A computer programme is being used to help Bell plan, control and monitor progress. At the time of publication the craft will be in the fourth month of the programme.



News In Brief

Hovercraft uses for Australia

Mr. Peter Thorneycroft, British Minister of Aviation, has suggested that Hovercraft ferries would be ideally suited for Sydney Harbour. He believes that hovercraft could also be put into operation over swampy country where railway tracks could not be laid and in places such as the Central Australian Desert.

Hydrofoil Boats to Bahamas, Denmark

The Norwegian boatyard, Westermoen Hydrofoil, Mandal, has secured three export orders for hydrofoil boats. One contract, worth £175,000, has been placed by Clay Shipping, Nassau, Bahamas, and is for a hydrofoil to carry 100 passengers between Miami, Florida, and Bahamas. The hydrofoil will make the trip twice daily. The other two orders have been received from Denmark and are for hydrofoils to take 65 passengers each. Each boat will cost £80,000.

Hovercraft Navaids

Since 1959 Decca's Hovercraft Study Group, composed of electronics engineers and operations specialists from Decca Radar and the Decca Navigation Company, has been investigating problems associated with the navigation of air cushion vehicles.

A special marine radar has been developed by Decca for the SR.N2 — the slotted waveguide aerial for this is sited just above the cockpit — and the craft is also fitted with the Mark VIII Decca Navigator.

At the moment the group is focussing its attention on the application of the Navigator for high speed, accurate route keeping in hoverways; the use of Doppler to provide precise navigational inputs; the most suitable types of radar for use aboard or ashore; and the best form of presentation for anti-collision radar.

Decca's experience with true motion radar displays in 55 knot patrol boats indicates that great advantages are offered by this type of presentation at high speed. Ground stabilisation of the radar picture is the most important factor in obtaining ease of interpretation with radar at speed. Not only is a stable picture of the land provided, and the true movement of all other vessels apparent at a glance, but, it permits the navigator in a craft manoeuvring at high speed to orientate himself correctly when poor visibility or darkness obscures visual marks.

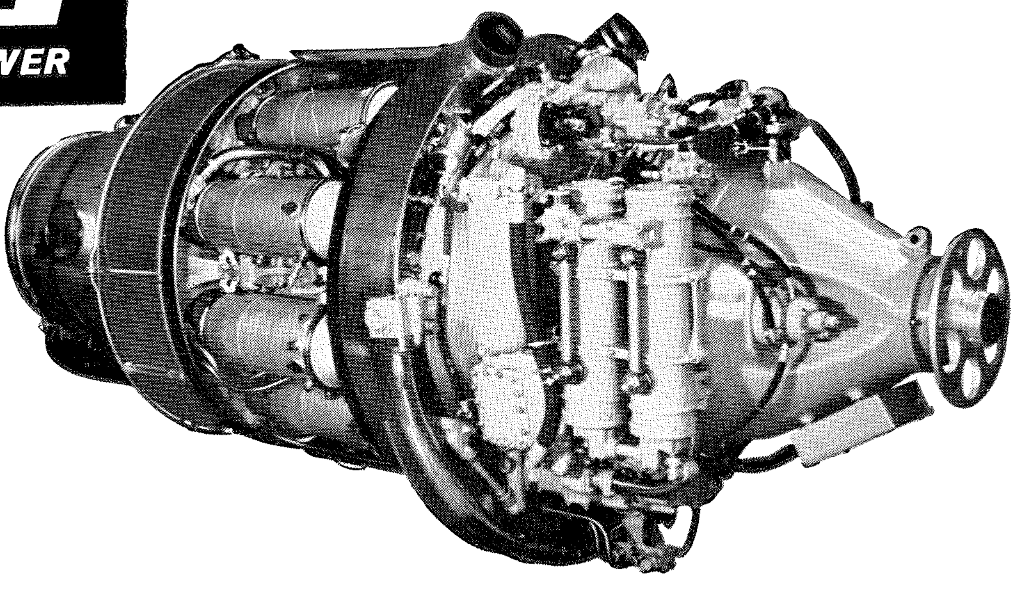
Decca state that large scale 12 in. and 16 in. true motion displays and Interscan range and Decca equipment of this type is already specified for large Hovercraft under construction.

A further aspect of the investigation being pursued by the study group involves the application of Doppler with particular reference to drift and speed measurement.

Saunders-Roe Plans

For the time being, at any rate, the SR.N6 remains simply a design project. The craft occupying the minds of the Saunders-Roe Division at the moment are the 37½ ton SR.N2 Mk. 2, a "stretched" version of the SR.N2 which will carry 150 passengers or 12 tons of freight; the SR.N3 military craft; and the SR.N4. The latter, again a development of the SR.N2, will weigh 100-150 tons.

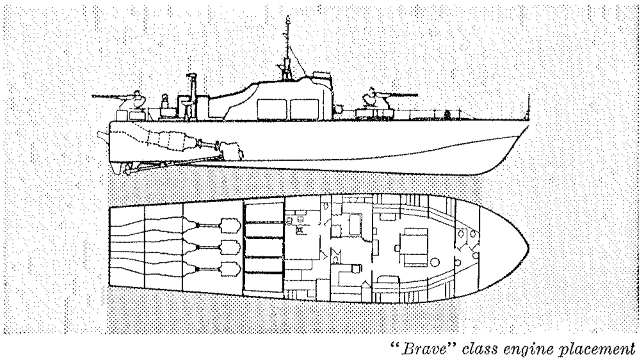
MARINE POWER



Marine Proteus gas turbine —proved in 2 years' service

The Marine Proteus, backed by Bristol Siddeley's 12 years of marine gas turbine experience, is the world's only lightweight marine gas turbine to have been proved in extensive service.

Three of these engines, delivering a total of 10,500 hp, power the Royal Navy's 96-ft "Brave" class fast patrol boats built by Vosper Ltd. With a top speed of more than 50 knots, they are the fastest naval vessels afloat. HMS "Brave Borderer," the first of the class, has been operating with great efficiency for over 2 years.



"Brave" class engine placement

The Marine Proteus, which passed 1,600 hours of rigorous tests to schedules laid down by the British Admiralty, was developed from the highly successful Proteus aero gas turbine with two million hours running experience.

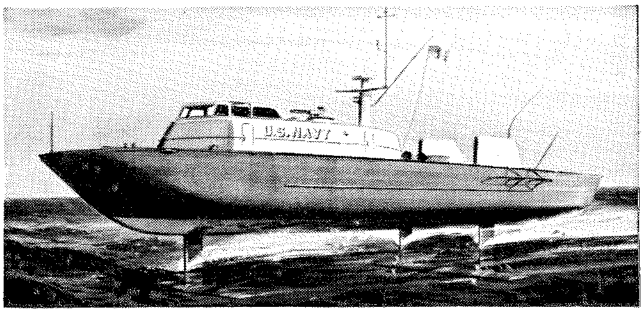
QUICK STARTING—QUIET RUNNING

The Marine Proteus, which operates on diesel fuel, reaches full power within 60 seconds from a cold start. It is an exceptionally reliable engine with a long overhaul life and it runs at a very low noise level and requires only half an hour's maintenance every 100 hours.

The latest versions, the Mk 1270 series, deliver 4,250 hp (4,310 cv) at alternative output shaft speeds of 1,000, 1,500 or 5,260 rpm for a weight of only 2,900 lb (1,320 kg), a fuel consumption of 0.60 lb/shp/hr (268 grm/cv/hr), and a lubricating oil consumption of ½ pint per hour.

SUITABLE FOR HYDROFOILS—HOVERCRAFT—FAST BOATS

The Marine Proteus is eminently suitable for any application where speed, light weight and space saving are important considerations: hydrofoils; hovercraft; and small patrol or passenger vessels.



Impression of Boeing hydrofoil PC (H)

The Marine Proteus has been ordered by the navies of Britain, Germany, Italy and Sweden, and by the US Navy Department, Bureau of Ships, for a Boeing hydrofoil designed for anti-submarine duties. The engine also powers "Mercury"—the world's fastest express yacht, owned by Mr Stavros Niarchos.

For further information, please write to: The Sales Manager, Power Division, Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED MARINE AND INDUSTRIAL GAS TURBINES—MARINE, RAIL AND INDUSTRIAL DIESEL ENGINES—PRECISION ENGINEERING PRODUCTS—TURBOJETS—TURBOFANS—TURBOPROPS—PISTON ENGINES—RAMJETS—ROCKET ENGINES

NAVIGATIONAL PROBLEMS

BY DEFINITION a hovercraft or air cushion vehicle is a vehicle capable of being operated so that its weight is partly or wholly supported by a self-generated cushion of air that is dependant for its effectiveness on the proximity of the surface over which the vehicle operates. Thus from the safety aspect of navigation a hovercraft must be treated as a surface vehicle or craft; for any collision risks involved are proportional to the amount of conventional surface vehicles or craft and static obstructions, in the area of operation. The clearance of minor obstacles less than the hoverheight is practical; but on present thinking with a maximum undersurface clearance of three feet, these clearances are limited to small buoys, waterlogged obstructions and rock outcrops of limited height.

To date very little information is available with regard to overland operation of hovercraft on other than specially prepared surfaces. It is possible and likely that hovercraft may play an important transport role in certain underdeveloped countries of this world; but until such time as these markets are more clearly defined and the practicability of hovercraft operation over such surfaces as desert and tundra have been fully investigated; it has been decided to omit the overland navigational aspect from this paper. The navigational problems presented here are related to the present proven capabilities of hovercraft — river, inland lakes and coastal water operation, whilst the land operation is confined entirely to the terminal facility; envisaged as a slipway and specially prepared apron for the ready turn around of passengers and cargo. Ideally this terminal facility should be situated outside the conventional harbour but adjacent to the port of operation thus avoiding the congestion of shipping within a very confined area. It would rely on the amenities of the port — railways, roads, etc., for the quick turn around of passengers and cargo. The length and width of the slipway would, like the runways of an airport, be largely dependant upon the size and power/weight ratio of the commercial hovercraft; but generally a 1:8 to 1:10 incline should be acceptable with a width twice that of the hovercraft. A small degree of concavity to the slipway would provide a natural self-centring property for any lateral drift.

Over the terminal area the hovercraft operates with its weight totally supported by the ground cushion whilst small amounts of forward, sideways or reverse thrust are applied as required for manoeuvring. Up and down the slipway decelerations and accelerations due to the sloping surface are similarly controlled by coarser applications of positive or reverse thrust control. Once over the water the hovercraft has the dual capability of either operating as a displacement vessel similar to a ship or as over the land, in the hover on its ground cushion. The method of operation upon leaving the slipway must, to a large extent, be determined by the approach hazards and presence of other craft. Where, by force of circumstance, as at Cowes, the terminal facility is in a congested harbour, then it is customary to proceed in and out of harbour by the shipping channel as a displacement vessel. The only difference between the ship and hovercraft in this condition is that whereas the former is fitted with water rudders and water screws, the latter is more likely to derive its thrust and directional control from air propellers and aerodynamic controls. There is nothing particularly new in this concept; for to obtain shallow draught some Japanese landing craft adopted this method of propulsion in World War II. Unfortunately from the commercial standpoint operation as a displacement vessel is highly uneconomic for high thrusts are required for low forward speeds, which together with an increase of time en route is comparable to lengthy taxiing of modern short haul jet aircraft. By placing the terminal facility outside the harbour this problem is largely obviated.

The procedure of transition from displacement vessel to hovercraft is purely a matter of increasing power of the lift fans and thus increasing the velocity of the airflow through the peripheral jet. Initially when hovering statically, the craft creates a depression in the water underneath the hull and dependant on cushion pressure and jet velocity a large amount of spray is generated by the deflected lifting jets. At low forward speeds, this depression is carried along with the craft building up a bow wave and noticable wake until at what is termed the hump speed, the hovercraft over-rides this wave system and, with a marked reduction of drag, acceleration is rapid. Hump speed will vary with the overall length of craft but as a rough guide it is in the speed range 14-20 knots with present-day hovercraft. It is marked by a longitudinal change of trim together with the rapid acceleration which ensues and also a marked reduction of spray over and around the craft.

From the navigational point of view, hump speed is most important for below hump the craft is tide borne whilst above hump the craft is windborne and subjected to drift angles differing from surface craft in tidal waters. With a surface clearance, underwater obstructions are no longer a problem. Shoals, mud flats and sandbanks are traversed with no concern, as are any vertical obstructions less than the under surface clearance.

Ideally the hovercraft is suited for transportation in the speed range 50-100 knots where, at three times the speed of passenger ships, but at a third the speed of passenger aircraft, design studies have shown it to be an economically sound proposition. It is for this speed range that the prototype SR.N2 is designed and which we are at present investigating with our experimental trials. These trials, still in an early stage, have basically proven the handling characteristics, structural and mechanical design in limited sea conditions through the lower speed bracket up to a maximum speed so far achieved over a measured mile of 68 knots. The following figures taken from test records are relevant and illustrate capability of maneouvre of hovercraft.

1. Radius of Turn

Due to the lack of surface friction of hovercraft, the turning circle over the water or track is, to a large extent, limited by the amount of lateral bank or side force available. To keep heading and track coincident (ignoring any drift component due to wind) there is for every alteration of heading a given side force that must be applied to prevent skidding. Thus for a comfortable banked turn with negligible skid the rate of turn of hovercraft approximates 3° per second.

On the other hand the hovercraft can, if so desired, pivot through 180° in a full skid turn in a matter of seconds. By this method a hovercraft proceeding on a northerly heading can pirouette onto south with the previous forward momentum then carrying it astern. This somewhat spectacular manoeuvre is considered to have little practical advantage commercially but illustrates the turning capabilities of hovercraft which are analagous to a car on an icy road where the alteration of heading must not exceed the minimum radius of turn. For the SR.N2 at 45 knots in a banked turn of 3° per second, the radius is 483 yards. This is comparable with the frigate at 33 knots which is 475 yards whereas the Queen Mary at 25 knots is 1,600 yards.

2. Stopping Distances

When travelling at speed there are two methods by which the forward motion of hovercraft can be arrested. Firstly the coarse application of reverse thrust and secondly a reduction of power to the lift fans allowing the craft to settle onto the water. The decelerations experienced by the latter method are dependant on forward speed and sea state and can, under the worst conditions, approximate 3-4g which is tolerable but slightly discomforting to passengers and crew. This method of deceleration is thus an emergency stop procedure.

The measured stopping distances for SR.N2 have been achieved by reducing speed with full reverse thrust to 25 knots whereupon the ground cushion was allowed to decay and the craft settle on the water. At 45 knots this distance is 160 yards which compares very favourably with the frigate at 37 knots — 490 yards, and the Queen Mary at 29 knots — 2,260 yards. The distances for both ships are based on the application of

F HOVERCRAFT

By Peter M. Lamb

full reverse thrust, which to a large extent limits their manoeuvring capability; whilst the hovercraft has positive directional control during the deceleration.

The limitations of sea conditions for hovercraft operation are not so easy to define. A large amount of this research is naturally predicted from model work in test tanks with simulated waves, for the majority of practical experience has been confined to the Solent area, where even under rough conditions the relationship of wave length to height is often irregular due to the effect of wind, tide and adjacent land areas. Generally, the limiting sea condition will depend upon the following factors:

Hoverheight and forward speed.
Length of craft in relation to length of sea.
Structural design limits and general craft shape.

With SR.N1 we have operated at 60 knots in seas two feet high and at 40 knots in seas 2 ft. 6 ins. high without any severe impacting. For the SR.N2, which is 27 tons, the limiting sea state should be in the region of 4-5 feet whilst a 100-150 ton size hovercraft could be made to operate economically over relatively short ranges at 90 knots in seas up to 6-7 feet and at reduced speed in seas up to 8 feet.

