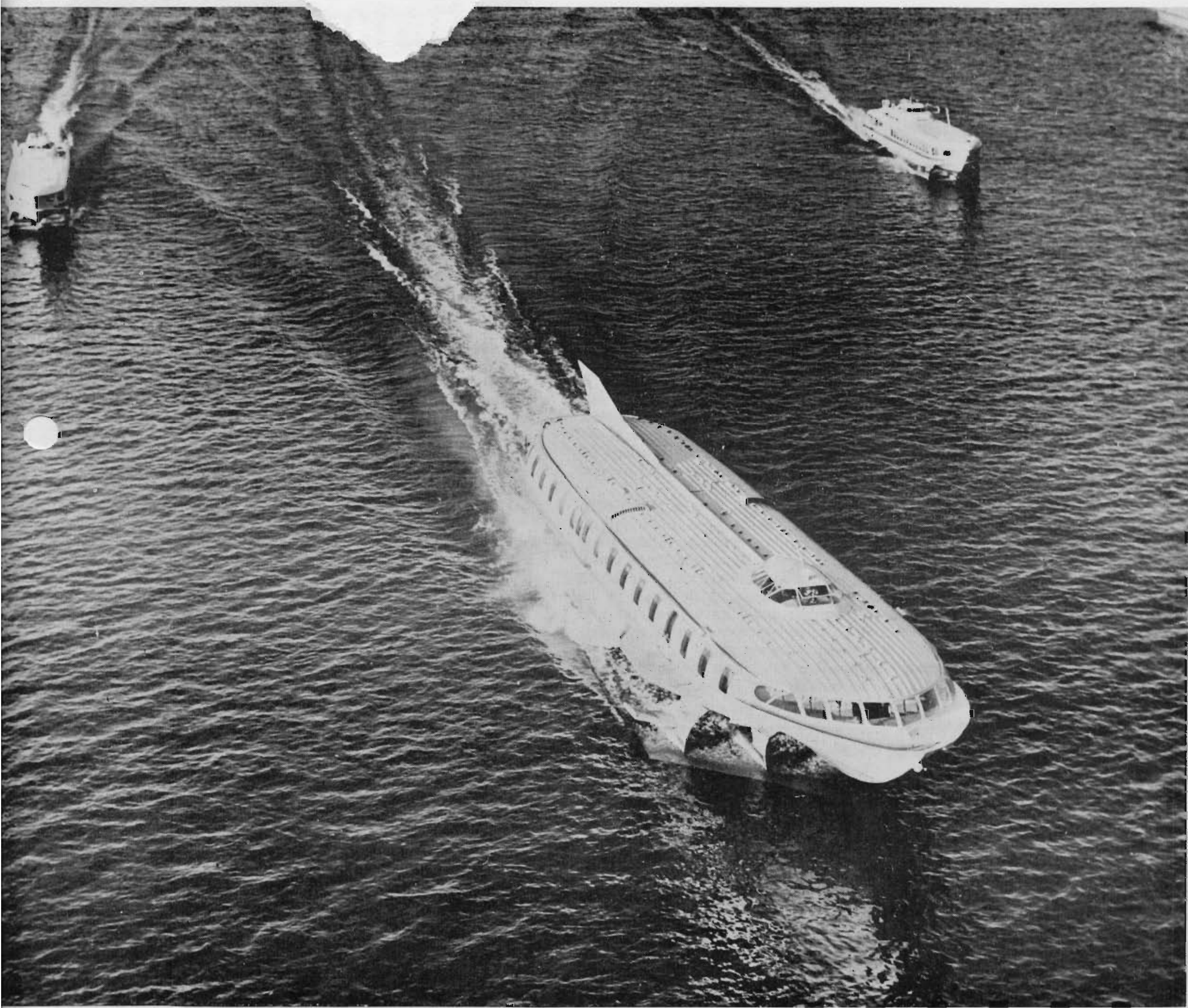
'/ERING CRAFT
ЧYDROFOIL

THE INTER. ...: CUSHION VEHICLES AND HYDROFOILS



SPECIAL RUSSIAN ISSUE

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HOVERING CRAFT & HYDROFOIL

FOUNDED OCTOBER 1961

First Hovering Craft & Hydrofoil Monthly in the World

An artist's impression of the Vickers VA-4 at a ferry quay. *For further details see page 4 of this issue*

HYDROFOILS AND ACVs IN THE USSR

A statement for Hovering Craft and Hydrofoil's *Special Russian issue by Engineer Vladimir I. Kiryushin, Second Secretary of the Department of Science and Technology at the USSR Embassy in London*

In recent years many countries have been devoting great attention to the building of hydrofoils and air-cushion vehicles, among these being the USSR, where scientific research and constructional work is going on in these fields. The survey which appears in this issue of *Hovering Craft & Hydrofoil* is based on articles which have been published in various Soviet newspapers and technical journals, and gives some idea of the actual work on methods of calculation and construction of new types of hydrofoils and ACVs which has been carried out in the USSR.

It must be well known that the USSR has accumulated a good deal of experience in the construction of hydrofoil vessels, which are nowadays in regular service in various parts of that country. Great attention is now being paid there, moreover, to the development of air-cushion vehicles, for which wide use may be found in the conditions which obtain in the USSR, owing to the geographical and climatic conditions of certain areas, in which the use of air-cushion vehicles is preferable to that of other means of transport.

Krasnoye Sormovo shipyard at Gorki, on the River Volga, is building an air-cushion vehicle, the *Delfin*, which will be completed this year, intended for fast passenger service between towns. Vessels of this type seem likely to prove useful to replace, or to supplement, the hydrofoil vessels which are now running regular services on many of the great rivers of Siberia, such as the Ob', the Yenisyey, the Lyena and others, as they would enable passenger transport services to be maintained throughout the year, i.e. even when the rivers are ice-bound. It is particularly noteworthy, moreover, that air-cushion vehicles are very useful as a means of transport in those parts of the USSR which have only recently been opened up, and where there are still few roads and railway lines.

Work on the development of air-cushion vessels is conducted in close collaboration with various scientific research establishments, and the industrial establishments concerned have benefited greatly from the help of the celebrated research workers of N. Ye. Zhukovskiy Institute of Aerodynamics. The Director of that Institute, the famous Soviet aircraft designer, V. M. Myasischev, visited Britain recently, together with several other specialists of the Soviet aircraft industry, as guests of the Society of British Aircraft Constructors, for the 1964 Farnborough Air Show.

IN THIS ISSUE

COVER PICTURE : *Three Russian hydrofoils of the "Raketa" and "Sputnik" class at speed on the Volga. (Photograph by courtesy of "Tass")*

OCTOBER, 1964 VOL 4, NO 1

Editor:
JUANITA KALERGHI

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Areas for the effective use of hydrofoil vessels and hovercraft

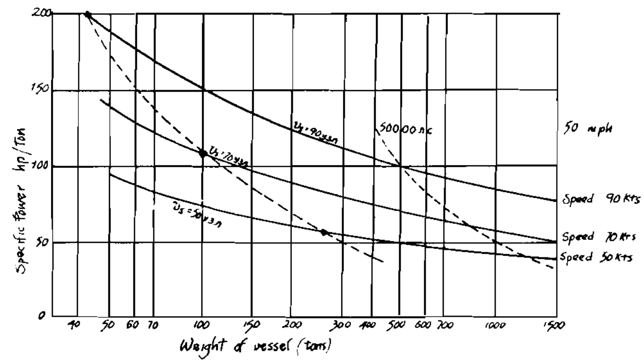

Figure 1. Specific powers
——— *Hovercraft (hoverheight 8 in)*
● *Hydrofoil vessels*
- - - - - *Line of equal specific power for hydrofoil vessels and hovercraft*

Engineer V. M. Pashin

SINCE the range of speeds attainable by hydrofoil vessels and hovercraft, respectively, overlap each other, the determination of the point at which, from a power point of view, one or the other of these two types of vessel becomes the more efficient for normal use, must be arrived at by comparison of the power per unit weight required for each of the types for various dimensions and at various speeds.

So far as hydrofoil vessels are concerned, the specific power was worked out and shown in a Paper on "Hydrofoil Vessels", presented by M. V. Shaybo of the Academy of Sciences, to the Academy of Sciences of the Ukrainian Soviet Socialist Republic in 1962, and published in *Interavia* IV, Vol 16, No 4, 1961, pp 479-484. It was assumed in that Paper that foils working in sub-cavitating conditions would be used at speeds of up to 60 knots, after which these would be replaced by foils working in super-cavitating conditions. The results arrived at were as follows: at 50 knots, 55 hp/ton; at 70 knots, 110 hp/ton; and 90 knots, 200 hp/ton. Changes dependent on the dimensions of the vessel were too insignificant to be taken into account (Transactions of the Society of Naval Architects and Engineers, Vol 67, 1959, pp 686-714).

The specific power for hovercraft of the air-cushion type were calculated by applying the exponential theory to a two-dimensional plan (*Journal of the Aerospace Sciences*, VII, Vol 29, No 7, 1962), and it will be seen from Fig. 1 that it changes with the increase of the dimensions of the hovercraft. Similar changes are observed with a side-wall hovercraft also. Fig. 1 shows the curve for a constant power of 50,000 hp (which may be obtained either with a nuclear power installation (*Transactions of the Society of Naval Architects and Engineers*, Vol 67, 1959. pp 686-714) or with a gas turbine installation (*Hovering Craft and Hydrofoil*, Vol 1, No 7, 1962).

By using graphical representation similar to that used in Fig. 1, it is possible to determine the speed and weight of hydrofoil vessels and hovercraft, respectively, at which the specific power will be the same (Figs 2 & 3). Comparison of the dynamic characteristics of hydrofoil vessels makes it possible to arrive at the following conclusion:

1. At speeds of 70-80 knots with vessels of small dimensions, corresponding with displacements of 50-100 tons, hydrofoil vessels are the more efficient, so far as power consumption is concerned. With larger vessels, however, hovercraft are preferable.

2. Proportionally as the speed is reduced and the hoverheight is increased, the range over which hovercraft may be used economically becomes smaller.