Having broadly looked at the present capabilities of hovercraft; it is now possible to see how this craft fits into a commercial application, and the navigational problems involved. Basically commercial operation from the marine aspect can be divided into three categories:

1. The underdeveloped areas of water and swamp in this world, where due to restriction of depth it is undesirable, if not impossible to operate conventional craft. In such areas the main navigational problem would be accurate route keeping where free of other traffic (except similar hovercraft), collision risks are at a minimum.
2. Fast flowing rivers, where being independent of draught and hence current, the hovercraft has a readily apparent economic advantage. Here, being at most times within visual sight of land, the problems of route keeping are greatly reduced, but due to the restricted area and the presence of other surface craft, the density of shipping is often very high and the collision risk consequently greater. This is particularly applicable to rivers such as the Rhine, on which a paper was recently presented to the Society by Mr. Beatty.
3. Coastal hovercraft with range of operation up to 100 miles. The immediate applications in this country are cross channel ferries and in specific areas port to port coastal operation. Scandinavia and the Mediterranean are but two other areas where there are many specific routes for this type of craft. To maintain scheduled operation for passengers and high rate cargo in this role, the two basic navigational problems:
   (a) Avoidance of all hazards;
   (b) Accurate route keeping;
   are both of paramount importance.

The last category embracing the navigational problems of the first two might now be studied in detail.

Ideally the hovercraft route should be kept clear of areas where there is a convergence of surface craft but practically this may be difficult to apply. Deep water channels and shipping lanes have to be crossed and near shore there are likely to be a number of the smaller pleasure craft and fishing vessels.

On the selected routes, e.g. Calais to Dover, Cowes to Southampton, where the density of shipping is high, the answer would appear to be the institution of Hoverways. These hoverways, similar to airways, should be clearly defined and charted between the respective ports of operation. The width of the hoverway would, to a large extent, depend upon the coastal waters and navigational facilities available, but envisaging two hovercraft travelling in reciprocal directions with a closing speed in the region of 200 knots; a mile is estimated the minimum width for lateral separation. From the terminal facility the hovercraft keeping to the right hand side of the hoverway should be routed to a point where it is convenient to cross the main shipping channel at right angles and once clear proceed by an inshore route to the destination. Every endeavour would have to be made to keep the inshore route clear of recognized fishing grounds and small craft; and the latter in their turn would have to be as aware of the hoverway as the private flier is of the airway. The commonsense yachtsman with his natural love for the freedom of the seas would, I think, accept and recognize a danger area without imposing, even were it possible, any restrictions of activity within that area.

It is inevitable though that small craft will find themselves at times within the hoverway and from the hovercraft Captain's point of view, the avoidance of these hazards are considered a greater problem than the crossing of the shipping lanes where the accuracy and reliability of the radar warning should be of a higher degree. The limitations of hovercraft speed and even operation on such a route will depend on the quality and warning that the radar picture can give. With the short time available by the operator for interpretation, the advantages of True Motion over relative motion would seem a basic requirement.

For route keeping, the maintenance of track would necessitate a high degree of accuracy. It is assumed that the Decca Navigator or any other accurate position keeping device in areas of reasonable coverage would have to give an accuracy never less than a quarter of a mile. Whilst outside areas of good coverage transponder beacons might need to be positioned.

Finally the measurement of water speed would have to be accurate enough to feed the True Motion Radar picture and also maintain a D.R. plot at constantly varying speeds. Early trials with Doppler have now achieved an accuracy of 2-3% error under optimum conditions. Bearing in mind the relatively low aerial positions in SR.N2 and hovercraft in general, I hope that Mr. Morgan of Marconi Wireless and Telegraph Co., will be able to elaborate on these requirements.

SUMMARY

1. Harbours and deep water channels are unnecessary for hovercraft operation and due to their areas of convergence should as far as possible be avoided.
2. From the commercial operators standpoint it is economically undesirable to operate hovercraft below its designed speed range. Lengthy periods of operation below hump speed, besides being highly uneconomic have a detrimental effect on machinery and component parts from the point of view of spray.
3. It is reasonable to assume that the manoeuvring capabilities of hovercraft at 80 knots should prove comparable with the conventional ship at 30 knots.
4. Initially, rough weather conditions will impose more severe restrictions on speed of hovercraft than speed of ships. Generally, adverse sea and weather conditions should not radically alter the manoeuvre capabilities.
5. The hovercraft being windborne will be subjected to angles of drift different from other surface craft. To an external visual observer this could give a false impression of track.
6. For commercial routes where the density of shipping is high; the institution and notification of hoverways would greatly reduce the collision risk.

It is reasonable to assume that the hovercraft with its greater speed and manoeuvring potential would normally initiate the avoiding action of other surface craft. But in circumstances where a hovercraft cannot avoid passing so close to another vessel that risk of collision might arise, she would go at moderate speed having regard to the existing circumstances and conditions and would comply with the International Regulations for Preventing Collisions at sea as if she were a power driven vessel, except that she would not give sound signals.

THE SURFACE EFFECT VEHICLE FOR THE PRIVATE OWNER

By ARTHUR W. J. G. ORD-HUME,

THE Surface Effect Vehicle must claim the singular distinction of being the only new type of transport machine ever designed which has progressed from initial conception to commercial production in so short a space of time.

Almost before the "reasons how and why" had been set down, schemes were afoot for passenger-carrying ferries, freight vehicles and a whole gamut of new and hitherto unthought of devices for such diverse uses as moving bricks on the building site to carrying five hundred people between cities at speeds of three hundred miles per hour.

Concerning only the transport of human beings, whilst we see rapid developments in the design of the SEV to serve as a high-speed passenger ferry and military transport vehicle, there is, at the other end of the size scale, remarkably widespread interest and enthusiasm in the evolution of small vehicles potentially useful for sport, pleasure and generally personal use.

The almost instant acceptance of this new concept of transport has in no small measure been due to the widespread interest and publicity given by the national press and TV Networks.

Where once he visualised the individual helicopter (and that was not so long ago either), the man in the street sees the day when he will commute in a "hovercar", gliding effortlessly along through halcyon highways. Whether or not this will come to pass is open to conjecture. The present ruling is that the SEV is not permitted on the highway and this is quite understandable pending the development of precise steering and braking control systems comparable to those systems in use on existing road vehicles. Furthermore, were the SEV to be introduced on the highway, unless new thoroughfares were expressly constructed for their use, the SEV would inevitably be operating alongside conventional road vehicles on the same highway for some considerable while to come. It would be fatuous to expect, therefore, a degree of precise control relative to operation less than that embodied in, say, the automobile or bicycle.

There are, however, those who see the SEV as a sporting vehicle, an aid to the individual who has to traverse terrain unsuitable for normal vehicles, a holiday resort attraction and a method of satisfying Man's ever-present desire to enjoy himself.

This should not be dismissed as just "small fry" for the simple reason that a demand exists "just round the corner" and so wide are the possible applications of the SEV principles that there is scope for development work on every level.

It is in this connection that this article is intended. The writer has recently been engaged in the evaluation and consideration of the small SEV and Surface Effect-Assisted Watercraft for such use. The following conclusions relating to the development of these devices will, it is hoped, provide a brief résumé of some of the work done to date and constitute a basis for further work of this nature.

As with the initial concept of any machine, the first consideration is the performance envelope to suit the likely requirements of the small SEV operator.

It would appear reasonable to expect that a hover height or cushion thickness of 3 in. should be the absolute realistic minimum for use on land. A more worthwhile altitude would be in the region of from 4 to 6 in. Tests have illustrated that deep ruts or depressions of an encompassed area not exceeding 10% of the area enclosed by the SEV peripheral jet do not appreciably affect the cushion thickness during motion, although as might reasonably be expected, a free-moving phugoid can result from a number of such depressions being crossed whilst the SEV is under sustained motion in a given direction where the pitch of such surface discontinuities is less than 15% greater than the chord of the cushion at right angles to the mean line of discontinuity. When the frequency of discontinuity is such that the cushion chord parallel to the direction of motion is greater than two-and-a-half pitches, these oscillations once more disappear. The effect of frequency and pitch must, of course, be related to horizontal velocity in a given direction and cushion height and area. Tests were conducted using a model producing a 2% cushion height (longitudinal cushion chord/height) for a length/breadth ratio of 1: 0.6. The 165-inch long model was "flown" remotely at speeds up to 12 mph and the conclusions herein refer to trials results made under this set of conditions. An application here would be the small SEV traversing a kerb-stone, crossing a railway track or a ploughed field.

When the SEV is required to operate on water or smooth ice, the theoretical minimum cushion thickness may be much less than 3 in. By using a large area cushion maintaining a surface loading of, say, 0.75 lbs./sq. ft., this cushion can be achieved for (a) minimum power, and (b) the minimum of water surface disturbance and spray.

In actual fact, however, the practical small water-borne SEV has to be able to overcome three operational obstacles. Firstly, there are water waves. On very few occasions is even an inland waterway perfectly calm and smooth. The SEV, operating at low cushion pressure and striking wave crests, would cause discomfort to the occupants in particular because the hull design is not intended to penetrate waves and any such wave contact would result in an uncomfortable and harsh slap to the craft with risk of possible damage to the underskin.

The second obstacle to be overcome is waterborne debris and partially-submerged obstructions. Weeds and branches in rivers, protruding rocks in shallows and so forth come under this heading.

The third stumbling block is beaching. The SEV must be capable of running up a reasonable beach, possibly strewn with stones. Unless a realistic cushion height is achieved, attempts to ride up all but the shallowest beach with a craft of realistic length will bring the fore end into contact with the beach and the aft end into the water. In practice, there appears to be no serious result of such contact or disadvantage performance-wise except that there is again risk of damage to the underside of the craft and possible discomfort to the occupants.

An obvious answer is to have provision for a reserve of power to enable the cushion height to be increased at will. Such a power reserve, though, must invariably demand a larger power unit and hence greater weight. The greater the weight, the larger must be the cushion area to maintain the same mean cushion height at a common surface loading.

Whether water-borne or land operating, the SEV is at present somewhat like a small child in a play-pen. Its utility is limited within physical boundaries, both geographical and man-made. Whilst it can be argued that the sailing boat is similarly limited by virtue of its inability to traverse a groyne or harbour wall, the SEV must see this shortcoming as a definite restriction in its potential utilisation. From the sea, it must either tie up at a jetty or find a way through a slipway in the sea-wall where beaching in the normal manner is impractical. From the land, the SEV can gyrate around a field but will seldom find either hedgerow it can cross or a gateway large enough for it to pass through. Cushion height is of course governed by surface loading and available power, but a point of instability is reached at a certain height.

Therefore it can be appreciated that the trend of thought which we shall call the straight-line conception (i.e. travel from A to B in the shortest possible distance) of operation which applies in normal air travel is not applicable to the existing SEV regardless of its present configuration and performance.

An interesting possibility currently under consideration is the SE-assisted gyrocopter or, more correctly, the gyro-assisted SEV. In this projected device is envisaged a marriage between the SEV and the autogyro. The rotors remain free-running under conditions of travel on the air cushion. When an

THE SURFACE EFFECT VEHICLE FOR THE PRIVATE OWNER . . .

obstruction has to be crossed such as a wall, fence or breakwater, a clutch is engaged which feeds power to the rotor. The rotor thus generates lift sufficient to overcome the obstacle.

This method of operation is the same as was successfully used in the so-called "jump start" Cierva autogyros of the 'thirties. Because forward motion would be derived by a method normal to the control of the machine as an SEV, the rotor would purely be used for lift relying on the momentum of the machine for forward "flight". Thus would be precluded the necessity for providing a tilting rotor head although it might be established as a desirable addition to rely on the rotor to some extent to provide some directional thrust as well as lift for practical use in conditions other than calm air.

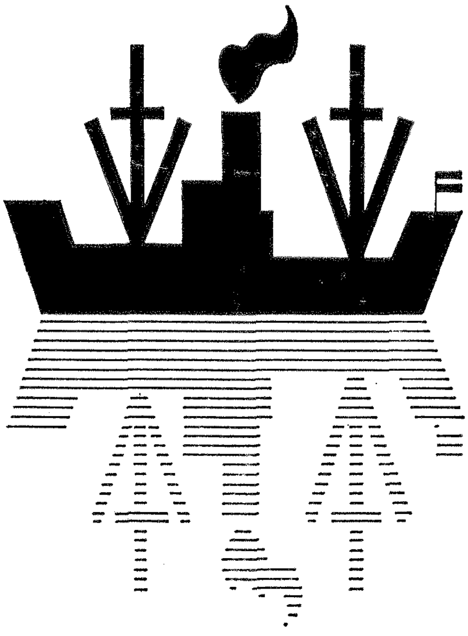
The main advantage of this system would seem to lie in the fact the the rotors, operating in the ground effect of the rotor disc, would require less power to lift the machine, say, 10 ft., than to sustain rotor-suspended flight in excess of that height.

It remains to be seen whether or not this device is economically sound since it is virtually two different machines coupled into one. It is, however, a solution to the play-pen problem and one method of crossing surface obstructions in a machine whose normal operating altitude can be measured with a dipstick.

From all this, then, can we see a future for the one- or two-place "private owner" SEV? Will our seaside resorts offer the SEV in place of the motor-boat and "pedalo"? The answer could quite easily be "yes". A number of firms have produced and tested small SEVs with this in mind. However, one thing is abundantly clear and this is that the SEV, being neither flying machine nor boat yet produced by aircraft companies and shipyards, has much to offer as a means of personal transport and sport.

This is assuredly so on land, but for the small water-borne SEV it seems probable that a combination of hydroplane, cushion-assisted, will be the most economic answer to the problems confronting the designer. The reason here is two-fold. The craft remains a boat when without cushion and it can therefore be operated as an ordinary boat when necessary, and, secondly, the results of experimental work with an air-lubricated hydroplane appear encouraging.

It will possibly fall to the wealth of talent and experimental initiative of the oft-maligned "back-yard mechanic" to develop the smaller SEV. As has often been the case, the "small man" armed with an enquiring mind and some knowledge and who is unfettered by industrial limiting directives, may well be responsible for quite startling strides in the evolution of the personal SEV.



HYDROFOILS TO THE RESCUE IN THE CASPIAN

THE Soviet passenger fleet operating on the Caspian Sea has found itself faced with a crisis. Under the current Seven-Year Plan it is expected to increase the number of passengers carried in its ships by 51%, as compared with 1958, by 1965, but in actual fact the number carried is falling — it fell from 278,300, in 1956, to 266,600 in 1960 — and to make matters worse, its services are being run at a loss. The problem is to be solved by the introduction of hydrofoil vessels, and full confidence is felt, on the basis of experience on the river Volga, that this will provide a satisfactory solution. Such, at least, is the opinion expressed in an article in the March number of "Morskoy Flot", monthly organ of the Soviet Ministry of Merchantile Marine, by N. Kudryavtsev and V. Yusin, head and senior engineer, respectively of the economic and operational department of the Krasnoye Sormovo shipyard, at Gorki, on the river Volga, the production centre for hydrofoil vessels in the USSR.

Recapitulating successful experience on the river Volga, the authors recall that the first trial service by hydrofoil was started between Gorki and Kazan on August 25th, 1957, with the Raketa, carrying 66 passengers. This proved so very popular that it was decided to go ahead forthwith in the further development of hydrofoil services on the Volga, not waiting for experience to be acquired in their operation, nor for the provision of facilities for servicing and repair. Several more vessels of the Raketa type were put in service in 1960, and the coefficient of utilisation of space aboard them — which, in the case of the original Raketa had been rising steadily, and was to reach the high figure of 0.96 in 1961 — proved to be between 0.82 and 0.86, the cost of transport per passenger averaging only 1 kopek per kilometre (about 1.6 kopeks per mile). Encouraged by this initial success, the Soviet authorities went ahead still further last year (1961), adding further Raketa-type vessels to their Volga fleet and supplementing these with a larger type, the Meteor, carrying 118 passengers. Longer distance services were introduced, and the cost of transport per passenger was reduced. A still larger type, the Sputnik, carrying 300 passengers at 40 knots, was tried out and will be put in service this year, and it is intended to continue this process of steady expansion right up to the end of the period covered by the current Seven-Year Plan (1965), the present type of Sputnik being succeeded by one powered with gas turbines, giving an increased speed of 55 knots.

Simultaneously with the foregoing, there has been development work, started last year (1961), in the introduction of hydrofoil vessels for short-distance coastal services at sea, and for pleasure trips at the seaside resorts of the Black Sea, a stiffened Sputnik being used for the former purpose, and a 6-seater cruiser being produced for the latter. This process also is to be continued until 1965; the development of a sea-going coastal freighter on hydrofoils being included in the programme.

It is on the basis of the latter experience that the decision has now been taken to deal drastically with the situation in the Caspian, where there are passenger services between ports in the Russian Federation of Soviet Socialist Republics (RFSSR) and the Soviet Republics of Azerbaidjan, Kazakhstan, and Turkmenia. As stated earlier in this article, these have been losing money, largely because they are being used less and less.

Analysing the Caspian situation, the authors attribute the growing unpopularity of the passenger services there to the fact that they are run with a mixed bag of cargo-passenger vessels, mostly of old construction, with low speeds of between 5 and 14 knots, and with a greater proportion of their accommodation devoted to cabins of the "hard" type and to deck seating than is in accordance with present-day demands of the Soviet peoples for comfort. The only ship in service there which may be regarded as complying with modern requirements as regards comfort and speed, is the 16.5-knot M.S. Kirgistan, running on the principal line, between Baku and Krasnovodsk.

Examination of the operational statistics of the various lines running in the Caspian shows that only one of these is at all adequately used, and may be regarded as economic. That is the line, already mentioned here, between Baku and Krasnovodsk, which operates regularly throughout the year, and carries 86.5% of the total number of passengers, the traffic fading somewhat during the winter months, as might be expected, and reaching maximum figures during the summer and autumn. It has all the better ships of the Caspian fleet, and can therefore guarantee a regular, if not always very rapid, service. The other lines, serving the ports of Astrakhan, Makhalachkala, Guriev and Bautino, carry only 13.5% of the total number of passengers between them. This disproportion is reflected, of course, in the figures for the productivity of the fleet, and of labour employed in it: the former is 109 passenger-miles per place per day, as compared with a maximum of 90, and a minimum of only 25, of the other lines, and it is the low figures on the other line, plus, it must be added, the fact that all the ships, with the possible exception of the M.S. Kirgistan, have large crews, numbering between 40 and 55, which accounts for the low average productivity of labour, which is only 175,000 passenger-miles per year per head of the sea-going personnel. The result is that the cost of transport, though it has been steadily reduced during the past 5-year periods, was in 1960 still 3.74 kopeks per passenger-mile, which is very far above what would be economic, and even further above what is being achieved on the Volga — with hydrofoil vessels.

It is for this last reason, in particular, that the authorities have now decided to turn to hydrofoil vessels for their salvation, and in this connection Messrs. Kudryavtsev and Yusin have drawn attention to the increasing importance, in recent years, of short-distance services, for what they describe as "local and suburban" transport, i.e. for transport between industrial centres on the Caspian and the numerous holiday resorts on that sea, and for pleasure cruises from the latter, as well as between the underwater oil workings and the mainland. Such services, in the main, would be required only during the summer months, but statistics show that they are used annually by between 40,000 and 45,000 passengers, and it is certain that these figures would have been substantially greater if the necessary vessels had been available. Experience has shown that, for services such as these, the hydrofoil vessel is ideal, so it is proposed to make a start by the acquisition of a large number of small hydrofoil vessels, of the 6-seater cruiser type, which are to be popularised also for use by yacht clubs and individuals. Such vessels could be produced at Batoum, where the yards are already building hydrofoil vessels to the designs developed by the Krasnoye Sormovo shipyard.

Experience on the Volga suggests, moreover, that the use of hydrofoil vessels on all the existing passenger services in the Caspian would be both practicable and economically

Hydrofoils to the Rescue in the Caspian . . .

desirable. It is recommended, therefore, that vessels of the Sputnik type (carrying 256 passengers in the sea-going variation) should be introduced as soon as possible for the Baku-Krasnovodsk service, and vessels of the Meteor type (118 passengers) for the other services. It must be taken into account, of course, that some allowance must be made for the fact that bad weather might interrupt these services, when run by hydrofoil vessels, but it is estimated that this would account for not more than 5, or at most 10%, of the year. It is estimated that the adoption of this innovation would enable round trips between ports to be made in daylight in between a half and one-third of the time now taken by passenger ships of other types, even including the M.S. Kirgistan, the time of transit being reduced to at most one-third of that now prevalent.

Such substantial reduction of the time of transit — not to mention the improved amenities, since these might be provided for otherwise — would undoubtedly attract far more passengers. The question arises, though, whether these would not be more attracted by air transport, which is undoubtedly faster even than transport by sea-going hydrofoil, and which the Soviet authorities are always ready to develop wherever the demand may exist, making the rates low enough to be within the means of most citizens, and which it is their declared policy to develop in replacement of the railways for long-distance passenger transport, at any rate.

Here the short distances to be covered in the Caspian work in favour of the hydrofoil vessel, for though the actual time of transit is far less by air than by sea, the incidental delays which are inherent, at present, in air transport, rather even things up. The hydrofoil vessel can embark and disembark its passengers in the heart of the towns which it serves, whereas travel between those towns by air entails long trips by road between them and their respective airports. Thus the trip between the centre of Baku and the centre of Krasnovodsk by hydrofoil vessel will take 4 hrs. 30 min., as compared with only 50 min. between their respective airports, but to the latter time must be added 1 hr. 30 min. to 2 hrs. for transit between the towns and their airports, and an hour or so for delays due to registration of passengers, etc.

Basing themselves on Volga statistics, Messrs. Kudryavtsev and Yusin, reckon that a fleet of hydrofoil vessels with an aggregate passenger-carrying capacity of 610 could cope with at least 90% of the traffic for which the existing fleet with a passenger-carrying capacity of 2,538 is required, and that the utilisation factor of their passenger-carrying capacity would be of the order of 0.7. The productivity per place per day would be 243 passenger-miles, and on some lines as much as 300 passenger-miles, with the result that productivity in the Caspian fleet would be 2.2 times greater than that of its best ships and almost 4 times greater than its average at the present time. The labour-productivity per head of the sea-going personnel, increased by the fact that crews would be reduced to an average of only 12 (as compared with 40-55) and that there would be more remote-control, would go up to 894,000 passenger-miles a year, or five times over.

Still further economy would result from the fact that building costs and running costs would both be substantially reduced, and it is estimated that it would thus be possible to reduce transport costs to 1 kopek per passenger-mile, i.e. almost to one-fourth of the existing costs, and on the Baku-Krasnovodsk line to as little as 0.83 kopek per passenger-mile. This would make it possible to reduce the fare charges, and thus to attract even more passengers, while at the same time turning a losing concern into one making substantial profits. These profits would be sufficient, it is estimated, to make it possible to amortise the capital cost of the construction of the new hydrofoil fleet in at most two years, which compares very favourably with the ten years required in the case of the existing, less satisfactory, fleet.

SR.N2 MAKES ITS DEBUT

WESTLAND'S 27-ton SR.N2 — a product of the company's Saunders-Roe division — made its press debut at Cowes, Isle of Wight, on June 17th.

An intensive development programme has been under way since the beginning of the year, and later this summer the craft is likely to be put temporarily into commercial use on a "wet-charter" basis between points along Britain's south coast. Interest in the craft and its successors is growing rapidly and the company is now holding discussions with Danish, Swedish, Indian, Greek and Egyptian transport operators as well as several British organisations, including British United Airways and Southdown.

A demonstration tour of Scandinavia is planned and later this year the craft will be loaned to the Royal Navy for tests.

Preliminary trials have made it clear that the performance of the craft is well in excess of the company's initial expectations. Higher speeds are now quoted and lower operating costs. As was reported in our April issue, the designed top speed of 70 knots was attained by the SR.N2 when operating on only three of its four engines. The normal cruising speed is now given as 80 knots, although in rough seas this will be reduced by 30-40 knots to avoid undue discomfort to passengers.

Typical fares quoted by the company, based on the latest assessment of likely operating costs, could be 8s. single for a stage of five miles, and £1 single for twenty miles.

Design Background

The design has a two-fold purpose — that of proving the fans, engines, transmission and control systems for following generations of Hovercraft and to help explore all the possibilities of commercial air rider operation.

The craft is built around a central cabin measuring 20 ft. by 16 ft. and able to seat between 56 and 76 passengers, depending on layout. A freight version could carry a payload of eight tons.

Power for cushion lift and propulsion is provided by four 815 hp Bristol Siddeley Nimbus free turbines, coupled in pairs and sited in an engine room at the stern. Each pair drives one fan/propeller unit.

Curtain air is generated by two centrifugal fans sited in the lower structure, and emerges through flexible duct extensions beneath the craft. Propulsion is given by two variable-pitch propellers mounted on pylons above the superstructure. Each pylon can be swivelled 30° on either side of its central line to give directional and lateral control.

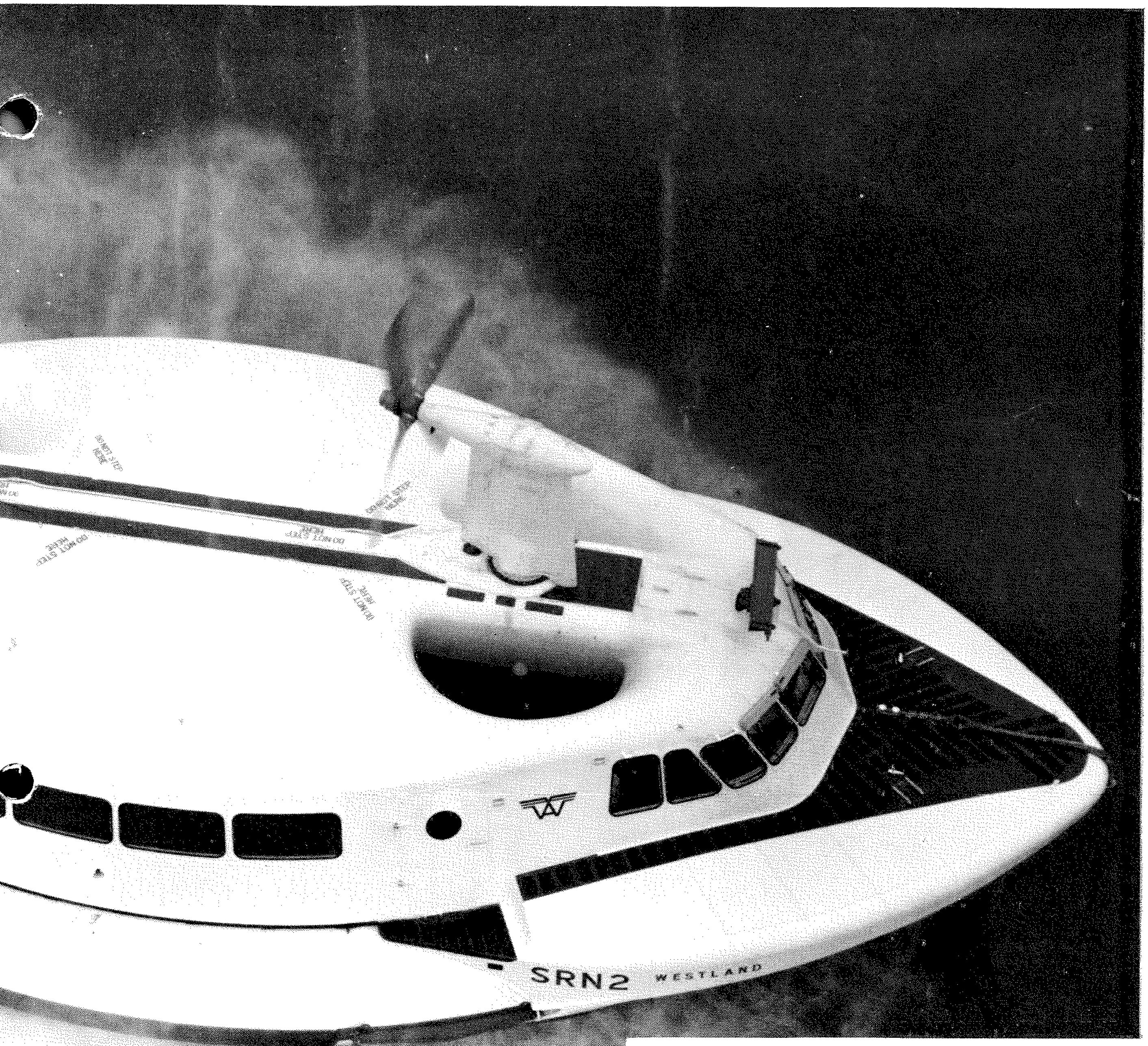
Sperry servo components are used in the steering control system. The craft is controlled from a single column using a normal aircraft-type spectacle to pivot one pylon, while lateral displacement of the column rotates the other. The pylon angle is automatically changed from port to starboard — or vice versa — to allow for the effect of applying reverse thrust when the craft is to be stopped or slowed during a turn.

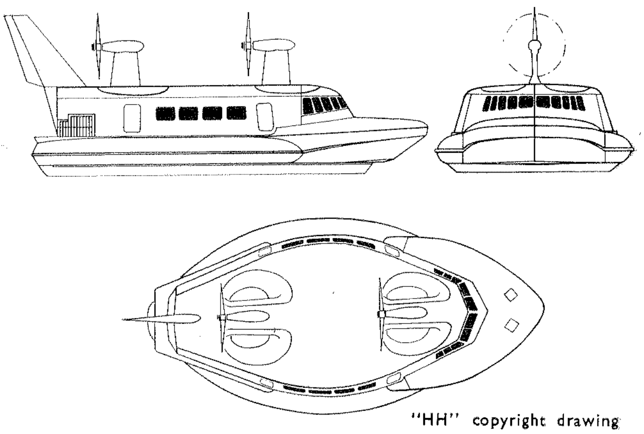
The craft is constructed primarily of high-strength aluminium-clad aluminium alloy suitably protected against the effects of sea water.

A buoyancy chamber is incorporated to enable the craft to float on the water and in an emergency to make its way at speeds up to eight knots as a displacement craft.

Developed Versions

A developed vesion, designated SR.N2, Mk. 2, is in hand. Intended for 120 passengers and weighing 37.5 tons it will offer a more economical service on civil routes as well as having an improved rough water capability.