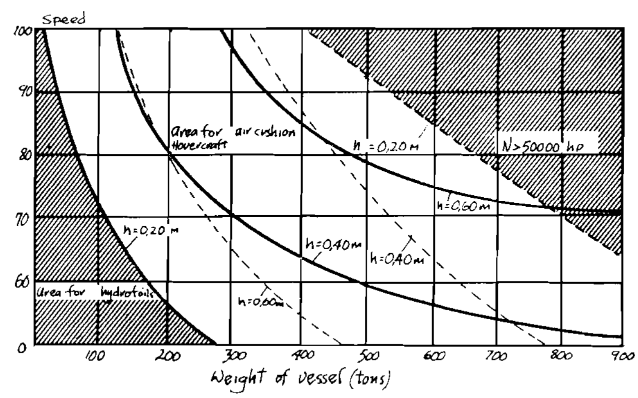

Figure 2. Areas of effective use, from a dynamic point of view, of hydrofoil vessels and side-wall hovercraft at various hover heights
- - - - - *Curves of constant power of 50,000 hp*

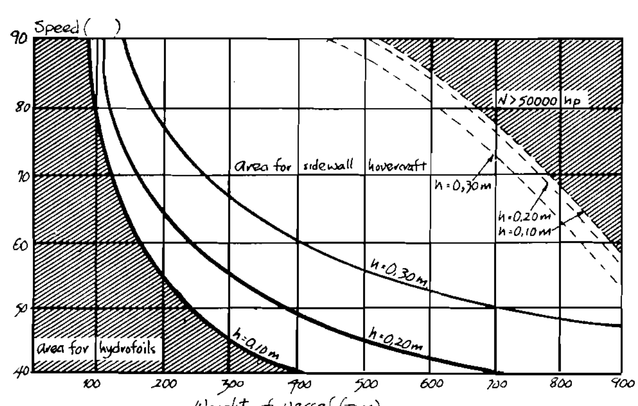

Figure 3. Areas of effective use, from a dynamic point of view, of hydrofoil vessels and air cushion vehicles

Adapted translation from Russian of an article in "Sudostroyeniye", No 5, 1964

M. A. Yuryev, Director of the Krasnoye Sormovo Shipyard, and R. E. Alexeyev, Lenin Prize Laureate and Chief Designer of the Shipyard, seen with the model of a new water-jet propelled hydrofoil

People and Projects

The world's largest hydrofoil — a $12 million virtually all-aluminium experimental craft for the US Navy — is being built in Seattle by Puget Sound Bridge and Dry Dock Company, a subsidiary of Lockheed Aircraft Corporation, for delivery in autumn 1965.

Designated the **AG(EH)** Hydrofoil Research ship, the craft will be 220 ft 5 in long and 40 ft 5 in in beam, with a displacement of 300 tons. It will be more than twice the size of any hydrofoil in existence.

The ship will be of all-welded aluminium construction except for foils and struts, which will be of steel. Of the more than 250,000 lb of aluminium that will go into the hydrofoil, at least 200,000 lb will be in the form of large extrusions, some as long as 40 ft. Kaiser Aluminium and Chemical Corporation is supplying these extrusions of alloy 5456 H113, and the plate of alloy 5456 H321.

★ ★ ★

On September 9th the *New Zealand Herald* reported that the **Waiheke Shipping Co Ltd,** would definitely buy a new and larger hydrofoil after the "Manu Wai" had proved itself and the Company had more experience of running it. No order has yet been made but the new hydrofoil the Company had in mind was the 130 ton PT50 which can carry 130 passengers at 33 knots cruising speed. It was further stated that the craft has a range of 377 miles, and it is believed that Sir Robert Kerridge plans cruises far beyond the Auckland harbour.

In addition to the present service to Waiheke Island, the "Manu Wai" will serve the Pakatoa Island Tourist and Holiday resort, now under construction, which should be open by the end of the year.

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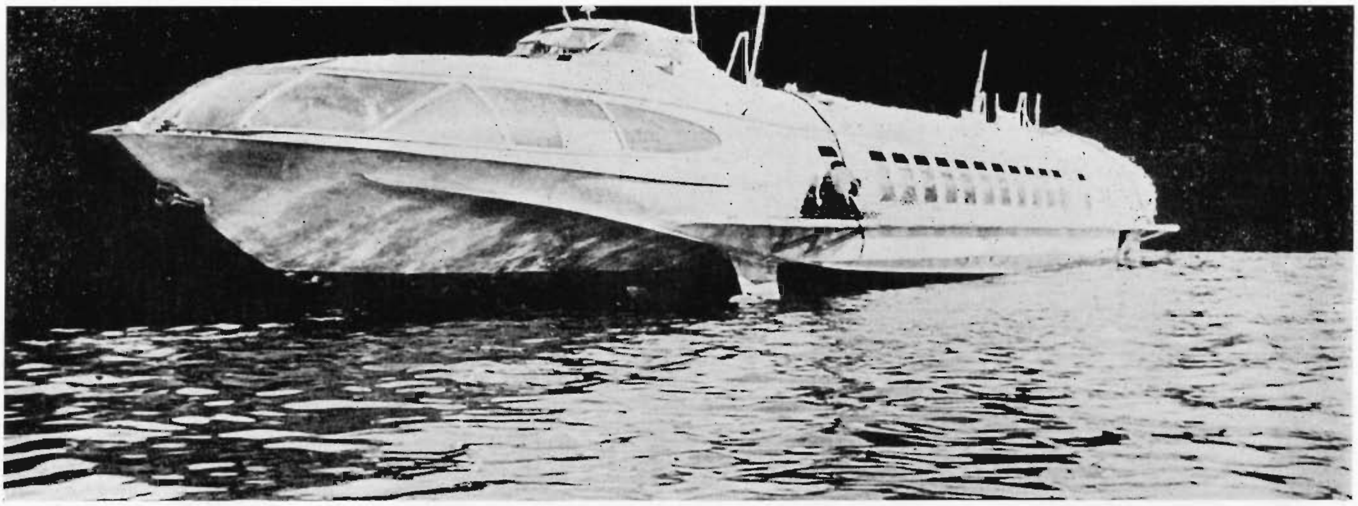
Vickers-Armstrongs Ltd have now finalized the design of their new hovercraft, the VA-4. Initially schemed to carry twenty-four cars and 200 passengers, the 150 ton craft will be capable of a top speed of over 80 mph, with an endurance of three-and-a-half hours providing an effective operating range. The incorporation of the Vickers flexible skirt system will enable the craft to operate at speeds of 50 mph in 6 ft wave conditions.

Leading particulars:

All up weight: 150 tons
Disposable load: 65 tons
Length overall: 133 ft
Width overall: 71 ft
Lift fans — centrifugal: Three 11½ ft diameter
Propulsion — propellers: Three 20 ft diameter
Engines: Three Bristol Siddeley Marine Proteus
Power (continuous cruise rating): Three 3,400 shp
Fuel (normal load): 2,800 gallons
Endurance: 3½ hours
Crew (driver, navigator, three stewards): Five

Typical loads	*Cars*	*Passengers*
High density Economy class	—	600
Low density First class	—	450
Low density seating	16	220
Tourist class	16	320
Tourist class	24	196

★ ★ ★



The "Burevestnik", claimed to be an advance on any hydrofoil vessel in existence, was launched in April 1964 by the Krasnoye Sormovo Shipyard. It carries 150 passengers and will operate on large inland seas and rivers with wide reaches which are extremely shallow. It is fitted with shallow draught submerged foils and can operate in waves of 1.2 m. The craft is propelled by two water-jets, instead of propellers, the power for these being provided by two marinised aircraft-type gas-turbines, each developing an output of 2,000 hp. The two engines have a consumption of about 300 gallons per hour. Ten tons of fuel can be carried, and this enables 500 km of non-stop operation. The water-jets help manoeuvrability, provide greater mechanical efficiency, and very substantial reduction of draught. The hull is constructed of all welded aluminium-magnesium alloy, and the foils are made of titanium alloy. The foils are secured to the hull by columns and brackets, and the angle of incidence can thus be changed when docking. There is a crew of four, and saloons are air-conditioned.
Length 43.3 m; width 6.7 m; height 3.7 m; cruising speed about 110 km/hr; static draught 1.8 m; at speed 0.4 m; displacement at full load 61 tons.

On September 29th **Bell Aerosystems Company** began demonstrations for the first time in the United States of a Westland SR.N5 air cushion vehicle. The demonstrations were launched in Houston in support of the "British in Texas" festival, and the craft will also be demonstrated in Morgan City, New Orleans, Louisiana, and other Gulf Coast cities later in October and in early November.

The purpose of the demonstration programmes is to introduce the craft to potential users and to evaluate its performance. Its applications include speedy transportation of personnel and cargo to off-shore oil facilities; harbour patrol and maintenance missions, such as those performed by the Coast Guard; as an emergency vehicle for fire-fighting, search and rescue work at airports bounded by marshes and/or water; military missions such as reconnaissance and amphibious warfare; public transportation.

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A syndicate of Australian and Japanese businessmen is reported to be planning to purchase a Japanese hydrofoil ferry to carry passengers on Sydney Harbour. It is hoped that the hydrofoil will be operating by the end of the year. Two types of hydrofoil are reported to be under consideration for use on the service. Both are made by the **Hitachi Company** of Japan. One model, the PT35 costs £125,000 and carries 100 passengers, while the other designated PT50 costs £200,000 and has a capacity of 140 passengers.

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UNIVERSITY OF SOUTHAMPTON — Research Fellowship

Applications are invited for a Research Fellowship for mainly experimental work in the Hovercraft field. The value of the Fellowship will be in the region of £1,200 per annum according to experience. Applications, in duplicate, should be sent to the Secretary and Registrar, Room 9, the University, Highfield, Southampton, giving the names of two referees by November 20th, 1964

A lecture entitled "Hovercraft" was delivered by G. T. Thomson, of Westland Aircraft Ltd, at a meeting organised by the **British Association for the Advancement of Science** held in the Nuffield Theatre of Southampton University on September 1st. A film shown at the conclusion of the lecture admirably demonstrated the enormous potential of the hovercraft as a vehicle for use in environments impenetrable by any other form of land or sea vehicle so far developed.

Mr Silverleaf, of the National Physical Laboratory, Feltham, delivered a lecture on hydrofoils on this same occasion. He attempted with considerable success to give both a broad explanation of the basic principles of hydrofoil flight and stability, and an "up to date" state of the art summary.

★ ★ ★

The **Orkney Island Shipping Company** has chartered the forty passenger Aquavion hydrofoil "Shadowfax" for passenger service in the Orkney Islands. A Ministry of Transport passenger certificate has been granted, following a period of trials in the area, an unusually turbulent corner of the British Isles. She will be operated by a crew trained by the Aquavion technical demonstration team. The craft was recently called out at night to carry Mr David Croat, a postman on the island of Papa Westray, to Kirkwall for urgent hospital treatment. The round trip was fifty miles. No other vessel could have undertaken the rescue operation in the time available and aircraft were unable to take off owing to lack of night-flying facilities.

★ ★ ★

An order for two hydrofoil ferries has been placed by the Wood's Hole, Martha's Vineyard and Nantucket Steamship Co, Massachusetts, with **Atlantic Hydrofoils Inc,** of Stony Brook, NY.

The two hydrofoils will carry seventy passengers each at a speed of 50 mph. The owners are planning a hydrofoil ferry service during the summer of 1965.

The two ferries will be 60 ft long and will have submerged hydrofoils manufactured by the Aluminium Co of America, and will have twin Cummins oil engines for main propulsion.

★ ★ ★

Mr Sidney C. Smith-Cox, who wrote the article which appears on page 16 of this issue, is managing director of P. & A. Campbell Ltd, who operate steamer services in the Bristol Channel and on the North Wales Coast. He is a chartered accountant and a Fellow of the Hotels and Catering Institute. He is a magistrate of the County of Somerset and is a chairman of the West of England Trust Ltd

Westlands have received an order for a 7 ton SR.N5 from Japan. The craft is scheduled for delivery in early December and is being imported by Marubeni Iida Co Ltd on behalf of **Mitsubishi Heavy Industries Ltd,** of Tokyo. It will be used for passenger carrying operations in the Kyushu area.

This latest order brings up to four the number of overseas countries taking delivery of the SR.N5, and sales negotiations with other possible civil and military customers in several parts of the world are well under way.

The SR.N5 is a 7 ton hovercraft capable of carrying up to twenty passengers or 2 tons of freight at a cruising speed of 70 knots. The craft is 38 ft long, has a beam of 22.5 ft, and is 15 ft high. It is powered by a 900 hp turbine engine. The same engine is used to supply the power to operate the centrifugal lift fan which is 7 ft in diameter, and the four-blade, 7½ ft reverse pitch propeller. Control of the craft is achieved by rudders and elevators mounted on the twin-fin, tailplane unit, which operates in the slipstream of the propellers.

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Denny Hovercraft Ltd have been studying the long-term possibility of a fast 140 ton craft — the D-3 — which would be capable of operating at 40 knots.

Progress has been made in modifying the D-2 to overcome the problem of floating driftwood which tended to damage the vehicle's waterscrews when it was used during an experimental service on the Thames last year. The vehicle's propulsion units have now been redesigned and sea trials of the modified craft will take place immediately the modifications have been completed.

So far Denny's expenditure has been nearly £400,000. Two additional glass-fibre hulls have been built, and these are expected to be completely fitted out and commissioned as soon as the sea-trials of the D-2 are over. On a cost-per-seat basis it is believed that these three hovercraft will represent an attractive proposition to transport companies operating on inland and coastal waters.

★ ★ ★

Former **Minister of Aviation,** Mr Amery, has informed the Society of British Aerospace Companies that Britain will proceed with plans to develop an ocean-going "hovership". Speaking at the Society's annual flying display dinner, Mr Amery outlined the important part which the Government had played in Hovercraft development by ordering them for research and evaluation purposes, and said that they had now ordered some for transport purposes as well. He said that they were considering the use of the cushion technique on larger ocean-going vessels and were proposing, in conjunction with the Ministry of Defence, to invite industry to undertake preliminary studies aimed at the possible construction of a hovership — a craft capable of operating with the fleet either as a displacement vessel using conventional waterscrew propulsion, or as a Hovercraft. A craft of this nature might well make a significant contribution to naval warfare.

★ ★ ★

Some 200 guests, many from overseas, attended a **display of Hovercraft** at HMS *Ariel*, Lee-on-Solent, on Wednesday, September 16th, 1964. The occasion provided a spectacle unique in the history of Hovercraft. Westland demonstrated the superb all-weather performance of the SR.N3 and SR.N5 by going out to sea in a 60 knot wind with waves 5 to 6 ft high. To the amazement and delight of all spectators, these craft proved beyond any measure of doubt that Westland Hovercraft are capable of successfully operating in appalling weather conditions. A Naval representative confirmed that no conventional ship of equivalent size could have taken to sea on this occasion.

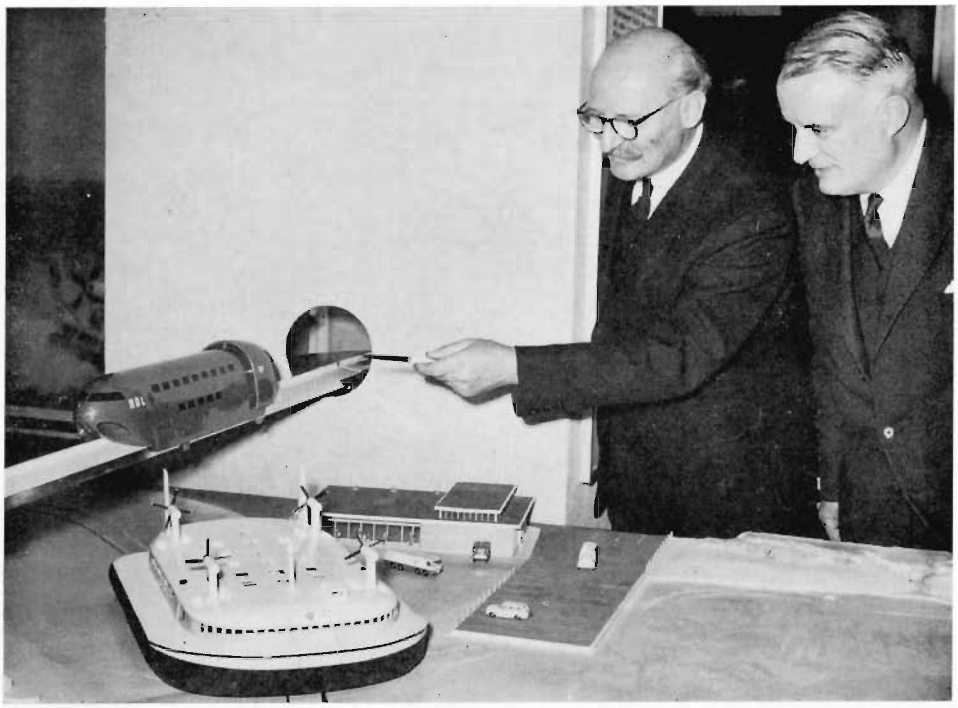
The many Hovercraft on static display included exhibits from Vickers HDL, Britten-Norman, and Westland. Guests were able to inspect these craft under the experienced guidance of Company representatives, and British Petroleum provided an indoor display of Hovercraft models.

Of particular interest was the demonstration of a radio controlled 1/50th scale model of the Westland SR.N4. The model capable of speeds up to 40 knots performed in wind conditions equivalent to 200 knots for a full-scale vehicle.

Among the many distinguished guests present on this occasion were the Prime Minister of Tonga, and Sir Vivian Fuchs. Sir Vivian expressed considerable interest in the possible application of Hovercraft in antarctic conditions. At a Press Conference held after the demonstration Mr Julian Amery confirmed that the Government were considering the development of a Hovercraft ship which would be required to function in the displacement mode as a conventional ship, and it was proposed at this stage to consider a vehicle having a retractable keel. He said that industry would be invited to submit design proposals in due course. Mr Amery, who was accompanied for much of the demonstration, by Mr Shaw, of the Ministry of Aviation, a personality well known and respected in the Hovercraft industry, went on to congratulate those responsible for the development of Hovercraft. In the relatively small period of eight-and-a-half years, Hovercraft have developed from the embryo stage to the sophisticated, reliable, well-engineered vehicle. This, Mr Amery concluded, together with the demonstration was, indeed, a tribute to the British Hovercraft Industry.

★ ★ ★

The Prime Minister of Tonga and Mr Julian Amery examining a radio-controlled model of the Westland SR.N4 at the Lee-on-Solent Hovercraft display



Mr Christopher Cockerell seen at the Engineering Industries Association Exhibition which was held in London from October 20 - 23. He is pointing at a model of the tracked Hovercar

A system using the air cushion principle for transferring heavy loads from one level surface to another will soon be introduced in Britain by **Crane Fruehauf Trailers Ltd.** The system was introduced in the USA in April, and rail, shipping and air freight operators have been investigating the low level of costs the company claims for it both in terms of its own operation and in the saving of other expensive equipment.

The principle of the "Freight Flyer" system is that air cushions of a size proportional to the weight of the load to be transported are fixed on the underneath of the container or pallet. A modest volume of low pressure air supplied by either a centrifugal or positive displacement blower feeds the centre of each air cushion, inflating the cushion to effect the seal.

The air supply can be mobile or fixed depending upon the distance that loads are to be transferred or transported. Power can be supplied by a small internal combustion engine or by an electric motor energised by either alternating current or by self-contained batteries.

★ ★ ★

Westland Aircraft Ltd have concluded an agreement with Autair Helicopter Services Ltd for the delivery of an SR.N5 to Canada in October. The craft will be used for a variety of tasks including Arctic operations in collaboration with the Canadian Government.