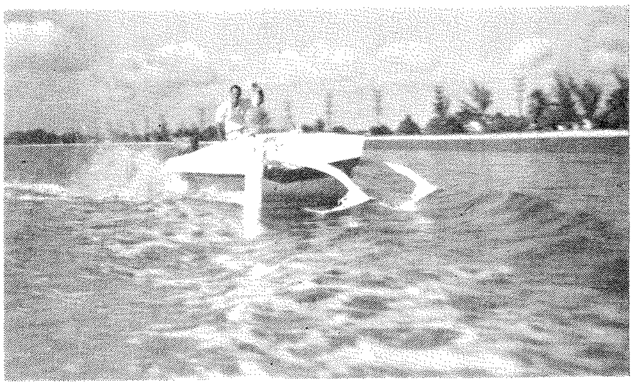



"HH" copyright drawing

Another developed version is the SR.N3 — a "stretched" model with an extra 10 ft. on the hull. It will use the same engines, fans, transmission and control system. The all-up weight will be 40-45 tons and the disposable load 18 tons. As a prototype military Hovercraft, it would be suitable either for use as an assault landing craft carrying 70-150 troops, or for anti-submarine warfare experiments.

The next step at Saunders-Roe will be the development of a 100-150-ton ferry capable of carrying 300 passengers and 26 cars across the English Channel. The cost will be between £500,000 and £1m. Looking still further into the future, Mr. Eric Mensforth, Chairman of Westland Aircraft, revealed the existence of plans for a nuclear-engined craft — the SR.N6. This, he stated, would be of 1,000 to 1,500 tons and be capable of use as an aircraft carrier for three V bombers; as a helicopter carrier or a guided missile base. If a production order were placed it could be produced for £5 million.

IN DEFENCE OF SIMPLICITY IN HYDROFOIL BOAT DESIGN



An early Hydrofin sports conversion off Miami

By
Christopher Hook

NOT ALL DESIGNS are progressive simply because they involve electronics and supersonics where mechanics will do the job. In fact I would submit that if and when it has been conclusively proved that there is a need for supersonics cum electronics cum hydraulics for the manipulation of hydrofoil incidence (which is, after all, only a rudder working in a horizontal plane and has been successfully done by purely mechanical means for a number of years) then it will be time enough to take an interest. That it can be successfully accomplished is a known fact: that this proves anything useful remains to be shown since, after all, would it not be more logical to apply this first to much simpler jobs? For example we could remove the wheel from a ship and arrange for the helmsman to *speak* his instructions into a microphone which would transform . . . etc., etc. But having done this (and clearly it *CAN* be done) it would then be legitimate to ask just what had been proved and for what purpose, seeing that the mechanical method works well and has never been proved to be inadequate to its task. That my comparison is a fair one I hope to show in the development.

I am forced to begin by attacking certain statements that have been made about incidence control: notably in "The Hydrofoil Boat" (I.N.A., March 1958) Peter Crewe writes that the hull water clearance can be kept relatively *low*. Now this, to me, is like writing that the advantage to the giraffe of its long neck is that it can eat grass whereas we know that nature's reason is quite different. For me hydrofoils have no point if they do not enable a vehicle to travel so high as to be practically removed from the troublesome interface of air and water and this ability far outweighs any possible speed advantage that there may be in the idea.

It is true that the incidence control idea commences as a simple skid with all its attendant shortcomings and to this extent it is then understandable that those who have not had the opportunity of following its evolution right up to 1962 still think of it as little more than an articulated Grunberg skid. They are to be excused for not knowing that it incorporates today small wave filtering, wave-height measurement and crash prevention, which latter the supersonic beam cannot copy, as will be shown.

It is then the purpose of this article to bring this information up to date and to show how much can be accomplished by mechanical means, after which it will be better understood why it is necessary to make out a much stronger case for supersonics before the idea can be said to contain much logic.

It is first necessary to know that the most salient advantage of incidence control (as compared to control in altitude by partial foil emergence) is its enormous lateral stability obtained by differential action on the two sides, giving if required enormously increased C_L on the low side combined with enormously decreased C_L (even negative) on the high side. This is very different from the recovery moments that can be obtained from any rigid foil configuration and we take full advantage of this to not only decrease the span over foils but also to lift the hull as high as possible to obtain a maximum wave ignoring ability.

In this department there is no difference in the method of obtaining the signal and all boats which manipulate their angle of incidence will be high fliers and wave ignorers.

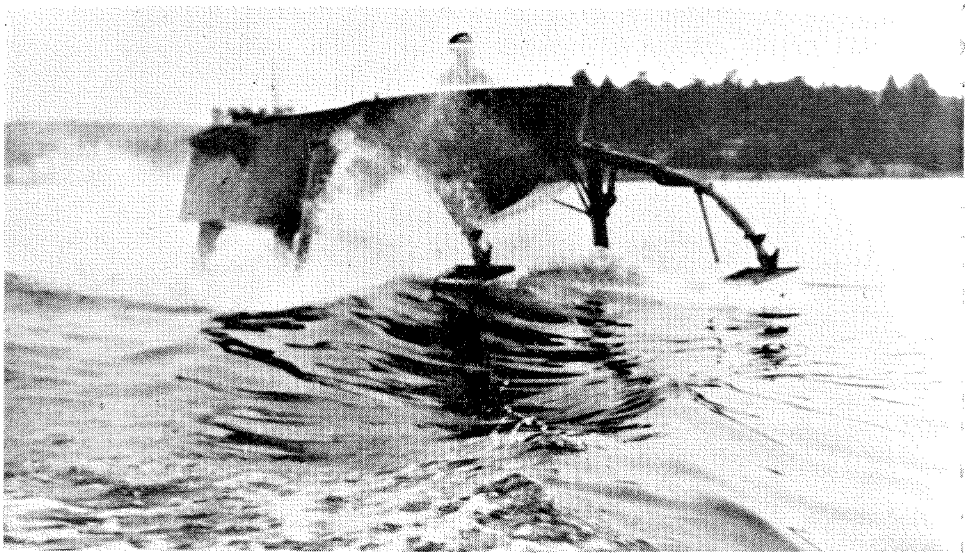
I always remember vividly with what difficulty I envisaged in my mind's eye what I expected would happen when I linked up a surface skid to a sub-surface foil. I trust that I will continue to remember this difficulty since it makes me the more apt to appreciate the difficulty of others when confronted with something much more complex and sophisticated still. I must now introduce the reader to a vertiable wave-system suspension assembly whose working in a confused sea is so hard to envisage as to be almost hopeless (without film) save to those who have "graduated" from something simpler, say, for example, a more primitive feeler skid. I find it impossible to even discuss details of manufacture with outsiders because their minds are always wandering back to that big question mark — how does this work? Why even the sequence of events that we call a wave is complex enough to the human mind for some strange reason and if the reader is not convinced, let him attempt to describe (for example) how a hydrofoil boat can fly down a wave front at wave speed, pointing down hill yet advancing along a *level line*: losing no height and using no power of its own.

The incidence control idea commences with the realisation that tandem hydrofoil systems will remain dangerous so long as a forward set remains subject to the sudden loss of all its top-side lift from air bleed or air entrainment after emergence in severe seas. The resulting drop of the bow causes all foil lifting forces to change sign and slam the craft with violence onto the surface or into a wave. Even if careful pilot training and wave avoidance can hide the danger it cannot eliminate it and this remains a danger which renders the production of a foolproof craft impossible.

There exist two known solutions, one of which accepts the danger as inevitable and seeks only to attenuate the effects. This is the Tietjens mid-hull foil location combined with the small tail area. In this method the crash tends to remain an even-keel drop and the negative trim is avoided. The other method is the Grunberg, and here we have a very lightly loaded forward skid or foil which is made to skim so that even the total loss of top side lift still leaves enough residual under surface lift to maintain trim so long as there is some water surface there on which to maintain it! The defect here is that in the absence of a flat plane of reference or surface the forward contact tends to degenerate into a series of random encounters accompanied by much spray. We have all admired the skill of the acrobat who manages to cycle on one wheel but we do not order this type when we require to sample the delights of the open road, knowing as we do, that one wheel in front and one behind is a practical minimum. To this extent then the tandem system is right: can we not draw from Grunberg's example the lesson that we require (and thereby avoid the dangers of the negative dive) while at the same time conserving the basic soundness of the tandem? Assuredly we can.

Now the experience of the planing hull should have taught us that a skid or a skimming foil is like a wheel with no tyres and quite unsuited to perform the function of a wave arrival signal. Furthermore, if we have drawn the full advantages from incidence control with its dynamic and powerful lateral trimming forces we have designed for very high flight and in so doing we have placed an air cushion under our keel of considerable depth to which our signal arrangements must now be

In Defence of Simplicity in Hydrofoil Boat Design . . .



Hydrofin K2 with twin power struts. The starboard feeler plane has just measured the wave and found it small enough to be taken without incidence change

equated. What interest have we in 3 in. waves if we clear them by 3 feet or more?

Clearly our water clearance has become a fixed constant from above which all heave distances (obtained by incidence change) are now to be measured. Therefore we must build in a corresponding constant to our signal device and we must cause it also to ignore all waves that are smaller than this. For a constant H it now requires a wave of height $H + \Delta H$ to provide a heave signal (which will correspond of course only to the increment ΔH. As the wave increases in size this increment will tend to equal H and then to become even 2H, 3H, etc., when the action will tend to become more and more that of coasting over wave shapes. Will the constant H then cease to have any further usefulness? No, because we know that large waves carry harmonics or superimposed wavelets and in respect of these the H constant will continue to be essential. These effects are in fact obtained by simple means. The advanced foil (provided with a device to cause it to maintain itself with constant α relative to the hull) is caused to fly at the required height over the surface so that it only engages the water (thus calling for an incidence increase) with waves of a height superior to H. Since some contact with the water (at least with the wave crests) must be maintained the feeler must "grope" downwards as a blind man going along a wall will tend to grope sideways to maintain contact, if not with each brick, at least with the general contour of the wall. Such contack must, however, be flexible so that the work done on the arm by the passage of a wave through these parts will remain too small to set off any appreciable incidence change. This effect could be obtained by using a very heavy arm but it is much better obtained by using a light one which is powerfully restrained by shock absorbers or dampers tending to resist the upward movement of the arm. The rate of fall is governed by the need to avoid flying out of a wave front. In more advanced designs the damping effect is made variable at the will of the pilot to suit different headings, speeds of encounter, etc.

Now insomuch as an arm which moves against a powerful resistance is tending towards an arm which does not move at all, the system described is tending towards the Grunberg system wherein a rigid arm transmits only direct trimming moments to the hull. It follows that a powerfully restrained arm will produce two distinct effects (a) Hydrofoil incidence manipulation, and (b) Direct trimming moment transmission and it is of course the latter effect which only an arm *can* transmit. (It is not possible to apply a bending moment to a supersonic pulse). To sum up this part we can therefore consider two extremes as follows:

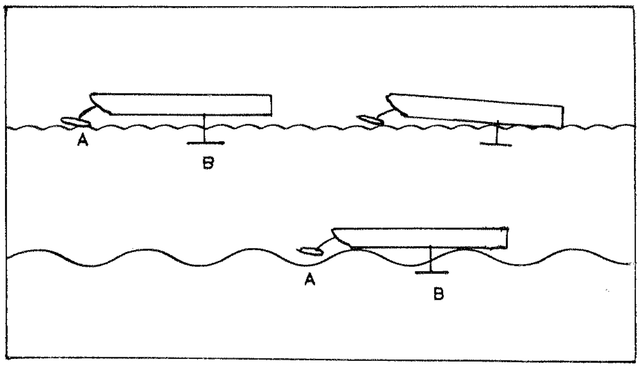
1. A skid forming part of the hull structure (Grunberg).
2. A skid which is freely pivoted (unrestrained) and used to transmit foil incidence changes (early Hydrofin).

They are about equally bad: the first because it must react to waves of even insignificant height which it is the whole object of hydrofoils to iron out and ignore; the second because it will react in the same way and will not even have the safety factor of the crash prevention created by Grunberg. Furthermore the rate of change of angle of attack will be far too fast for efficient flight so that it will become like a pilot hitting his "stick" with a sledge hammer. However by the introduction of the air cushion under the skid combined with the powerful restraining force, we create a cross between the two, having the advantages of both and the drawbacks of neither.

Whereas in road suspension systems we are accustomed to interpose the springs (combined with dampers) between the vehicle and a point in contact with the road, in a hydrofoil boat it is easier to incorporate them in the instrument which triggers off the lifting forces which latter depend on the incidence.

Whereas altitude control obtained by partly emerging foils produces lifting forces which depend on the engaged area at any given time it follows that this must be a wave following method while the inertia effects introduce some phase lag. By contrast the altitude control method based on incidence control is a wave ignorer and can be made to subtract a constant and otherwise react to wave shapes only in the measure decided upon by the designer and modified on the spot by the pilot. Given a suitable predictor effect by reach forward the time lag is removed.

Whereas a signal taken at the strut itself (instead of in advance of the same) would have to transmit a signal of zero time lag in order to reproduce the phase lag of the emerging foil, and since this is obviously both impossible and undesirable for comfort, it follows, that the time lag must be greater and must result in a crash for a wide range of different wave lengths which means that this can only work in almost calm water.



One way to eliminate the negative dive danger is to use a lightly loaded skid at A instead of a foil. This Grunberg system is stabilised by the surface since the whole boat can be considered to revolve about A which is a fixed point on the water. The disadvantage is that in waves there is two point support only when A is on a wave crest. Thus maintenance of steady incidence is not possible.

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It can be argued that the predictor should comprise a telescopic arm if different wave lengths and speeds of encounter are to be dealt with and in theory this is true. However, in practice it is found that an arbitrary length, if well chosen, is perfectly satisfactory and it is possible to so rig a hydrofoil craft with this equipment as to render the sea crash impossible to produce, even with the pilot doing his best to obtain it. It is also possible to rig the craft so as to obtain the crash but the effect is a mild one since we have part of the load thrown onto the forward foil in the feeler unit as well as an increasing angle of attack as the craft falls. The swept wing form has the effect of shedding all the air from the tips and the combined result is that the crash generally does not carry through and the boat recovers after only a slight limp. The rate of change of α (i.e. $\frac{d\alpha}{dt}$) for the arm control method is now a function of the forward foil incidence and this is under pilot adjustment at all times so that exactly the correct rate can be obtained.

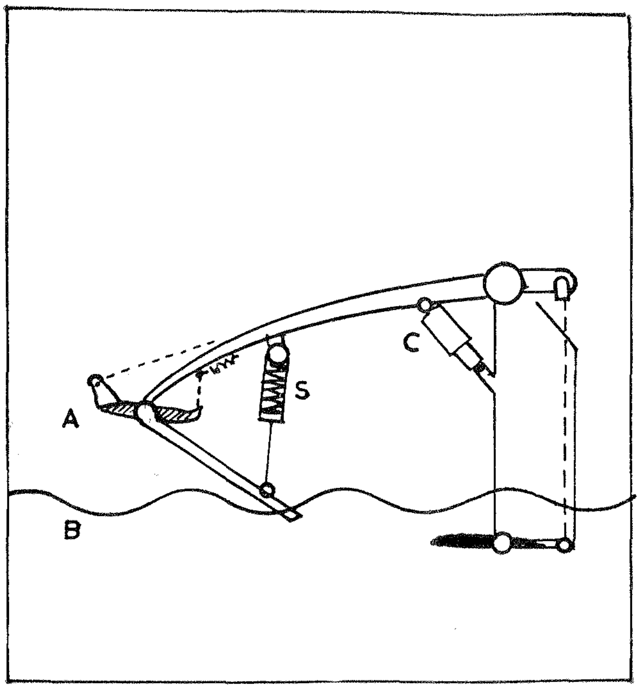
If as some maintain, arms cannot be built to take the strains, then struts cannot be built either, since the measured forces on the latter are very much greater, while the method of attachment to the hull is similar. Retraction of arms is similar to strut retraction and both units lie along the side of the boat. For patrol work this is a *sine qua non* since long range with foils down is impractical on two counts, fuel consumption and weed collection. Weed will collect at slow patrolling speeds but not at foiling speeds.