Another SR.N5 has been ordered by Scandinavian Hovercraft Promotion Ltd who plan to eventually have ACVs for hire in Norway, Sweden and Denmark.

★ ★ ★

The US Peace Corps has ordered a number of Dobson Air Dart II's from **Aircars Inc** of Los Angeles. The Air Dart II is a fibreglass ACV with combined lift-propulsion power of 15 hp, and is an improved version of the plywood and vinyl Air Dart which won the ACV races at Canberra in March.

Mr Harry Laufman, the president of Aircars Inc, was recently interviewed in London where he stated that he had concluded agreements with a go-kart company in Britain to manufacture the Air Dart II under licence. He has arranged similar licence agreements in South Africa and Australia.

★ ★ ★

Mr Christopher Cockerell, technical director of Hovercraft Development Ltd, a subsidiary of the State-owned National Research Development Corporation, has announced that he hopes British Railways will lease about five miles of disused track for use in Hovercar experiments. A model of the Hovercar is on display at the Engineering Industries Association Exhibition.

The Hovercar uses the hovercraft air cushion principle to elevate itself about half-an-inch above a prepared track (which would probably be a shallow inverted V-form in concrete). Having no direct contact with the surface beneath it, a vehicle of this type could be propelled at 200 - 300 mph by electric linear motor or propeller.

A small vehicle carrying two people and test equipment will be propelled along the five mile track at speeds of up to 80 mph for the initial experiments, but in commercial operation a car weighing 100 tons and carrying about 600 people might be used.

Mr Cockerell has estimated that a track between London and Glasgow would cost about £100m at current prices, using prefabricated concrete sections.

★ ★ ★

A noteworthy feature listed among the shipbuilding loans in Spain for 1965 is that granted to **Hydrofoil Española,** S.A., Barcelona, for the first hydrofoil to be built in Spain. The amount of the loan is 9,593,472 pesetas. The repayment period is ten years at an interest of 5% per annum. The loan covers 80% of the cost of the vessel less the amount corresponding to the Government tax rebate to shipyards, understood to be 9% of cost.

The company intends to own three units initially and they will be given the names of *Pinta, Nina,* and *Santa Maria.* The *Pinta* will have the following characteristics: length 18.25 m; breadth 5 m; draught in raised position 1.5 m; seating for seventy-six persons; displacement 22 tons; speed of elevation 22 knots, maximum speed 36 knots (65 kilometres per hour. Power: 720 hp gas turbine. Propulsion speed: 1,342 rpm. Hull: aluminium alloy.

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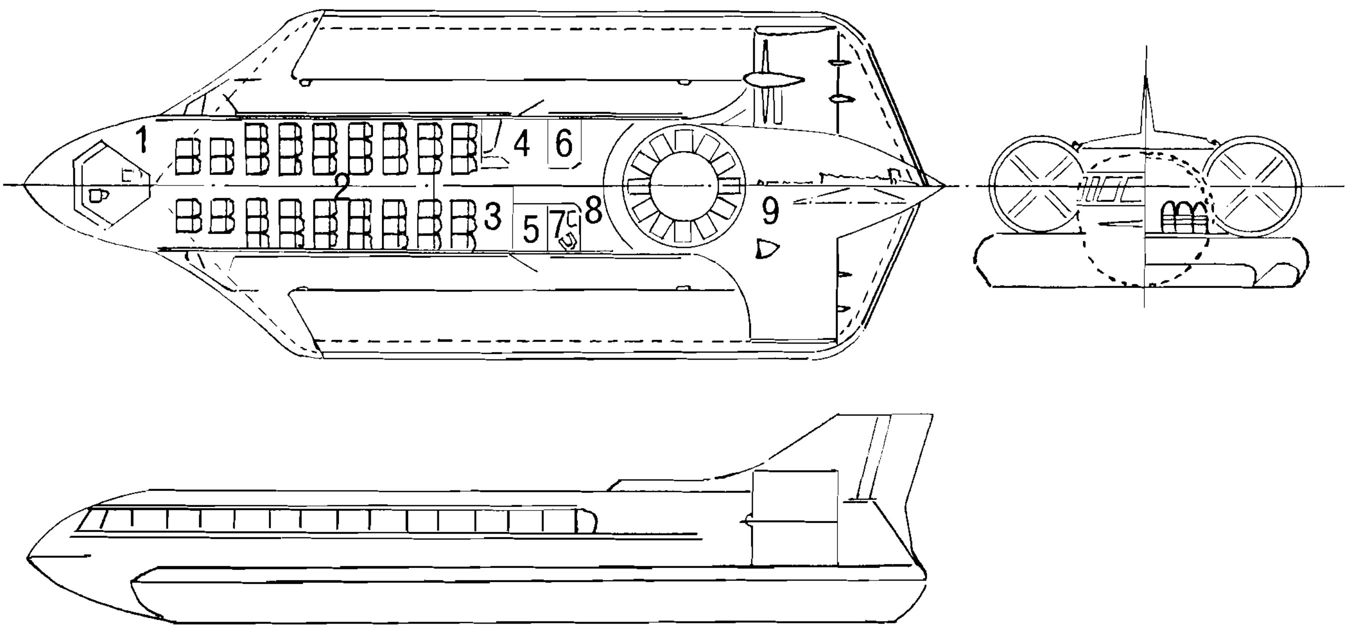


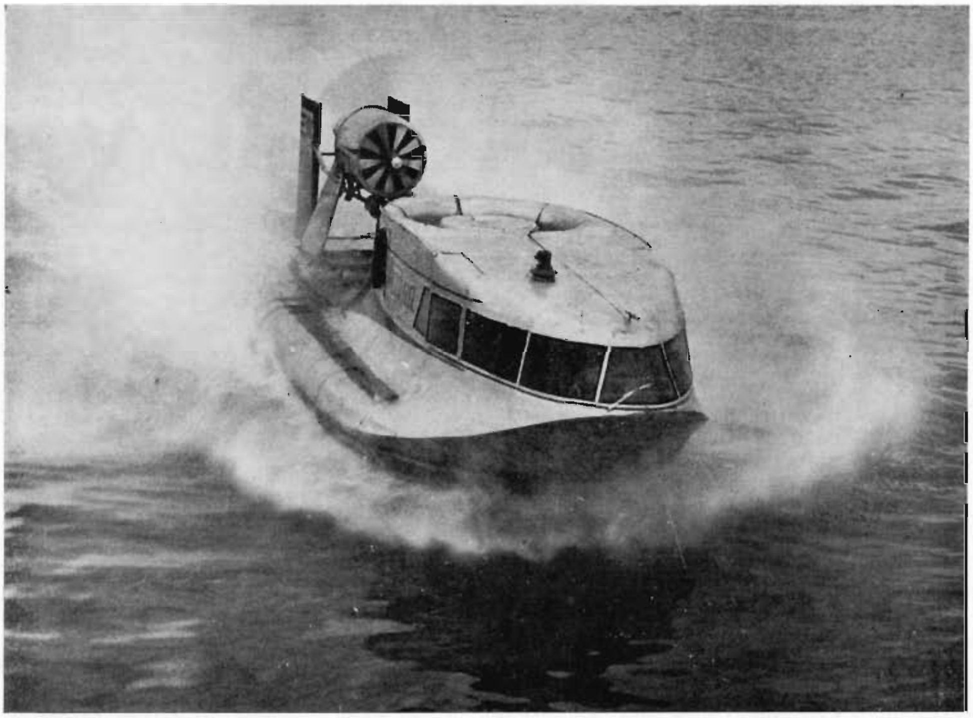
Plan drawing of general layout of the "Delfin":
1. Wheelhouse; 2. Saloon for fifty passengers; 3. Cloakroom; 4. Buffet; 5. Companion way; 6. Storeroom; 7. Toilet compartment; 8. Luggage store; 9. Engineroom

DEVELOPMENTS IN

THE June number of *Ryechnoy Transport,* monthly journal of the Ministry of River Transport of the RSFSR (Russian Union of Federated Socialist Republics) gives details of a new hovercraft passenger vessel, the *Delfin* (*Dolphin*), to carry fifty passengers at a maximum speed of 140 km/hr (about 87 knots), now being built at the Krasnoye Sormovo shipyard at Gorki, on the River Volga. She is to be launched at the end of this year, and should be ready for service by next summer.

Designed by the Soviet naval architect Valeriy Schoenberg, chief constructor of the Krasnoye Sormovo shipyard, in consultation with experts at the "N. Ye. Zhukovskiy" Central Institute of Aerodynamics, this vessel is of the air-cushion type, and embodies experience gained during 1962-63 with a very similar vessel of smaller dimensions, the *Raduga,* also designed and built at Gorki, which gave every satisfaction in service on the Volga last summer, and with a smaller vessel of the side-wall type, the *Neva,* designed and built at Leningrad. She is designed primarily for inter-urban services on inland waters, over distances of the order of 400 km (250 miles), and the decision to proceed with her development is based on the fact that experience with the *Raduga* proved that the estimated reduction of transport-cost per passenger of about 30%, as compared with that of a hydrofoil vessel of the *Raketa* type, was correct, and that she can be used throughout the year, i.e. when hydrofoil vessels are unusable on account of the ice. It may be noted here in the latter connection, moreover, that a novel feature of the *Delfin* is that she is provided with wheels, which are normally folded into the bottom of the hull, but which can be lowered when required, e.g. when running over unusually bumpy ice or terrain, to save the hull from being damaged. These are sprung in such a way that they yield gently when some extra hard obstacle is encountered, returning into position when that obstacle has been negotiated. This fitting will come in useful where the vessel is used in places such as abound in Siberia, to which access by river is made difficult, or impossible, by the shallowness of the water, and roads are non-existent, a fact which might usefully be noted in, for instance, Canada.