It is now seen that the arm is not merely a control element to be replaced by a beam, a pressure measurement or any other device just as there is no known way to hold a jib except on a bowsprit. Thus any proposal to replace the feeler-predictor-wave-height-measurer-Constant-subtractor-crash-preventer by a simple signal of zero mechanical strength must be recognised for what it is, namely the replacement of a multi-purpose integral part by a gadget of highly questionable reliability which would explain why the method does not appear to have yet been used for passenger transport. The mechanical method pays insurance premiums at the same rate as for normal speed boats.

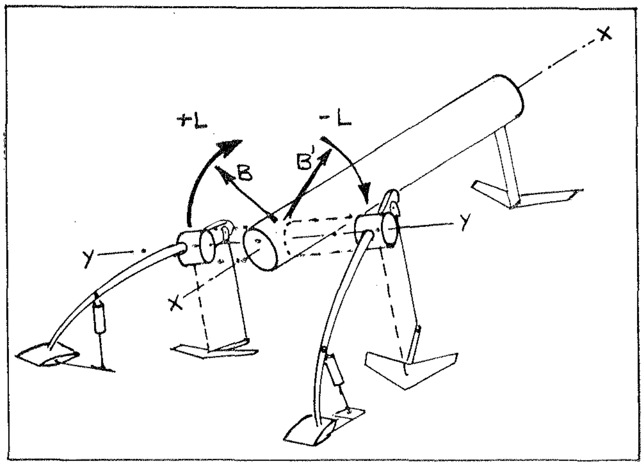
It is highly probable that the official opposition to hydrofoil projects in Britain was due to the failure of early Navy investigators to appreciate the difference between air bleed and cavitation. The accounts given of the constant attempts by filing to modify the foil sections (which could have had relatively little effect on the air bleed that was causing the instability) seems to prove that cavitation alone was suspected. From there to conclude that the problems had no solution likely to be attained by any private development was a fairly easy step. It so happened that my early Hydrofins developed the same air bleed problems but that I was fortunate in spotting it under conditions which proved that no cavitation was present. From then on the cure was not particularly difficult.

Documents S 96 to 98 in the Library of the RAS are photos of the Burney Hydrovane Seaplane built by the British & Colonial Aeroplane works at Filton in 1912 and are of great interest today. The designer offers a complex mass of underwater spars and cables and was quite obviously oblivious of the effects of air bleed. Yet this failure was also still being pointed out in 1949 as clear proof that no hydrofoil project could be expected to work: had it not been tried?

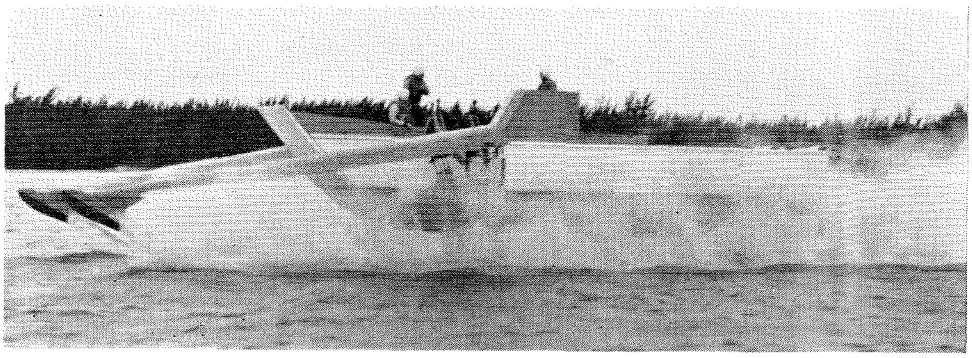
I tend to the view that it has been the absence of any interchange of information which has been at the root of all these troubles. Let us hope that *Hovering Craft & Hydrofoil* will now change all that.



Feeler plane A only lifts to a wave of height AB or over. All smaller waves are absorbed by the heel H and the spring S which is weak compared to the shock absorber C, and it is this restraining force which causes the plane A to also work as a preventer of negative dive, since on dropping it causes some load to be thrown onto the arm.



Incidence control on the front foils provides powerful lateral stability which permits a high line of flight essential on the sea. The reason is that on heeling to starboard two moments tend to cause recovery, $+L \times B$ and $-L \times B^1$. For clarity in this drawing the struts are shown as dotted lines only.



The U.S. Navy's high speed landing craft. U.S. Navy photo.

THE ARCOPTER GEM PROJECT

by

William R. Bertelsen

THE OBJECT OF research by the author has been to produce a high speed personal vehicle for four passengers which will negotiate unprepared terrain, open water, ice, snow, desert sand, dry river beds, rapids and roads under all conditions of weather the year round.

Before the phenomenon of ground effect was appreciated my work centred on a vertical take-off aircraft as the obvious answer to the problem of a truly amphibious or omnivagant vehicle.

The VTOL aircraft or "Arcopter" was to be a four passenger machine of deflected slipstream type (Fig. 1). It had an excellent ground effect which I decided to explore with models and full scale machines which specifically produce and amplify ground effect. The craft would then remain close to the ground and relinquish the ability to fly higher.

Pure plenum chamber machines were tested and found wanting for altitude, controllability and efficiency.

The peripheral jet looked unbeatable from a theoretical standpoint and is best in stability and weight lifting efficiency per horse power at lower clearances.

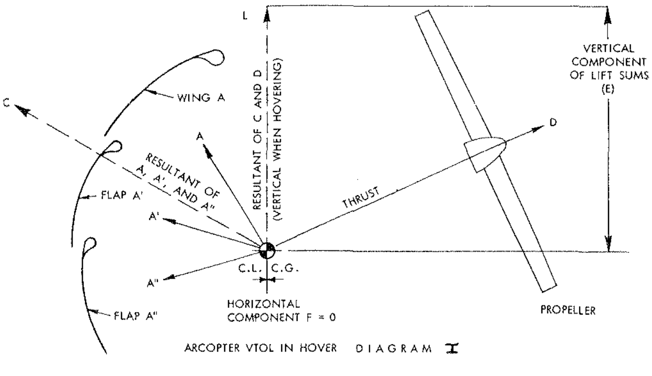
But many models and five full scale peripheral jet machines later following many modifications and extensive field testing I have returned to explore the ram wing Arcopter as a ground effect vehicle.

Problems arise in pure peripheral jet machines which limit utility and practicability in a small vehicle:

1. Immense spray, dust, and mud throwing are ever present at hover and low speed, eroding the fan and spattering occupants and nearby persons and property because of the high jet velocities.
2. It is necessary to achieve at least 20% h/d clearance to negotiate ordinary off the road terrain. Peripheral jet machines are unable to rise this high because of the stability "barrier" at over 10% h/d above which the craft begins wildly destructive cyclic rolling and pitching, and the horse power "barrier" at over 10% h/d where exponential installed power rise seems unnecessary.
3. Insufficient horizontal force is available to a pure peripheral jet from tilting or thrust deflection below 10% h/d to accelerate, propel, turn at high speed, climb grades, resist winds or stop from high speed.

Whereas the ram wing theoretically has no lift at zero speed, the Arcopter can hover. Its hover altitude depends on installed power, disc diameter, wing and flap area, slip stream turning, etc. Power required is reasonable and stability is no problem. At high speeds the ram wing comes into its own and the craft can rise to any height.

Diagram I shows the forces involved in the Arcopter VTOL, a machine capable of hovering at any height above the ground in or out of ground effect.



ARCOPTER VTOL IN HOVER DIAGRAM I

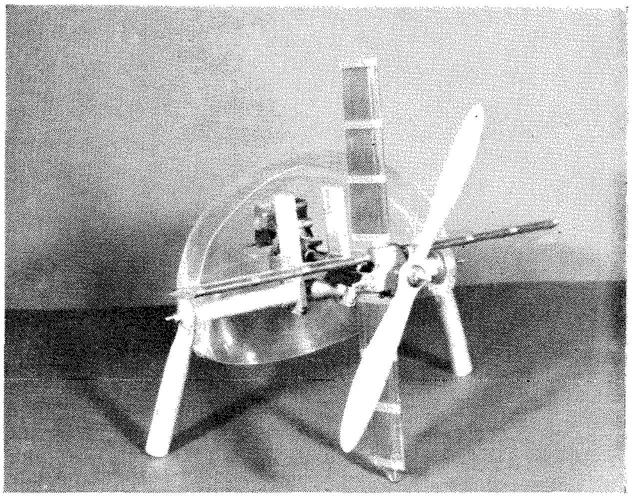


Fig. 1

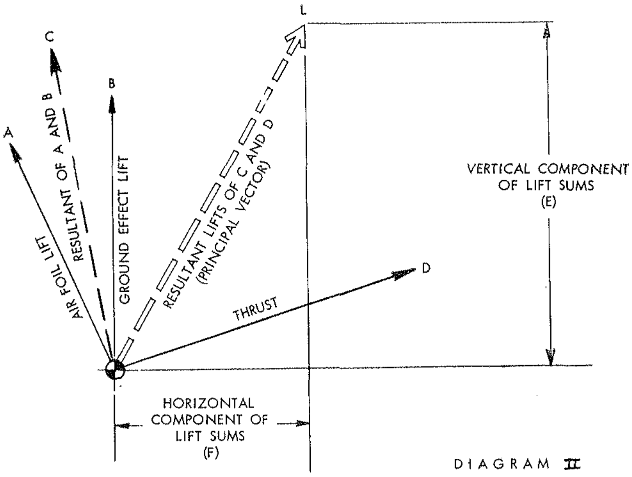


Diagram II shows the forces involved in the Arcopter GEM machine. This craft will not hover in the true sense since the horizontal component of lift sums (F) is forward. It moves forward on becoming airborne but in practice can remain almost stationary at full throttle by turning.

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Fig. 2. Arcopter GEM-2 (Business Week photograph)

The Arcopter GEM (Figs. 2 and 3) turns the slip stream very little compared to 70° for the Arcopter VTOL in hover. The slipstream moves over and under the wing in both machines. At zero speed airfoil lift is produced by the propeller slipstream on top the wing and is increased by forward motion. Pressure is produced in the open chamber under the spanwise arc shaped wing by the slipstream and is sufficient to render the craft weightless at low throttle. As speed rises ram air increases the dynamic pressure and higher and higher altitude is attained with great stability.

There is very little "duct loss" in the Arcopter GEM which has a minimum of wetted surface exposed as compared with a fixed wing aircraft or the internal flow area of the peripheral jet. The air goes straight through without ducting or turning.

Design problems in small machines are in many ways more difficult than in large machines. I am attempting to get lift and thrust from a single engine and a single fan for the sake of economy of first cost and maintenance, reliability and lightness of weight. A large machine logically has separate lift and thrust systems.

The eight foot maximum highway vehicle width restricts the small GEM to a beam of eight feet or less since we will want to operate down roads either on air or on wheels and the Arcopter GEM may be transported on trucks or trailers.

The ram wing GEM offers the following advantages over the peripheral jet GEM:

1. Lower slipstream velocity causes less dust, spray or mud spattering.
2. Higher ground clearance is attainable at high speed with little power and at hover with something less than VTOL power because of the ground effect. Rougher water or terrain can therefore be negotiated with the Arcopter GEM than with the peripheral jet machine at h/d of 20% plus.
3. Good stability is maintained at altitude over 10% h/d.
4. There is no steep rise in horse power requirement starting at about 10% h/d but a more gradual power curve which levels off at VTOL power out of ground effect.
5. There is excellent propulsive force to accelerate and propel the craft against strong wind and up grades of 20% or more. Turning is more effective at higher clearance by greater banking. Braking is achieved by pitching up the nose or by reversible pitch propellor. This is an inherently fast vehicle like an aeroplane with a propulsion oriented thrust axis.
6. Higher l/d efficiency is attainable because of the small wetted area and minimized "duct" losses.
7. Very light structure is possible because of the close coupled, single shell design, allowing higher pay load to gross weight ratio.
8. Simple design cuts costs of construction and maintenance.
9. Control forces in pitch and yaw are powerful, using conventional tail surfaces plus canard surfaces. Because of the low aspect ratio roll control is weak without augmentation.
10. Arcopter GEM is convertible to LTOL, STOL, or VTOL with changes in design parameters only. Folding or detachable wings with CL at vehicle C.G. will increase allowable gross weight or h/d at cruise speed and will improve roll controllability.

We have failed to produce a craft which is navigable on air on conventional roads. It is my observation that roadability in traffic with cross winds and grades on crowned roads will never be achieved by airborne GEMs. The slippery GEMs gravitate to the ditch or go with the wind or with the gusts of other passing vehicles. Roadability on good roads in good weather can be achieved by adding steered and braked wheels to the Arcopter GEM driven by its air propellor or by shaft power to the wheels. With flotation built in this is a composite vehicle for air, land, and water.

Ideally, the road should be built for the GEM in the shape of a graded groove which would provide wind proofing, inherent guidance, and would be a very cheap road to build (Ref. 3).

While the original object of research has not been totally fulfilled, a great deal has been learned by experiment and we have developed a vehicle of exceptional performance on water and reasonably smooth land, ice, snow, etc. I am confident that further refinement of the Arcopter design will result in vehicles completely fulfilling the object of an omnivagant all-weather, all-service, all-terrain craft.

Figure 3 is a design drawing of Arcopter GEM-3 and Table II shows its approximate specifications. This craft will be flying in a few months.

The Arcopter Gem Project...