As will be seen from the accompanying plan drawing, the general layout of the *Delfin* has been conceived with the object of providing for the comfort of the passengers in respect of noise from the engine, which is considerable. The engine and propeller unit are situated right aft, well separated from the passenger saloon, forward, by two soundproof bulkheads, enclosing a cloakroom, a buffet, a toilet-compartment, a first-aid post and a baggage-store. Forward of the passenger saloon,



The Soviet Hovercraft "Raduga" seen on the Volga

SOVIET HOVERCRAFT

Commander Edgar P. Young R.N. Retired

and separated from it, is the wheelhouse, with excellent all-round vision, from which the main engine, and its ancillaries, are remote-controlled, and the rudders are hydraulically operated, and which is equipped with such a wealth of navigational aids that the vessel can be operated with complete safety at night or during the dark periods of the year which occur in the Arctic.

The principal particulars are as follows:

Weight (fully loaded): 21.75 tons
Length overall: 26.5 metres (about 87 ft)
Breadth moulded: 10 metres (about 33 ft)
Draught when water-borne: 32 cm (about 1 ft)
Height: 6 metres (about 20 ft)
Hover height: 20-30 cm (8-12 in)
Surface area of bottom: 165 sq metres (1,778 sq ft)
Pressure of air cushion: 200 kg/sq metres (4 lb/sq ft)
Speed (maximum): 140 km/hr (87 knots)
Speed over rough surfaces: 60-80 km/hr (37-50 knots)
Passengers: Fifty
Crew: Two

The *Delfin* differs from most hovercraft in the USSR or in other countries in having only one engine to provide power both for main propulsion and for creating the air cushion. This is an aircraft-type jet unit, Type AI-24, designed by A. G. Ivchenko, developing 1,800 hp coupled through a distributing gear to the reducing gears of the compressor for the lifting jets and the two airscrews, mounted abaft it, both of which have adjustable rotating blades, to provide for alterations of the distribution of power between them. When the hovercraft is running over smooth water, or any other very smooth surface, and the minimum hover height is required, maximum power is diverted to the air screw, with consequent achievement of maximum speed. When the surface is a rough one, however, greater hover height is required, with consequent greater diversion of power to its maintenance and, *ipso facto*, the speed is reduced. This engine, though occupying relatively little space and being relatively light, is about ten times as powerful as the piston engines used in earlier Soviet hovercraft. The vessel is steered by four aerial rudders, mounted abaft the two airscrews, which are hydraulically controlled from the wheelhouse.

In order to reduce weight to a minimum, the hull and superstructure are made of light alloy, the latter being designed on the lines of the fuselage of an aeroplane, to reduce air-resistance. Ballast-tanks are fitted, for trimming purposes, and there are the usual systems for pumping, sanitation and fire-fighting. Fire-resistant synthetic materials are used for the furnishing and decoration.

A NEW TYPE OF ENGINE FOR HYDROFOIL VESSELS

Engineer Yu. A. Bordovitsyn

THE effect of rolling and pitching on passengers and crew of a hydrofoil vessel is minimum when the wave-height is less than the clearance of the hull. In such conditions, a vessel fitted with controllable foils can develop her full speed with minimum acceleration of her centre of gravity. It is not possible to fit smaller types of hydrofoil vessel with very large struts for the foils, as this would reduce their stability too much, so it is obvious that only vessels of larger tonnage can have the requisite sea-keeping qualities.

At the time when a hydrofoil vessel is becoming foilborne, she is subjected to what is called the "hump of resistance", which is practically equal to the resistance at full-speed (notwithstanding that the latter is two to three times greater than the speed at which this "hump" is encountered). The propulsion plant must, therefore, provide sufficiently large thrust in both cases. It is particularly important that the thrust shall be capable of increase to ensure the quick emergence of the vessel on to her foils when there is a high sea, so that the shock of the waves on the hull at that time shall last for as short a time as possible. Hydrofoil vessels may be classified according to their foils, either as those with non-cavitating foils, or as those with foils working in fully cavitating conditions. For vessels of the former type, with speeds of up to about 60 knots, the resistance encountered is mainly that due to the foils (that due to the struts and other projecting parts accounting for only 15-20% of the total). At the speeds at which they go, the resistance of the foils varies only slightly, remaining steady at about 10% of the displacement, but that of the struts increases in proportion with the square of the speed.

The use of super-cavitating foils permits of the development of greater speeds with only moderate increase of foil-resistance, but the resistance of the struts and other project parts represents about 5% of the total resistance, and may reach as much as about 20% of the displacement.

The most promising types of sea-going hydrofoil vessels, and those which make full use of all the advantages of the hydrofoil, are high-speed vessels of large displacement with their foils working in fully cavitating conditions.

In an article by V. Yu. Tikhoplava, published in *Sudostroyeniye* No 11, 1961, the essential requirements of the propulsion installation of a hydrofoil vessel were specified as follows: low specific weight, great efficiency, high propulsive horsepower, simplicity, and reliability. To these should now be added that it must develop increased thrust at low speeds, so as to lift the vessel on to the foils quickly.

When it comes to the actual choosing of the type of power unit and the system of power transmission, many factors must be taken into consideration, such as the type of vessel and the service for which it is intended, the region in which it is to operate, and, of course, the displacement and speed.

It is obviously doubtful whether a gas turbine with reduction gear, mounted in a hydrodynamic pod can be used for high speed vessels with super-cavitating foils, because, as has been remarked earlier in this article, the resistance of protruding parts constitutes an important part of the total resistance. The propulsion unit of this type proposed by V. Yu. Tikhoplava is therefore suitable only for medium-speed vessels of large displacement with deeply-submerged, automatically controlled foils, working in sub-cavitating conditions. This is the opinion arrived at by Engineer A. N. Vashedchenko also in his article on "The New Type of Engine and Sea-Going Hydrofoil Vessels", in *Sudostroyeniye* No 9, 1962. It must be borne in mind that the great length of the fuel pipes and the considerable wastage of working gases must inevitably cause an increase in the loss of pressure in both the feed and the exhaust pipes, and that this affects the power and the fuel consumption of the proposed unit or calls for an increase in the diameter of the pipes which would increase the total resistance of the vessel.

The power required for larger and faster hydrofoil vessels can be obtained only by the use of a gas turbine unit of which two types have been developed for this purpose: a gas turbine with bevel transmission, driving a super-cavitating propeller, and a gas turbine driving an airscrew. The hydrodynamic qualities of a hydrofoil vessel with propellers working in sub-cavitational conditions are practically the same as those of one with an airscrew. In the former case, however, transition into a condition of greater cavitation with the increase of speed causes more rapid deterioration of the hydrodynamic qualities than that which occurs in the latter case, caused by the resistance of the airscrew.

The use of super-cavitating propellers is made more difficult by the fact that at low speeds the propulsive power of a super-cavitating propeller is extremely low, which means that the propeller cannot develop the high thrust required to raise the vessel onto the foils. It considerably increases, moreover, the complication and the weight of the propulsion unit.

The airscrew, on the other hand, being directly connected to the engine, requires no cumbersome shafting, or bevel transmission gear, and so on. The diameter of the propeller used must be very large, however. That required for a twin-screw installation must add up to little less than the breadth of the vessel, and this in itself makes airscrews unsuitable for use in hydrofoil vessels, quite apart from their susceptibility to the effects of spray and wash.

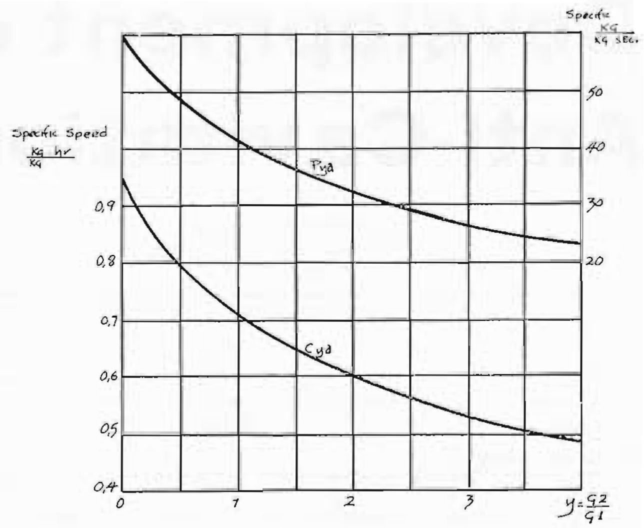
There is reason to believe, however, that in certain conditions aircraft-type turbo-reactor units, and especially those with a double-chamber, could be used in high-speed hydrofoil vessels.

Aircraft engine building has now become very successful. The double-chamber turbo-jet unit TRDD, Type 1TZD-1, for instance, as used in the Boeing 707-120B passenger liner, is officially reported to have a specific fuel consumption at full-power of 0.68 kg/kg thrust per hour and a specific weight of 0.27 kg/kg thrust. The relative air consumption through the second chamber is 1.4. With an increase of this value the flow from the exhaust nozzle of the second chamber decreases continuously, which leads, as can be seen from the attached graph (1) to a reduction of the specific fuel consumption. The increase of horsepower combined with the reduction of the speed of outflow in the second chamber leads to a reduction in the specific fuel consumption (2). It would be possible to design for a hydrofoil vessel a double chamber turbo-jet unit of this type which would be competitive, so far as specific fuel consumption is concerned, with a gas-turbine unit driving an airscrew or a marine propeller.

Effective steps could be taken to minimise the amount of sea water which passes into the air-intake, and to reduce noise, with the result that such an engine could satisfy all the requirements for a propulsion unit for high-speed hydrofoil vessels.

(1) Parameters of the working process:
  Coefficient of increase of pressure in the compressor of the 1st chamber. p = 6.0
  Coefficient of heating of the air in the first chamber. D = 4.0
  Fraction of the work transferred to the 2nd chamber for 1 cycle. x = 0.5
  Ratio of compression to expansion of the 1st and 2nd chamber $\eta_{s_1} = \eta_{r_1} = \eta_{s_2} = \eta_{r_2} = 0{\cdot}85$

(2) B. S. Stechkin, P. K. Kazandzha, and others, *The theory of jet engines working process and characteristics*, published by Oborongiz, 1958.



Dependence of the specific thrust and specific fuel consumption on the distribution of air between the first and second chambers

Adapted translation from the Russian of an article in "Sudostroyeniye", No 5, 1964

Development of Anti-Cavitation Erosion Alloys

	Chemical Composition (%)							
	Cu	Zn	Mn	Fe	Al	Ni	Sn	Be
Mn-Bronze	56.83	38.68	0.76	0.89	0.98	0.35	0.47	—
Al-Bronze	80.90	—	1.41	4.82	9.68	4.86	—	—
Cu-Al-Be Alloy	90.72	—	—	—	8.33	—	—	0.93

Table 1. Chemical Compositions of Mn-Bronze, Al-Bronze and Newly-Developed Cu-Al-Be Alloy

As materials for the marine propeller, Ni-A1 bronze or Mn-A1 bronze have lately come to be used extensively. These alloys, as compared with manganese bronze hitherto used, provide greater resistance to erosion and greater strength.

These aluminium bronze alloys, however, are more or less easily affected by cavitation-erosion if used on a hydrofoil boat, the propellers of which have greater numbers of revolutions, or large-size ships, the propellers of which similarly have a greater rotational speed. In recent years there is an evident tendency for the size of ships to become larger and larger and the speed greater. In view of the circumstances, it is inevitably desired that a material provided with a better resistance to cavitation-erosion than aluminium bronze be made available.

In order to satisfy the aforementioned requirement a series of search of adding beryllium to copper alloy, giving a higher property of precipitation hardening, has been conducted, and through these experiments a new propeller material, equipped with a higher rigidity and an improved resistance against cavitation-erosion, has been developed.

This new material is an alloy which contains in the base metal of copper, 4.0 - 9.8% of aluminium and 0.04 - 2.5% of beryllium, and, besides, its chemical composition is such that the ratio in weight of aluminium and beryllium content is more than 4.0.

A comparison between the above-mentioned Cu-A1-Be and the alloys conventionally used as marine propellers (manganese bronze, aluminium bronze), particularly in respect to their respective mechanical properties and anti-cavitation-erosion resistance, shows the following result:

Table 1 shows the chemical composition, respectively, of a specimen of the newly-developed Cu-A1-Be alloy, and the conventional manganese bronze and aluminium bronze hitherto used for marine propellers.

Figure 1 indicates the mechanical properties, respectively, of the three alloys listed in Table 1.

Figure 2 refers to the results of a test conducted on these three alloys in respect to their respective resistance to cavitation-erosion, on a magnetostriction vibration system cavitation-erosion testing apparatus having an oscillation frequency of 6,000 cycles, output 100 w, and amplitude 100μ.

The newly developed Cu-A1-Be alloy as shown in Figure 1 is provided with these properties: tensile strength 70 kg/mm^2, elongation: 16%, impact values: 5 kgm/cm^2, hardness: 180H; and thus it is proved to have better mechanical properties than manganese bronze or aluminium bronze.

At the present moment, experiments are being carried out on a hydrofoil boat equipped with actual propellers made respectively, of the three alloys listed in Table 1. The experiments so far undertaken amply attest to the superior properties possessed by the Cu-A1-Be alloy.

It may be added that a patent application is now pending for the Cu-A1-Be alloy.

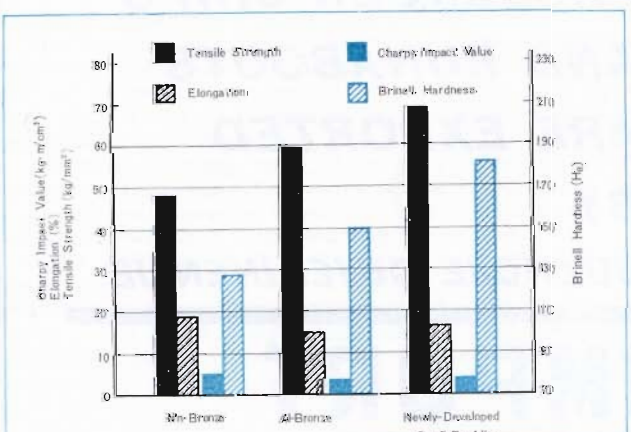


Figure 1. Comparison on Mechanical Properties of Mn-Bronze, Al-Bronze and Newly-Developed Cn-Al-Be Alloy.

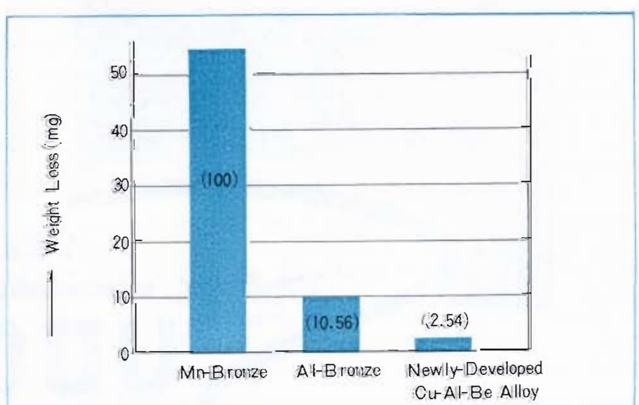


Figure 2. Comparison on Cavitation Erosion of Mn-Bronze, Al-Bronze and Newly-Developed Cu-Al-Be Alloy

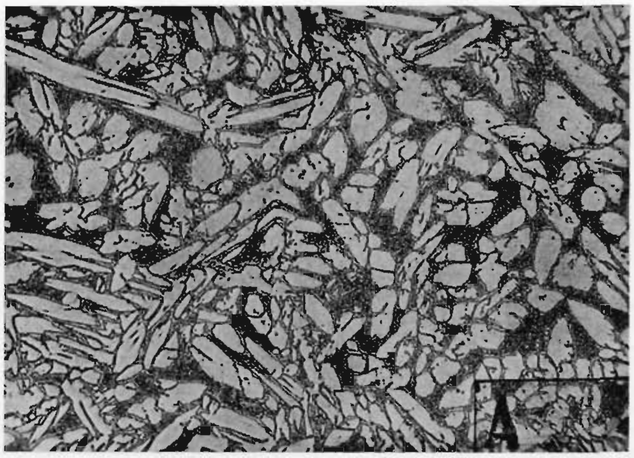
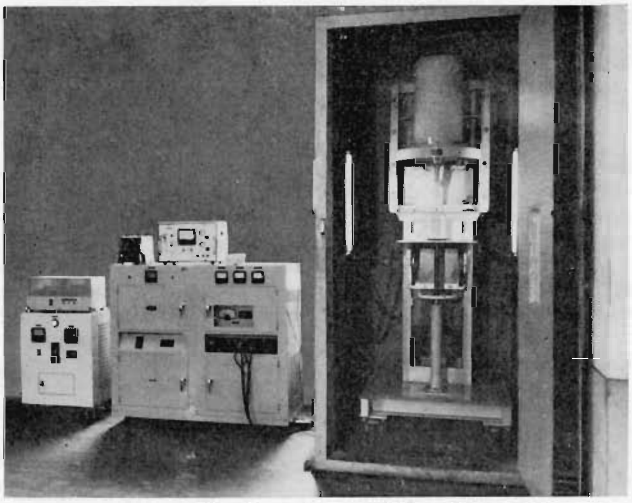
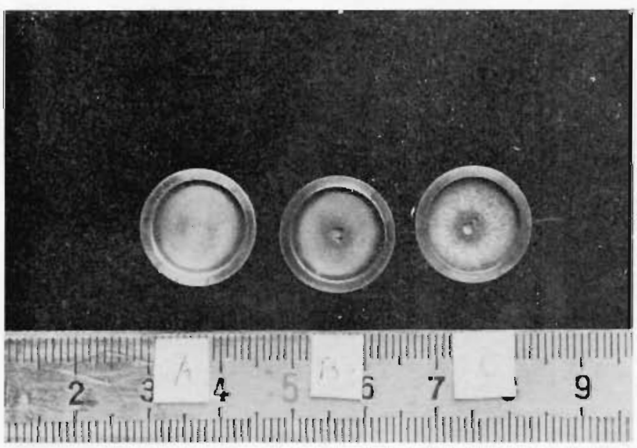


Figure 3. Micro Structure of Newly-Developed Cu-Al-Be Alloy (×200)



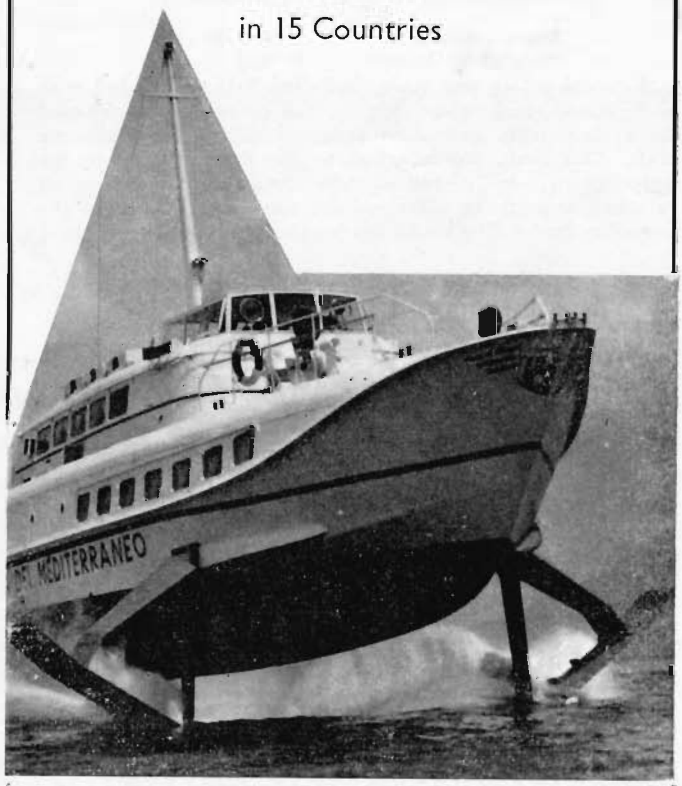
Magnetostriction Vibration System Cavitation Erosion Testing Apparatus, showing, from left to right, stabilizer, amplifier and phase control circuit, magnetostriction vibrator