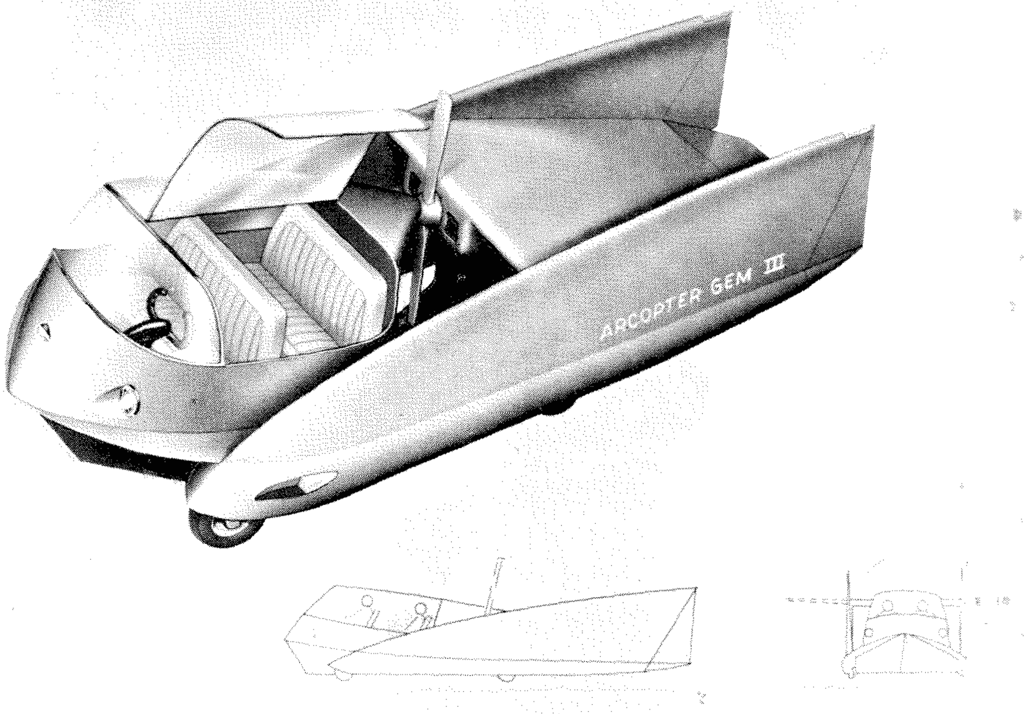

Fig. 3
Arcopter
GEM-3

Table I
ARCOPTER GEM-2 SPECIFICATIONS

Type of Vehicle:
Ram Wing ground effect
General:
Empty weight — 1,050 lbs.
Gross weight — 1,400 lbs. (two passengers)
Maximum useful load — 600 lbs.
Length — 18 ft. 9 in.
Width — 92 in.
Height — Nose — 3 ft. 5½ in.
Tail — 7 ft. 5 in.
Engine:
115 hp Lycoming 0-235
Fuel — 80 octane
Fuel consumption — 7 gal/hrs.
Performance:
Maximum forward speed — 75 mph
Altitude — 2 in. at zero speed
12 in. at top speed
Operating terrain: any unobstructed surface without projections higher that the operating altitude; snow, ice, sand, open water, water and ice, marsh land, rice fields, river, or any type of road.
Construction:
Aircraft alloy steel tubing
Aluminium sheet
Control:
Canard control surfaces (at the nose)
Conventional control surfaces (at the tail)
Flotation:
2,000 lbs. displacement

Table II
ARCOPTER GEM-3 APPROXIMATE SPECIFICATIONS

Type of Vehicle:
Arc shaped ram wing ground effect
General:
Empty weight — 1,800 lbs.
Gross weight — 2,500 lbs. (four passengers)
Maximum useful load — 1,000 lbs.
Length — 24 ft.
Height — to propeller tip — 6 ft. 9 in.
to canopy top — 5 ft. 6 in.
Width — 7 ft. 10 in.
Engine:
150 hp Lycoming 0-320-A2B
Fuel — 80-87 octane
Fuel consumption — 10 gal/hr.
Performance:
Maximum forward speed — 90 mph
Cruise speed — 70 mph
Altitude — 3 in. at zero speed
18 in. at top speed
Operating terrain: any unobstructed surface; snow, sand, open water, ice floe, thick ice, thin ice, marsh land, rice fields, or any type of road.
Grade climbing — 20 to 25% slope (14°)
Construction:
Aircraft alloy steel tubing
Aluminium sheet
Control:
Elevons and rudder for pitch roll and yaw control
Flotation:
3,000 lbs. displacement

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SOME APPLICATIONS OF FIBREGLASS REINFORCED PLASTICS TO THE DESIGN OF HYDROFOIL BOATS AND HOVERING CRAFT

by Norman P. Pascoe
(The Research and Development Co., Farnborough, Hants.)

(Continued from previous issue)

IT IS DIFFICULT, if not impossible, to cover most aspects of this subject within the space available in this series of articles. The reader is, therefore, asked to forgive the author for what must inevitably seem a discordant sequence of topics. The subject matter of this series of papers is taken from the author's manuscript, shortly to be published as a book, entitled "Basic Principles of Hydrofoil Boats", and comprises a number of abstracts.

In this, the concluding article of the present series, emphasis is laid upon fibreglass and resin types and properties. Some information is also included concerning mould types, and it is hoped that the tabulated data contained in the following pages, will provide a convenient summary of what has been mentioned in previous issues. The tables are by no means complete, and many figures are approximate only, but it is, nevertheless, felt that as a means of providing as much information as possible in as few words as possible, these tables may fulfil a worthwhile function.

In view of the current development work on Sonar and Radar Navigation systems for high speed hydrofoil craft, electrical properties of fibreglass materials are included. Clearly, any scanning device requiring weather protection at high speed, should receive a serious design study, and in this respect the fibreglass radome is eminently suitable.

Resins

So far, no mention has been made of resin types and properties, and while this is a subject which can occupy many volumes, it seems worthwhile to summarise a few important facts at this stage.

Briefly then, the designers choice of resin is mainly influenced by strength requirements and anticipated environmental conditions, consistent with ease and economy of manufacture. Table I indicates, in an approximate manner, how these factors vary from one type of resin to another, and serve as a guide to initial thinking on choice of resin. It will be seen that for a set of conflicting requirements (which is usually the case) a compromise is called for in choosing a resin. For example, a highly stressed under-water component for use at high speed demands (a) High Strength, (b) High Moisture Resistance, (c) High Cavitation Erosion Resistance. At a glance, an epoxy resin appears to satisfy these conditions. If now, one is required to make one or two only of these components, cost and complexity of fabrication may prove prohibitive and one would choose perhaps a polyester, at the expense of some structural quality.

TABLE I

Property	Polyester	Modified Polyester	Epoxy	Phenolic	Phenolic Filled	Silicone
Strength	G	F	E	F	P	P
Stiffness	F	F	E	G	P	P
Heat Resistance (Long Exposure)	P	G	F	G	No Data Available	G
Moisture Resistance	F	P	E	G	G	G
Electrical Characteristics	G	Depends on Crazing during Cure	F	P	P	E
Cavitation Erosion Resistance	F	F	G	F	F	P
Ease of Fabrication	E	G	P	G	G	P
Cost	G	F	P	F	F	P

E = EXCELLENT G = GOOD F = FAIR P = POOR

(All materials post-cured for high wet strength retention)

Table II shows some Physical Properties compared for a number of different resin types for a given test laminate. In the double columns, the left hand figure indicates value at Room Temperature and the right hand figure indicates value at 500° F. This latter figure is included for reference only, and is merely intended to show how strength deteriorates at elevated temperatures. (Deterioration of strength with prolonged water immersion has been discussed in the first article of this series.). Great care must be taken in selecting a resin to ensure that all aspects of design requirements have been borne in mind. While an epoxy resin yields higher strength figures than a polyester it is not necessarily as easy to manufacture an epoxy void free laminate as a polyester one, and for prolonged water immersion and use under conditions of cavitation a void free polyester laminate may be superior to a non void free epoxy laminate in spite of the inferior strength of the polyester. The correct choice of materials provides an interesting challenge to the designer's insight and full appreciation of the requirements of the structure, and with due care and skill, exceptionally good laminates may be designed. With fibreglass, an inferior finished product may, by no means, be indicative of inferior material!

TABLE II

Material	Tensile psi	Compr psi	Flexural psi	Flexural Modulus psi x 106		Resin Content %	Specific Gravity	Water Absorp % in 24 hrs.
Polyester	23,850 45,000	12,250 35,000	17,200 50,000	3.2	1.1	38.0	1.81	0.18
Modified Tac Polyester	30,000 36,000	19,500 35,000	32,500 39,800	3.0	2.6	36.8	1.91	3.0
Heat Resistant Phenolic	28,800 34,100	31,100 56,240	54,700 69,700	3.6	3.25	29.5	1.85	0.50
Epoxy with Aromatic Polyamine	48,000	42,000	11,700 75,000	4.2	1.3	28.0	1.90	0.15
Silicone Resin	31,100 53,900	6,280 23,800 at 375°F	15,500 41,000	2.6	2.1	40.0	1.93	0.10

Relationships between Glass reinforcements, Moulding Methods and Physical Properties

In general, laminate thickness decreases and glass content percentage increases with increasing moulding pressure. Strength properties of the finished laminate improve linearly with increase of glass content.

Laminate thicknesses, weight and strength properties for a particular type of glass reinforcement will vary with differences in manufacturing techniques. This variation can, and should, be reduced by quality control, and manufacturers experienced in working with a particular type of reinforcement, resin and moulding method can consistently produce good quality laminate.

Table III indicates the relationship between types of reinforcement, moulding methods and physical and mechanical properties. The figures given are approximate only and should be verified by laboratory tests where precise values are required. A number of other minor factors give rise to variations in laminate properties. Among these are humidity, shop temperature, storage conditions, handling of basic materials and so on.

A brief description of the glass reinforcements tabulated is included here for completeness.

Chopped strand mat (C.S.M.)—This consists of chopped strands of fibreglass orientated in random fashion to form a sheet or layer. These strands are usually bonded or held together by a high solubility resin binder compatible with moulding resin.

Unidirectional Cloth.—This consists of a relatively large number of closely packed heavy filaments in the warp direction and a smaller number of light filaments in the weft direction.

Woven rovings.—This consists of plane bundles or rovings of filaments woven into a plain square pattern. The filaments are spun or twisted.

Unidirectional rovings.—These consist of straight bundles of continuous strands resembling loose untwisted rope and form one of the most economical forms of fibreglass reinforcements for boat construction.

TABLE III

Moulding Technique	Glass Reinforcement	Glass Content (%)	Moulded Thickness (in.)	Tensile PSI × 10^3	Flexural PSI × 10^3	Compressive PSI × 10^3	Shear PSI × 10^3
Open Lay-up	CSM. 2oz	25	.060	11—12	20—21	16.5—17.5	9.5—10.5
	SQ.WV Fabric	35	.060	23	41	33	20
	U/Dir Cloth	46	.020	24	31	19	12
	Wor. Rovings	50	.040	33	27	17	13
	U/Dir Rovings	70	*	*	155	*	*
Vacuum Bag	CSM. 2oz	40	.040	18—19	26.5—27.5	22—23	12.5—13.5
	SQ.WV Fabric	60	.040	35	50	45	25
	U/Dir Cloth	50	.015	37	35	22	12
	Wor. Rovings	65	.025	*	*	*	*
	U/Dir Rovings	70	*	*	155—160	*	*
Matched Metal	CSM. 2oz	50	.027	22—23	32—33	23.5—24.5	13.5—14.5
	SQ.WV Fabric	75	.028	*	*	*	*
	U/Dir Cloth	68	.010	*	*	*	*
	Wor. Rovings	65	.020	*	*	*	*
	U/Dir Rovings	*	*	*	*	*	*

* Denotes data not currently available.

SOME APPLICATIONS OF FIBREGLASS REINFORCED PLASTICS TO THE DESIGN OF HYDROFOIL BOATS AND HOVERING CRAFT . . .

TABLE IV

Requirement	Mould Type Plaster	Wood	Metal	Plastic	Matched Metal
No. Off Required	1 — 4	12 — 20	75 — 100	100 — 150	10,000 Up
Surface Finish	Poor	Fair	Good	V. Good	Excellent
Sharp Edges	No	No	No	No	Yes
Taper (ins.)	1	½	⅜	¼	⅛
Radii (ins.)	1	½	⅜	⅜	¼
Release Characteristics	Fair	Fair	Good	V. Good	Excellent
Accuracy (± ins.)	0.2	0.06	0.09	0.03	0.01
Cost of Typical Mould	£12	£18	£15	£12 10s	£1,000
Production Rate/Shift	1 off	1 off	3 off	2 off	50 off

Choice of Moulds

In many cases there is no need to produce elaborate moulds. This is particularly true where surface finish and dimensional accuracy are not critical. As indicated in Table III, three main types of moulding processes are available (excluding of course extrusion) injection, etc., etc.). For the components with which we are mainly concerned in boat design our moulding techniques will fall into one or more of the three main groups shown in Table III.

The selection of the most suitable material for a mould will depend on many factors. These include the type of moulding to be fabricated, the degree of finish required, the moulding process, the dimensional accuracy required, the rate of production, and so on. Where more than one material satisfies these conditions, the ultimate choice will be influenced by economic considerations. Table IV summarises, in general terms, the more important qualities of various mould materials. As it is impossible at this stage to discuss each material in detail, it is hoped that the information given in Table IV, combined with the knowledge that the reader already has, will prove sufficient in making a correct selection of mould type.

The following brief considerations of mould design can be taken to apply generally:

(a) avoid large flat areas where possible;

(b) establish the exact length of production run required before selecting mould type;

(c) avoid rapid changes in thickness on the mould because they may lead to dimensional instability;

(d) always design so that assembly and finishing is reduced to a minimum;

(e) to increase stiffness endeavour to increase moment of inertia rather than section thickness. This can be achieved by added curvature, the use of top hat sections, or composite laminates with low density cores;

(f) allow generous tapers wherever possible. Allow also generous corner radii;

(g) bear in mind that when a fibreglass component is designed to replace a metal one, it is frequently unnecessary to reproduce in the laminate the mechanical characteristics of the metal because being an inexpensive material metal is often over designed;

(h) use pigmented resins rather than plain resins which will subsequently have to be painted, thus helping to offset high material cost.

Table V indicates comparisons between physical constants for a number of commonly used boat building materials.

Property	Fibreglass	Marine Ply	Aluminium	Steel
Specific Gravity	1.70	0.80	2.70	7.8
Tensile Strength psi × 10^3	50	8.4	74.2	180
Compressive Strength psi × 10^3	35	4.2	74.2	180
Shear Strength psi × 10^3	22	1.7	49.5	134
Poisson's Ratio	.6	—	.33	.287

SUMMARY

It is evident from the foregoing that in order to justify the use of fibreglass reinforced plastics in Hovering Craft or Hydrofoil Boat Design, the designer has to make a very thorough investigation of all anticipated requirements. If his popularity within his company is to remain high he must further concern himself with (or engage others to concern themselves with) the economical advantages or disadvantages of the material. We therefore complete our summary under three main headings, as follows:

Structural considerations

A fibreglass laminate may have a higher strength to weight ratio than a metal or wooden laminate but may need to be of greater thickness to achieve this. In certain conditions, i.e. hydrodynamic shaping, etc., this may not be practicable, in which case there is no justification for using the material. In cases where thickness, profile, etc., are not critical, fibreglass can easily have an overwhelming advantage over conventional materials.

Fabrication considerations

If structural requirements can be met using fibreglass, then it is almost always possible to manufacture a fibreglass component more quickly and more easily than a metal or wooden one. Quite often the fibreglass component is cheaper to manufacture than its conventional counterpart.

Environmental considerations

The only factor which limits the use of fibreglass in Marine Design with regard to environmental conditions is its inferior resistance to cavitation erosion. As mentioned in an earlier article this may not be critical in a super cavitating foil design.

It is the express wish of the author that these articles shall stimulate interest in this field of Marine Design, and any criticism from readers will be greatly valued.

tomorrow's transport TODAY

WESTLAND SR.N 2 the World's biggest and first practical hovercraft signals a new transport era. The 68-seat SR.N2—or its immediate development, the 130-seat Mark 2 version—will provide the prototype for the super-ferry of the future. Westland's plans envisage hovercraft between 100 and 200 tons, capable of carrying 200 passengers plus 32 cars—and more! No costly dock installations will be necessary and the hovercraft will be able to operate irrespective of the tides, at a very low cost. Its utilization can be increased by its extremely high speed and its ability to load or embark very rapidly on dry land. SR.N2 will begin experimental passenger services this summer.

WESTLAND the first name in HOVERCRAFT

WESTLAND AIRCRAFT LIMITED YEOVIL ENGLAND

Incorporating: Saunders-Roe Division Fairey Aviation Division Bristol Helicopter Division

BIBLIOGRAPHY OF REFERENCES TO HOVERCRAFT AND GROUND EFFECT MACHINES

Bell Helicopter Company Bell's new approach
Hovering Craft & Hydrofoil, 1, 1 (October 1961) 14-16.
This article gives an outline of the aerodynamics involved in the design of the stabiliser controlled flow and the controlled flow configuration stabilised by two concentric discharges. Description and details are given of four types, viz. The Leap (Land effect air pickup), Command car, one and one-half ton utility truck, and Assault Troop Carrier.

Bliss, D. S. The tracked hovercraft for inter-city transport.
Hovering Craft & Hydrofoil, 1, 4 (January 1962) 18-25.
Hovering Craft & Hydrofoil, 1, 5 & 6 (February/March 1962) 8-13.
New Scientist, 12, 263 (November 30th, 1961) 541-544.
This is a specialised application of the hovercraft principle. Research is under the direction of Mr. C. S. Cockerell, Director of Hovercraft Development Ltd. Comprehensive article discusses the possibilities of such a vehicle and the technical advantages and disadvantages. Comparison is made with trains, cars, helicopters and aeroplanes.

Cansdale, G. W. Hovercraft and the Thames
P.L.A. Monthly, 437 (March 1962) 74-77.
P.L.A. Monthly, 438 (April 1962) 98.
Author opens with the arrival of the Saunders-Roe SRN-1 arriving in London in May, 1960, and goes on to trace the development and future possibilities of hovercraft. Some mention is made of the functions of the Hovercraft Policy Committee. Further information is given in a letter from F. D. Storrs of Baily-Watson & Associates.

Copeland, E. They ride on air
Ordnance, 46, 249 (November/December 1961) 457-460.
Author states there are five types of air cushion vehicles under development, two of which have not been successfully demonstrated. He then discusses the various types and their applications and gives some details of dimension, speeds, load capacity, price, etc.

Design & Components in Engineering Hovercraft
Design & Components in Engineering (January 1962) 22-26.
This is a general informative article covering principles, configuration, machinery and development. Drawings and photographs are included, together with graphs of fan performance.

Dibartola, P. E. & Bulinski, R. J.
Home is anywhere for GETOL airplane
S.A.E. Journal, 70, 1 (January 1962) 76-78.
Air cushion supports plane on take-off roll, so no prepared field is necessary.

Engineer Sidewall hovercraft
Engineer, 211, 5501 (June 30th, 1961) 1093.
Article discusses the possibility of saving power and improving stability by use of a solid boundary along the direction of travel of the craft. The disadvantage is additional skin friction, but this can be reduced by increasing speed so that wave making drag is at the minimum.

Engineering Crossing the channel without a tunnel
Engineering, 189, 4844 (February 5th, 1960) 188.
This is an Automobile Review, but discusses the possibility of using hovercraft as an alternative to the tunnel, ship or aircraft for transporting cars across the channel.

Engineering Rapid application of hovercraft
Engineering, 189, 4900 (March 18th, 1960) 373.
In the "Impact" section, and discusses the possible uses of hovercraft as the result of the successful building of the Saunders-Roe SRN-1.

Flight International Soon to hover
Flight International, 81, 2760 (February 1st, 1962) 155.
Drawings of the VA-3, now under construction by Vickers-Armstrongs. To operate over 2 ft. waves whilst carrying 24 passengers. Also artist's impression of XHS-4 Hydroskimmer being built by Bell Aerosystems under U.S. Navy Bureau of Ships contract.

Flight International SRN-2—Stepping stone to the economical hovercraft
Flight International, 81, 2768 (March 29th, 1962), 475-482.
This is a comprehensive article and continues from the analysis of SRN-1 published on 11.9.59. Graphs are given for fuel-consumption, cushion-pressure, speed, payload, cost and design parameters, etc. Photographs, general arrangement drawings and pictorial cut-away views are included. The general design details are given very fully and an extensive comparison is made with the earlier SRN-1.

Flight International Russia and the ground effect vehicle
Flight International, 81, 2769 (April 5th, 1962) 513.
Discusses an article in "Pravda" in which C. E. Tsiolkovsty is claimed the "father" of the air cushion vehicle. Several types are thought to be under development in U.S.S.R., some comparable with "Western" productions.

Flight International VA-3 on view
Flight International, 81, 2771 (April 19th, 1962) 598.
Gives brief details of this craft which is to be put into ferry service between Rhyl and Hoylake in July 1962.

Greenwood, S. W. The challenge of the tunnel
The Aeroplane, 102, 2624 (February 1st, 1962) 123.
Discusses this project and considers the hovercraft as a possible alternative.

Haynes, A. L. & Jay, D. J. Sliding on air
Ford Motor Co., America.
(S.A.E. paper No. 133B).

Helicopter & V.T.O. World Where the helicopter and hovercraft meet
Helicopter & V.T.O. World. Inter-monthly news sheet (February 1962) 36.
Article describes the hovercraft as a carrier for helicopters with particular reference to the Drone Anti-submarine Helicopter (DASH).

Helicopter & V.T.O. World Annual hovercraft review
Helicopter & V.T.O. World, 5, 2 (March 1962).
This special issue is devoted almost entirely to the annual review of hovercraft progress.

Helicopter & VTO World Progress at South Marston
Helicopter and VTO World, 4, 6 (November/December 1961) 240.
Discusses past work and possible future developments of Vickers-Armstrongs in this field.

Hovering Craft & Hydrofoil Vickers hovercraft programme announced
Hovering Craft & Hydrofoil, 1, 1 (October 1961) 17-18.
A description is given of the VA-2, VA-3, VA-4 and future projects. Outline diagrams are included.

Hovering Craft & Hydrofoil The Westland Aircraft SRN-2
Hovering Craft & Hydrofoil, 1, 1 (October 1961) 23.
Data sheet.

Hovering Craft & Hydrofoil
Hovercraft are the transport of the future
Hovering Craft & Hydrofoil, 1, 1 (October 1961) 40-41.
This is a resumé of an article in "Pravda" (16.7.61) of the Russian attitude towards hovercraft. It gives past progress and future concept of the type and uses for such vehicles.

Hovering Craft & Hydrofoil Hughes hydrostreak water-wall concept
Hovering Craft & Hydrofoil, 1, 1 (October 1961) 42.
In this system the vehicle is supported on air which is contained by a wall of water, forming, in effect a "bubble". Water is taken in through scoops and pumped to a peripheral manifold. It is claimed that due to the much greater density of water greater efficiency is obtained.

Hovering Craft & Hydrofoil Russian air-rider
Hovering Craft & Hydrofoil, 1, 3 News Supp. (December 1961) 3.

Hovering Craft & Hydrofoil
Rolls-powered Cushioncraft
Hovering Craft & Hydrofoil, 1, 1 (October 1961) 44.
This article gives a general description of the cushioncraft, produced by Britten-Norman, Bembridge, Isle-of-Wight. Dimensions, performance and other technical data are also included.

Hovering Craft & Hydrofoil Aeromobilia

Hovering Craft & Hydrofoil, 1, 3 News Supp. (December 1961) 9-11.

Aeromobile 200 is driven by a 178 hp 6 cy-air cooled and fuel consumption is 9 gals. 80-octane fuel/hr. The designer and constructor, Dr. W. R. Bertelsen of Neponset, Illinois, has considerable experience of small craft and considers if mass-produced cost would be about two-thirds that of a family car.

Hovering Craft & Hydrofoil ACV from Sweden

Hovering Craft & Hydrofoil, 1, 4 (January 1962) 30.

This article gives general details and dimensions of the Saab 401 which has been ordered by the Swedish Navy from the Swedish Saab Aircraft Co. It is 6.96 meters long, 3.10 meters wide and has a speed of 50 knots.

International Science & Technology High hopes for hovercraft

International Science & Technology, No. 1 (January 1962) 72-73.

This is under the section "World deadlines" and discusses the "second generation" of ground effect machines. These include the SRN-2, and VA-3. General technical information is given, together with two illustrations.

Jones, R. S. Over the hump

Hovering Craft & Hydrofoil, 1, 4 (January 1962) 8-10.

Machine Design An eleven ton payload

Machine Design, 34, 2 (January 18th, 1962) 31.

This LOTS (Logistics Over the Shore) air-cushion vehicle is designed for economical off loading of cargo vessels. Range 300 miles, accelerating to 80 mph in 22 seconds. Produced by Aeronautronic Division of Ford Motor Co. for U.S. Army Transportation Research Command, Ft. Eustis, Va. (Picture only).

Maddock, L. S. Design approach to ground effect machines

Engineering Materials & Design, 5, 1 January 1962) 12-20.

The author surveys the principle existing machines and discusses some of the problems associated with various design configurations. He also comments on possible future trends and applications.

Mechanical Engineering GEM

Mechanical Engineering, 84, 2 (February 1962) 54.

Donald W. Douglas, Jr., president of Douglas Aircraft Co., suggests a vehicle 250 ft. long, 100 ft. wide and travelling at 100 knots max. be part of U.S. Navy by the 1970s. This article is condensed from a speech delivered at the National Naval Aviation Institute—Institute of Aerospace Sciences meeting in August, 1961.

National Research Associates Custom-styled aquaGEM

Hovering Craft & Hydrofoil, 1, 1 (October 1961) 10-11.

This organisation produced the first man-carrying machine for the U.S. Government, and the first gas-turbine powered U.S. machine. One man vehicles have been designed and others up to 50 tons. Speeds of up to 50 mph can be attained for some craft and the power used includes gas-turbines and small 2-stroke engines. A specification of the AquaGEM is given.

Pascoe, N. P. Some applications of fibreglass reinforced plastic to the design of hydrofoil boats and hovering craft

Hovering Craft & Hydrofoil, 1, 5 & 6 (February/March 1962 14-16.

Author gives a brief account of some aspects of the use of fibreglass reinforced plastics in hydrofoil boat and hovering craft design.

Poisson-Quinton, P. & Beveret, A. Principles and applications of ground-effect machines (in French)

Ass. Tech. Marik (1960 Meeting).

Contains a brief review of possible types and explains the theoretical basis of air-cushion craft using the annular-jet principle. This is compared with results of experimental work and conclusions are drawn regarding the influence of principle parameters. Operating problems are considered and experience with SRN-1 reviewed. Paper is illustrated by curves, sketches and diagrams (and includes a comprehensive bibliography).

Reed's Marine Equipment News New transportation medium

Reed's Marine Equipment News, 6, 2 (February 1962) 25.

Photograph and details of the CC-2 Cushioncraft built by Britten-Norman Ltd., Bembridge Airport, Isle-of-Wight.

Ship & Boat Builder Some highlights from the 1962 International Boat Show

Ship & Boat Builder, 15, 2 (February 1962) 94.

In paragraph headed New Hovercraft details are given of a prototype 4-seater pleasure craft by Saro (Anglesey) Ltd. 19 ft. 2 ins. long, 7 ft. beam and 3 ft. draught. A Cleaton 80 c.c. engine developing 3 hp maintained air cushion. A Johnson 18 hp outboard motor gave a speed of 12/14 mph.

Shipbuilder & Marine Engine Builder Ship or Aircraft

Shipbuilder & Marine Engine Builder, 69, 653 (April 1962) 186.

British United Airways are to operate a passenger service between Cheshire and North Wales. Preliminary testing of Vickers-Armstrongs VA-3 Hovercraft is being undertaken under the auspices of the Air Transport Licencing Board and the Ministry of Aviation. The Chamber of Shipping state they are keeping an open mind on the question.

Shipbuilding & Shipping Record Hovercraft to be tried soon

Shipbuilding & Shipping Record, 93, 17 (April 23rd, 1962) 551.

Editorial gives a brief description of the SRN-1 which is to undergo preliminary trials in June. An Artist's impression of a 40,000 ton American version is included.

Shipbuilding & Shipping Record British-built experimental hovercraft

Shipbuilding & Shipping Record, 93, 22 (May 28th, 1959) 698.

Artist's impression of SRN-1 produced by Saunders-Roe under contract from N.R.D.C.

Shipbuilding & Shipping Record The Hovercraft flies

Shipbuilding & Shipping Record, 93, 25 (June 18th, 1959) 795.

Announcement that SRN-1 had its first "flight" on June 15th, 1959.

Shipbuilding & Shipping Record Hovercraft & Vickers

Shipbuilding & Shipping Record, 95, 22 (June 2nd, 1960) 730.

Negotiations almost concluded for design and manufacture of two craft. One to be about 4.5 tons, a fast hovercraft launch and the other in the range 15-20 tons for operation as possibly a car and passenger ferry.

Shipbuilding & Shipping Record Twenty-five ton hovercraft

Shipbuilding & Shipping Record, 95, 26 (June 30th, 1960) 848.

Announcement that Hovercraft Development Ltd. has agreed with Westland Aircraft Ltd. (Saunders-Roe Division) to continue collaboration in development of Hovercraft.

Shipbuilding & Shipping Record Hovercraft and Dracone developments

Shipbuilding & Shipping Record, 97, 5 (February 2nd, 1961) 164.

Report of press conference with Sir Wm. Black in connection with publication of the report of accounts of National Research Development Corporation for July 1959-June 1960.

Shipbuilding & Shipping Record The Denny hovercraft

Shipbuilding & Shipping Record, 97, 23 (June 8th, 1961) 747.
Shipbuilding & Shipping Record, 98, 1 (July 6th, 1961) 15-17.

This article gives technical details of the research hovercraft which has been built and demonstrated by Wm. Denny & Bros. Ltd. It is intended for water operation only, probably over rivers and estuaries.

Shipbuilding & Shipping Record First trip of passenger hovercraft

Shipbuilding & Shipping Record, 99, 5 (February 1st, 1962) 159.

People and Projects

King Gustav of Sweden looking at a working model of the Vickers VA-3 Hovercraft which was on show at the British Exhibition in Stockholm.

The first crossing of the Mississippi River by a ground effect vehicle has been accomplished by William R. Bertelsen of Neponset, Illinois, in his **Arcopter,** latest in his series of ground effect vehicles. The Mississippi is one mile wide at the point where the round trip was made.

Hovering over ice and water, the Arcopter reached seventy miles per hour, although Dr. Bertelsen did not use full throttle on this first test over the Mississippi. The 1,200 lb. craft traversed ice floes, solid ice and open water, stopped and floated on the water and then started again, climbing on its air cushion back over the edge of the ice. After travelling two miles back and forth over the river, Dr. Bertelsen drove the machine up the sloping shore for an amphibious landing. There was no boat traffic problem as no other vehicle can navigate the half-frozen river.

The Arcopter is a ram-wing ground effect vehicle, propelled and supported by a stream of air from a forward-mounted propeller on a horizontal shaft. It is steered by vertical control surfaces in the front and in the rear. It derives its name from its wing — "opter" — which is arc-shaped around the airstream, presenting an aerofoil surface to increase lift. It is powered by a 115 hp petrol engine.

☆ ★ ★ ☆

Britain's Forestry Commission is investigating the possibility of using hovercraft for hauling timber from Scottish forests. Preliminary talks have been held with the manufacturers on the feasibility of the idea and the commission hope to include a prototype at the Exhibition of Forestry Machinery to be held in Edinburgh in June.

★ ★ ★ ☆

A new combined degree programme will be offered next fall to **University of Michigan** engineering students interested in working in fields concerned with high-speed, water-borne vehicles or ground effect machines.

By completing one semester beyond that now required for a single degree, students in the programme will be able to obtain Bachelor of Science in Engineering degrees in both naval architecture and aeronautical engineering.

The programme was established because of the growing industrial and government interest in such fields as underwater weapons system development and the design and manufacture of such vehicles as the hydrofoil and ground effect machines.

The U-M is one of only a few schools in the country that offers degrees in both fields, it was noted by Prof Wilbur C. Nelson, chairman of the U-M aeronautical and astronautical enigneering department, and Prof. Richard B. Couch, chairman of the U-M Department of Marine Engineering and Naval Architecture, who announced the new programme.

Both of these regular programmes include many courses which deal essentially with the same material, differing mainly in application. These include such areas as structures, propulsion, performance and control. In addition, both cover basically the same ground in mathematics and mechanics, and both allow for a number of technical electives — so establishing this new programme at the U-M was feasible.