Cavitation Erosion Tested Specimens :

A. Newly-developed Cu-Al-Be Alloy
B. Aluminium Bronze
C. Manganese Bronze

With acknowledgements to "Hitachi Zosen News"



A Note Concerning Cavitation on Hydrofoil Propellers

by

I. Eggestad

Scientific Officer at the Norwegian Ship Model Experiment Tank

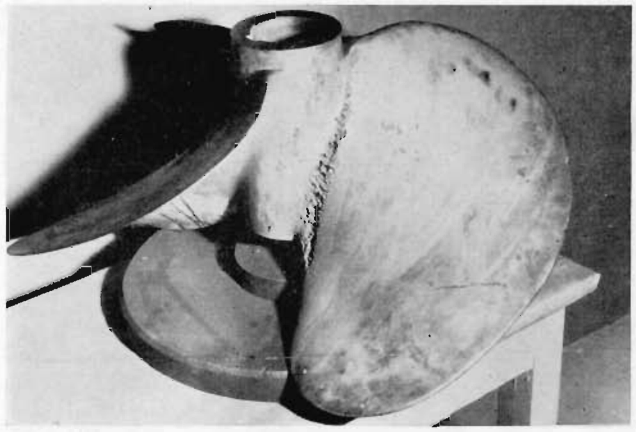


Figure 1

A COUPLE of years ago, the Norwegian Ship Model Experiment Tank (SMT) was asked to seek the reason for severe blade root cavitation on a hydrofoil boat propeller, shown in Fig. 1. The hydrofoil boat concerned has a displacement of sixty tons fully loaded, and is equipped with two propellers each driven by 900 shp at service speed of 34 knots. The propellers very often had to be replaced after only 300 hours service.

The propeller rata are:

Diameter	D	= 770 mm
Face pitch at 0.7 D		= 1,013 mm
Pitch ratio $(P/D)_{0.7}$		= 1,315
Blade area Ae/A		= 1,00
Number of blades	Z	= 3

A model set-up was made, including half the aft foil with shaft bearing and rudder (Fig. 2). The propeller was mounted on a shaft with inclination equal to that on the full-scale craft. This shaft was attached to the driving shaft in the water tunnel, by a rudder tube "universal" coupling of sufficient strength to withstand the torque and thrust of the propeller model. The cavitation number, based on the relative speed of propeller blade section at 0.7 D is $\sigma_R = \dfrac{P-P_V}{\frac{1}{2}\rho\, V_R^2}$ for the condition which should be investigated.

Reynolds number for model propeller, based on water speed at section length at 0.7 D was on an average $Rn = 1.27.10^6$.

Relative air content in the tunnel water during the tests, measured with van Slykes apparatus was $\dfrac{\alpha}{\alpha_s} = 0{,}15$.

Torque and thrust properties were checked in the usual way by plotting K_Q and K_T versus speed of advance J, and these characteristics show normal trends for the degree of cavitation which appear at this condition, Fig. 3. The propeller efficiency $\eta = 0{,}64$ at service speed = 34 knots was also found satisfactory.

The extension of caviation at various angular positions of the blades to the foil was thoroughly investigated. Besides the rather pronounced tip vortex cavitation and partly sheet cavitation, fluctuating cavities appeared at the base of the blades. Any steady blade root cavitation was not observed.

However, there was a marked tendency to cavitation at the bearing sleeve on the foil, which undoubtedly influenced the fluctuating bubbles mentioned above. Furthermore, cavitation was evidently formed also in the clearance between propeller hub and bearing, that, like the cavities travelling from the upstream end of the bearing sleeve, also created a sort of blade root cavitation.

After these statements it was decided, firstly, to elongate, and make it much more streamlined. Finally, the space between sleeve and propeller hub was closed with a thin walled tube, but still allowing the propeller to move somewhat in axial direction.

These alterations effected the cavitation appearance in a

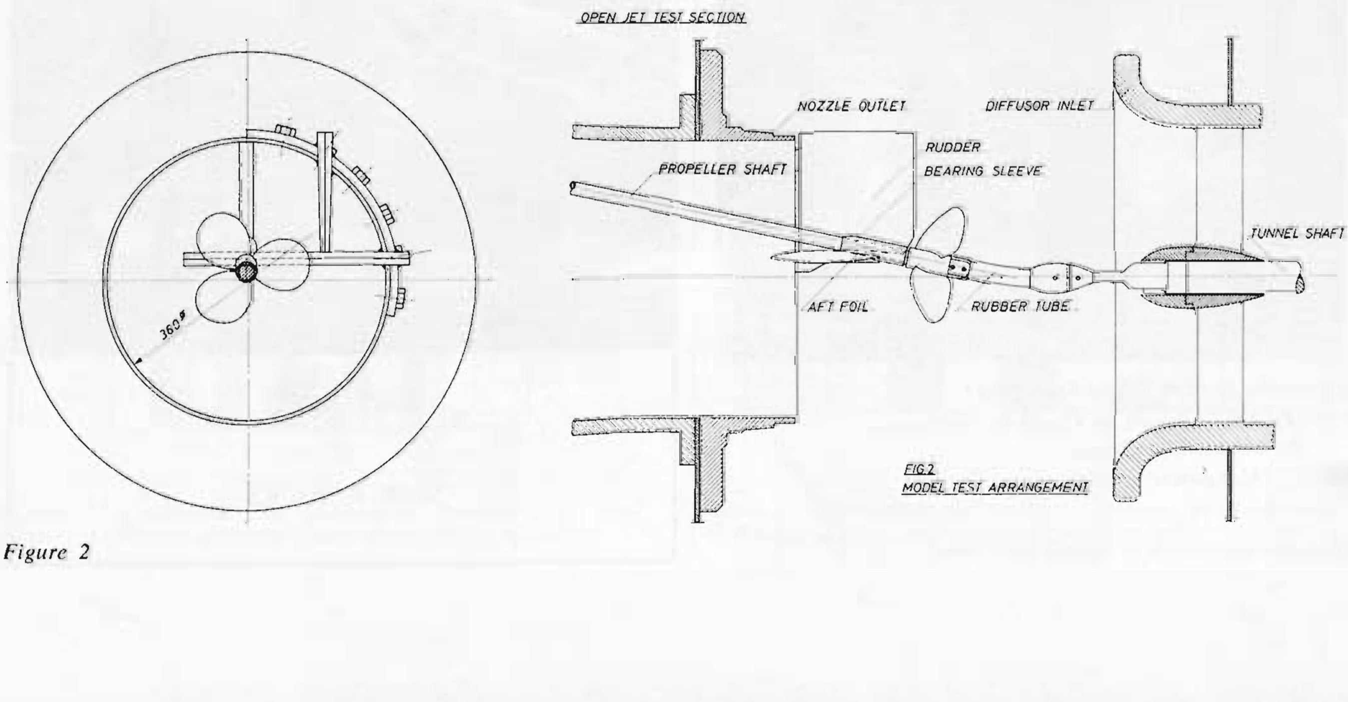


Figure 2

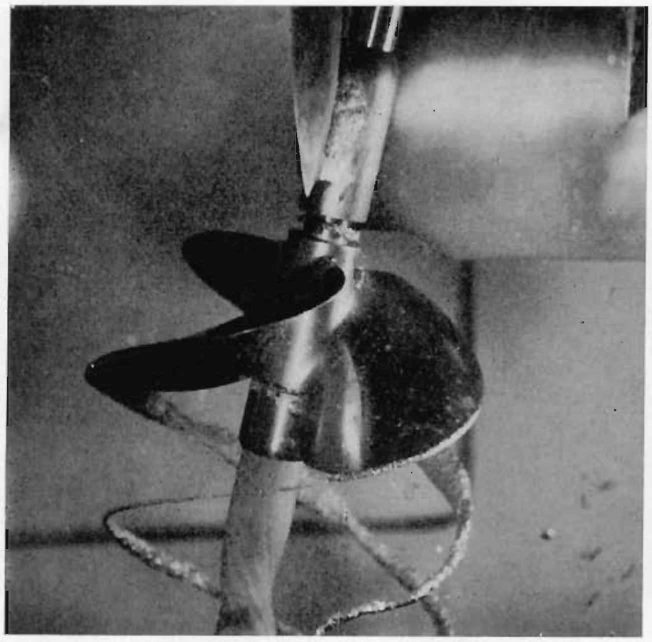


Figure 3

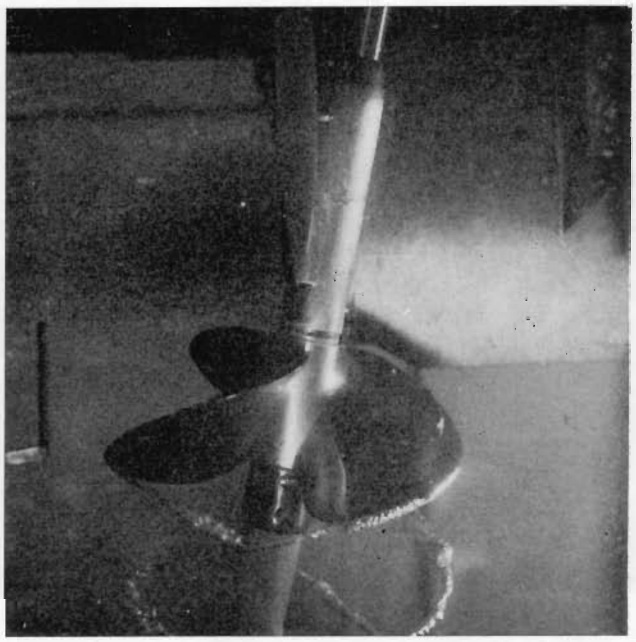


Figure 4

rather remarkable way, Fig. 4. Fluctuating cavities no longer exist near to the blade root, and also tip vortex cavitation seems to be less pronounced, probably due to a more steady flow around the bearing sleeve and consequently an improved wake distribution behind the foil.