It is believed that most students taking the combined degrees will also seek advanced degrees in one field or the other.

★ ★ ★ ★

The ACD-1, a new type of air cushion craft, had its first tethered lift trials on the lake at Luton Hoo, Bedfordshire, on June 23rd. Full scale sea trials are expected to take place in about two months' time.

The ACD-1 is rectangular in shape, 25 ft. long, 15 ft. wide and 7 ft. high, and weighs four tons. It has been designed by

People and Projects . . .

Mr. Kenneth Gray, managing director of **Air Cushion Development Ltd.,** of Dibden Purlieu, near Southampton, Hants, to carry passengers or frieight at an estimated speed of 50-60 knots.

It is powered by a de Havilland Gipsy Queen engine developing about 200 hp which drives the four fans — cast integral tapered aerofoil impellers — housed in the air intake, which comprises the entire frontal area of the vehicle to reduce resistance there. Driven from a central shaft by means of a V-belt and pulley system, the fans, which are set at an angle of 25° from the vertical, absorb a total of 185 bhp at 2,350 rpm and between them impel 160,000 cu. ft. of air per minute.

Mr. Gray claims that his design is a new concept of the principle of air cushion or ground effect craft in that it employs a controlled air cushion propellant system which provides lift and rearward thrust to the vehicle.

Air is ducted through a differential system to four sectors within the cushion and is contained laterally by the outer side walls. Air from the top half of the fans is ducted to beyond the centre of gravity, and that from the lower half of the fans is ducted in front of the centre of gravity and on to the water.

The hull design includes three keels to give the craft greater manoeuvrability as it skims over the water. Induction dampers are incorporated to enable the craft to bank slightly on the turn.

Although the craft is designed primarily as a water rider, hydraulically actuated flaps are incorporated fore and aft to contain cushion pressure and to allow the vehicle to move on to a slipway for maintenance and refuelling.

★ ★ ★ ★

The **Fan Division of Airscrew-Weyroc Ltd., at Weybridge,** have been associated with almost all the British developments in the hovercraft and air cushion vehicle field.

They designed and made a 7 ft. diameter axial flow fan for the SRN-1, and were consultants on the design of the high efficiency aerofoil centrifugal fan for the SRN-2.

Eight Airscrew-Weyroc engine oil cooling fans are installed in the Vickers VA-3, and the company has been acting as consultants on the fan installation of the Britten-Norman Cushioncraft, enabling more air output to be achieved through the use of a high efficiency aerofoil bladed centrifugal fan.

★ ★ ★ ★

Over 2,000 bookings have already been taken and tickets are being printed now for the **British United Airways** service which will start on July 20th and will finish on September 16th. At both Rhyl and Wallasey control-centres/booking offices will be established. The VA-3 will be based and serviced at Rhyl, but will be refuelled at Wallasey between trips.

★ ★ ★ ★

Pravda of June 17th reports the arrival at Bucharest on June 16th of the Soviet hydrofoil vessel **Raketa,** the first vessel of her type to be seen on the Danube. The Raketa will call first at Roussé, in Bulgaria, then cross the river to Giurgiu, in Rumania, after which she will proceed upstream to Belgrade, Budapest, Bratislava and Vienna.

Pravda of June 18th reports from the famous Black Sea holiday resort, Yalta, that a regular summer service by hydrofoil vessel between there and Sevastopol was inaugurated on the previous day by the 53-knot **Stryela** carrying about 100 passengers, the time taken on the trip being reduced from 6 hr. 30 min. to 1 hr. 25 min.

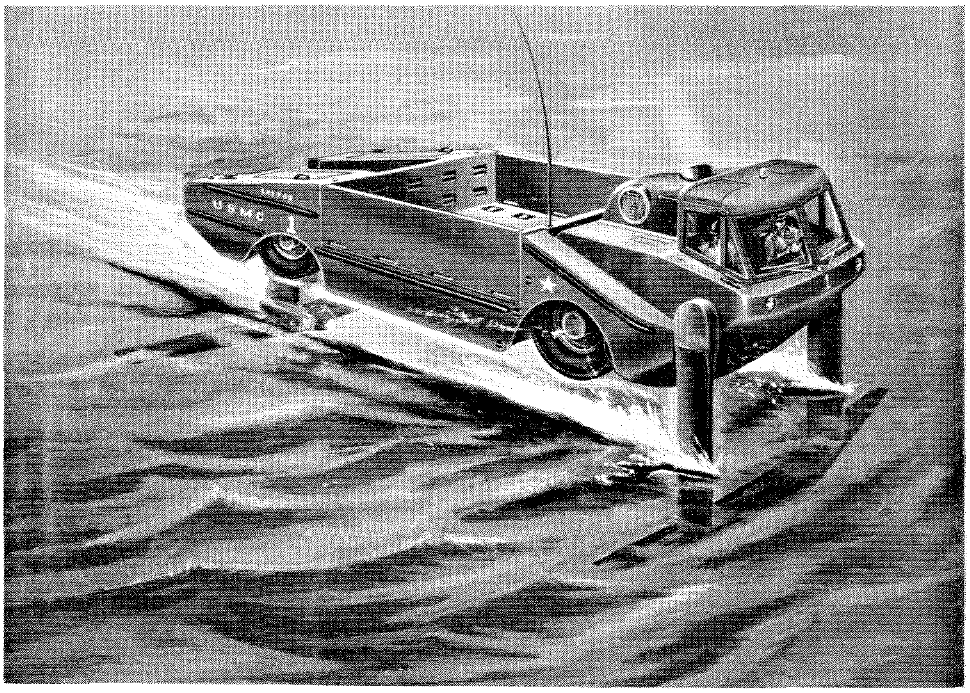
The Stryela is described as a twin-screwed vessel, propelled by twin diesels developing an aggregate of 2,400 hp, and as being fitted with an automatic helmsman.

Pravda of June 11th reports the entry into service on the Moscow-Volga Canal of a new hydrofoil passenger vessel, **Meteor,** carrying 130 passengers, accommodated in two comfortable saloons with aircraft-type seats. She has a speed of 42½ knots.

The Meteor will be running a regular service between Severny (North) River Station and Tikhaya Bay, in the Klyazminsk reservoir.

★ ★ ★ ★

Final configuration of the U.S. Marine Corps' new hydrofoil amphibious landing craft now being developed by **Avco Corporation's Lycoming Division,** Stratford, Connecticut, under contract with the Bureau of Ships, is revealed in an artist's sketch which was released by Lycoming following approval of the engineering and design study phase of the contract and authority to proceed with phases 2 and 3 (detail design and construction of a prototype amphibian). Major changes made as a result of the study include a completely redesigned bow section and cab for improved flight and boating and handling characteristics. The antenna has been relocated to the front of the cargo compartment which itself was somewhat enlarged. An improved suspension system was also incorporated. Under phase 2 of the contract Lycoming has begun fabrication of the first prototype unit with delivery scheduled in 12 months. Phase 3 covers a 12 month test programme which will take place at the Marine Corps Test and Experimental Unit, Camp Pendleton, California. The amphibian is designed to travel at up to 35 knots in rough seas and 40 miles per hour on roads. For land operation the hydrofoils fold and retract into the hull.



An artist's impression of the hydrofoil amphibious landing craft developed by Avco Corporation's Lycoming Division for the U.S. Marine Corps.

SR.N2 MAKES ITS DEBUT

WESTLAND'S 27-ton SR.N2 — a product of the company's Saunders-Roe division — made its press debut at Cowes, Isle of Wight, on June 17th.

An intensive development programme has been under way since the beginning of the year, and later this summer the craft is likely to be put temporarily into commercial use on a "wet-charter" basis between points along Britain's south coast. Interest in the craft and its successors is growing rapidly and the company is now holding discussions with Danish, Swedish, Indian, Greek and Egyptian transport operators as well as several British organisations, including British United Airways and Southdown.

A demonstration tour of Scandinavia is planned and later this year the craft will be loaned to the Royal Navy for tests.

Preliminary trials have made it clear that the performance of the craft is well in excess of the company's initial expectations. Higher speeds are now quoted and lower operating costs. As was reported in our April issue, the designed top speed of 70 knots was attained by the SR.N2 when operating on only three of its four engines. The normal cruising speed is now given as 80 knots, although in rough seas this will be reduced by 30-40 knots to avoid undue discomfort to passengers.

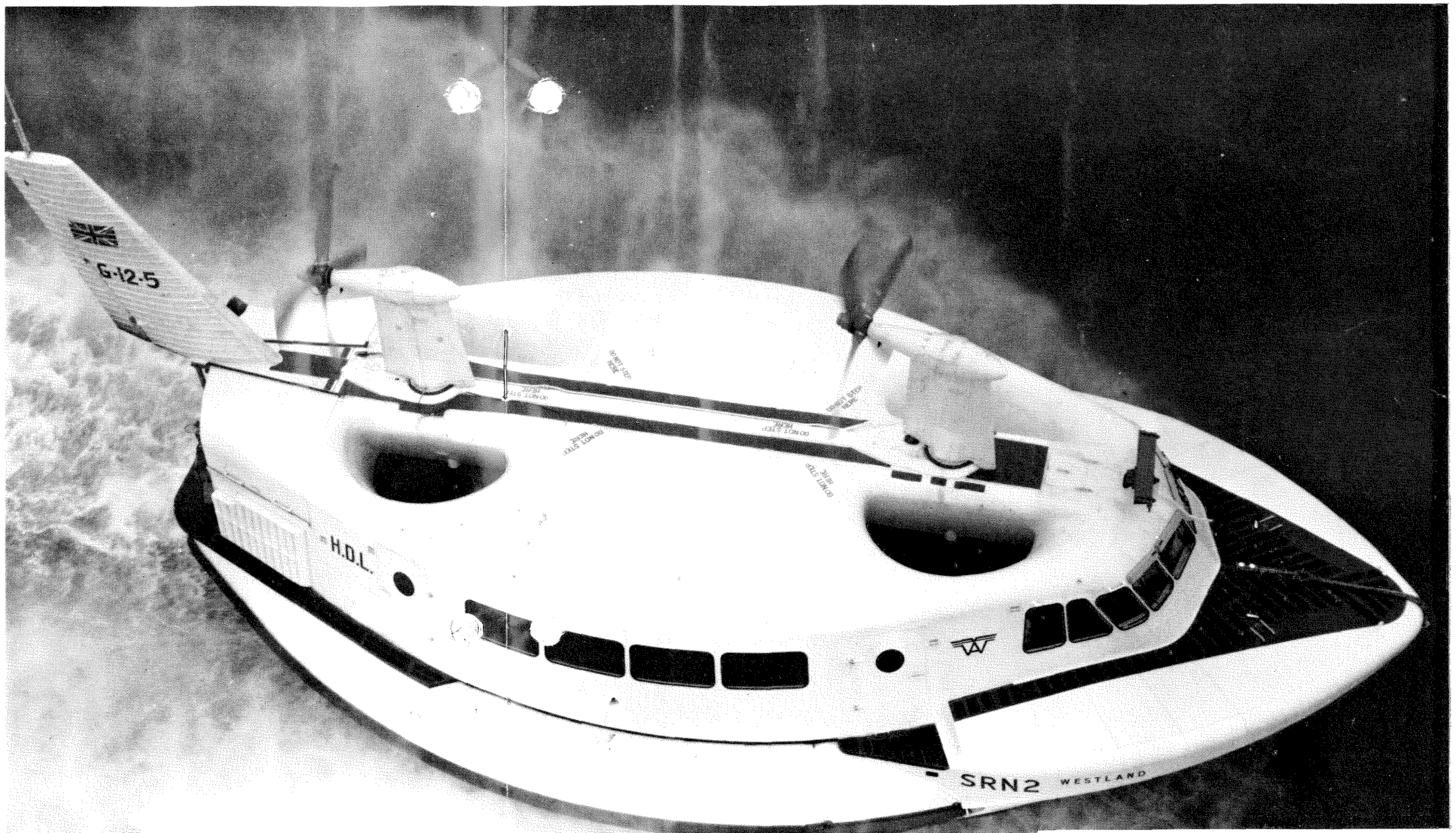
Typical fares quoted by the company, based on the latest assessment of likely operating costs, could be 8s. single for a stage of five miles, and £1 single for twenty miles.

Design Background

The design has a two-fold purpose — that of proving the fans, engines, transmission and control systems for following generations of Hovercraft and to help explore all the possibilities of commercial air rider operation.

The craft is built around a central cabin measuring 20 ft. by 16 ft. and able to seat between 56 and 76 passengers, depending on layout. A freight version could carry a payload of eight tons.

Power for cushion lift and propulsion is provided by four 815 hp Bristol Siddeley Nimbus free turbines, coupled in pairs and sited in an engine room at the stern. Each pair drives one fan/propeller unit.



Curtain air is generated by two centrifugal fans sited in the lower structure, and emerges through flexible duct extensions beneath the craft. Propulsion is given by two variable-pitch propellers mounted on pylons above the superstructure. Each pylon can be swivelled 30° on either side of its central line to give directional and lateral control.

Sperry servo components are used in the steering control system. The craft is controlled from a single column using a normal aircraft-type spectacle to pivot one pylon, while lateral displacement of the column rotates the other. The pylon angle is automatically changed from port to starboard — or vice versa — to allow for the effect of applying reverse thrust when the craft is to be stopped or slowed during a turn.

The craft is constructed primarily of high-strength aluminium-clad aluminium alloy suitably protected against the effects of sea water.

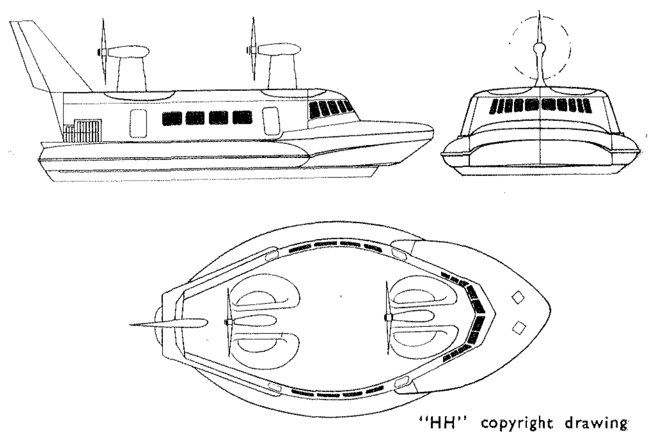
A buoyancy chamber is incorporated to enable the craft to float on the water and in an emergency to make its way at speeds up to eight knots as a displacement craft.

Developed Versions

A developed vesion, designated SR.N2, Mk. 2, is in hand. Intended for 120 passengers and weighing 37.5 tons it will offer a more economical service on civil routes as well as having an improved rough water capability.

Another developed version is the SR.N3 — a "stretched" model with an extra 10 ft. on the hull. It will use the same engines, fans, transmission and control system. The all-up weight will be 40-45 tons and the disposable load 18 tons. As a prototype military Hovercraft, it would be suitable either for use as an assault landing craft carrying 70-150 troops, or for anti-submarine warfare experiments.

The next step at Saunders-Roe will be the development of a 100-150-ton ferry capable of carrying 300 passengers and 26 cars across the English Channel. The cost will be between £500,000 and £1m. Looking still further into the future, Mr. Eric Mensforth, Chairman of Westland Aircraft, revealed the existence of plans for a nuclear-engined craft — the SR.N6. This, he stated, would be of 1,000 to 1,500 tons and be capable of use as an aircraft carrier for three V bombers; as a helicopter carrier or a guided missile base. If a production order were placed it could be produced for £5 million.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