If the simple alterations reported here improve the full scale cavitation condition to such an extent as should be expected from the test results, one cannot be too careful in designing upstream constructions to the propellers for high speed craft.

ACROSS THE SOLENT 1964

by

S. C. Smith-Cox C.B.E.

Chairman, Hovertransport Ltd

29,999, or 30,000 if you include the chimpanzee. From June 17th until September 1st, Hovertransport Ltd. operated a Hovercraft service across the Solent between Eastney Beach at Southsea and Appley Tower at Ryde. During the period 28,800 passengers were carried on the crossing, but including those who journeyed between Cowes and Southsea, and in reverse, when the craft started and finished its day's run, the total number was 29,999. In addition, one chimpanzee from a local Zoo was carried and thus the 30,000 was reached.

The service was planned to give nine crossings each way each day with the SR.N2. In practice these were augmented, when occasion demanded, and on days when the SR.N5 was in operation as many as twenty crossings in each direction were made.

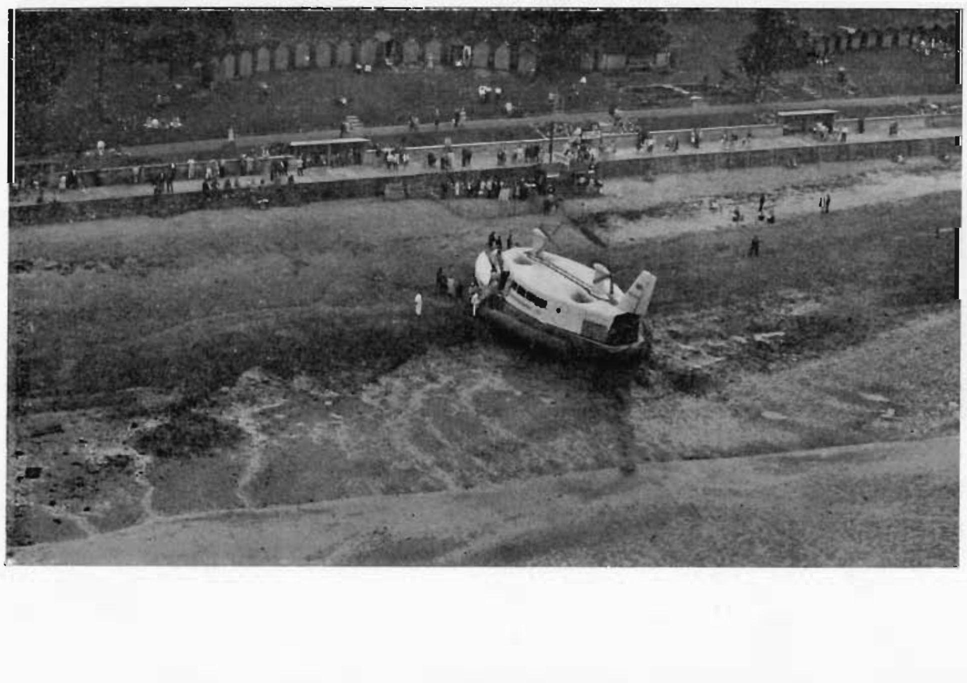
P. & A. Campbell Ltd (a subsidiary company of George Nott Industries Ltd) had operated a service with the SR.N2 in the Bristol Channel in 1963 and being one of the companies interested in Hovertransport Ltd, it can be said that the 1964 venture was a logical continuation of the one operated in 1963.

During the scheduled period, the service in fact operated on fifty days, either during the whole or some part of the day, and in almost every case during the whole day. Of those fifty days, the SR.N2 operated on all or part of thirty-three days and the SR.N5, which was used for a good deal of the time as a relief or standby machine, operated on all or part of thirty-six days. Both machines operated together on nineteen days. The service was suspended for weather reasons for two-and-a-half days only and for mechanical reasons on two complete days and six separate half days. These figures show a very considerable improvement on those obtained in the Bristol Channel in 1963 and have certainly confirmed, so far as I personally am concerned, my faith in the future of this type of craft.

Statistics can be boring, or they can be thrilling. Those operating the service viewed the latter word as the right one when on five days during the period over a thousand passengers were carried. Top day was Thursday, August 27th, when 1,431 people crossed the Solent on this form of transport. On this day, N2 made twenty-three crossings and N5 twenty-six. Second best was Thursday, August 20th, when 1,353 passengers were carried; the N2 making twenty-two crossings and the N5 twenty-seven.

A feature of SR.N5's participation was its continuous operation on several occasions for as much as nine hours in a day, without the engine being stopped. This reliability in a craft which is the first of its type and which had been launched only two months previously, indicates the technical strides since 1963.

To facilitate the handling of passengers, barriers were



erected on both beaches, together, in the case of Southsea, with not only an enquiry office, but a further small kiosk for the sale of souvenirs. Passengers on arrival were told by which journey number they could travel; issued with tickets accordingly and returned to take their places on the craft some ten minutes prior to departure. Enclosures into which passengers for each service were moved were erected on the beach, and a number of chairs for persons who wished to watch the operation were provided. Similar arrangements, on a slightly smaller scale, were in operation at Ryde and except for the fact that a string of buoys were laid to indicate the approach line of the craft on the Ryde side, no further work on the ground had to be done in connection with the service.

The issue of tickets, control of crowds and general handling of passengers was done by a staff of five on either side. One cashier, three beach staff who were for the most part students on vacation, and one beachmaster. In addition, a full time Manager for the service was seconded from P. & A. Campbell Ltd in respect of the Southsea side and a similar official from Britten-Norman Aircraft, from the Isle of Wight.

A total expenditure of approximately £500 was incurred in advertising the service, by means of handbills and posters throughout the Isle of Wight and in particular in the Ryde area and also on the Portsmouth side of the Solent. Newspaper advertisements opened the service and the amount of publicity and help given by the newspapers was phenomenal.

Reactions to new foms of transport are always interesting, as indeed are reactions to almost anything new in life. Conversations with passengers on the crafts and leaving them, showed a complete satisfaction with this new form of transport and indeed a great deal of enthusiasm for it. The fare was 10/- in each direction, but this proved no deterrent and during all except the last two services of the day, the crafts ran full to capacity. By the end of the service, numbers of business people were using it between the Island and the mainland, and the experiment as a whole proved a major success. Experiments are one thing: planned transport services another, and these crossings of the Solent were the second in the series of operations designed to get the necessary data to provide the craft necessary for commercial operation. The information gained during 1964 has encouraged those who are concerned with the operation of Hovercraft, and every effort is being made to speed the time when craft carrying both cars and passengers in large numbers will be in operation across the Solent.

Of 1965 it is as yet difficult to speak. Suffice it to say that, if possible, the service will once again be in operation across the Solent, thus ensuring that the goodwill built up in 1964 may be increased until finally a planned full scale service comes to fruition.

PRACTICAL EXPERIENCE WITH THE POWER UNIT OF THE HYDROFOIL MOTORBOAT "VIKHR"

A Alekseyenko
Chief Engineer "Vikhr"

The "Vikhr" is a hydrofoil built at the Krasnoye Sormovo Shipyard, Gorki, on the River Volga, and can accommodate 200 - 300 passengers. She has a cruising speed of about 50 knots, and a range, at that speed, of about 500 miles. She was completed in the late summer of 1962. Intended primarily for use at sea, rather than on rivers, she has been running regular services in the Black Sea, and is reported to have proved very satisfactory, even in rough weather

THE hydrofoil motorboat *Vikhr,* an experimental prototype vessel for carrying 260 passengers, has been in regular service in the Black Sea, in various sea conditions on the lines between Odessa and Kherson and Odessa and Nikolayev during the autumn of 1962 and the summer and autumn of 1963.

Her power unit consists of four diesel motors Type 150-F-4, each developing a maximum of 1,200 bhp at 1,850 rev/min, and a nominal 900 bhp at 1,600 rev/min. She has four propellers.

The following is a survey of the working of this power unit in various sea conditions, and with various conditions for the hull and foils.

For purposes of analysis, it is assumed that the regular characteristics of the engines are all the same, and that this applies also to all the propellers. In such conditions it would be correct to assume that the relative torques of all the engines are equal

$$\mu_1 = \mu_2 = \mu_3 = \mu_4 \;;\; \mu = \frac{M_i}{M_n}$$

where M_i is the torque of engine *i* in the assumed conditions

where M_n is the torque of the same engine in nominal conditions.

Equality of these relative torques is fundamentally essential for the working of the engines in parallel, since it provides for equal distribution of the load among them.

The following method has been adopted for expressing the working characteristics of the propellers.

If it is assumed that hourly consumption of fuel is directly proportional to the travel of the shaft of the fuel pump, one can arrive at a relationship between the hourly consumption of fuel and the travel of the shaft of the fuel pump at every number of revolutions per minute from slow speed to full speed (see Fig. 1).

When constructing the graph shown in Fig. 1, the maximum hourly consumptions of fuel with the fuel pump shaft in the "limiting" position have been taken from the outer factory characteristic shown in Fig. 3, and the minimum hourly consumptions for the same number of revolutions per minute, from their relationship to the travel of the shaft.

Fig. 2 shows the curve of the change of the relative consumption of fuel according to the number of revolutions per minute, as recorded on the test bed. If the position of the fuel pump shaft and the number of revolutions per minute at a given time are known, the hourly consumption of fuel can be taken from Fig. 1, and the power developed can be determined from the relative consumption of fuel.

Fig. 3 shows the outer and limiting characteristics. To facilitate analysis, these are related to the propeller characteristics obtained in practice in various conditions and constructed in the manner described.

Let us consider now the more usual working conditions in which the power unit of the *Vikhr* may operate.

Case 1 :

Hull and foils in clean condition; propellers not cavitating; 260 passengers aboard; no waves.

The normal propeller characteristic corresponding with these conditions is as shown in Fig. 3. The vessel becomes foilborne in Section B of this characteristic with some transfer according to the limiting curve.

The character of this section depends entirely on the rapidity of the build-up of the number of revolutions. Point A corresponds with the nominal condition of 900 bhp at 1,600 rev/min, with maximum power in reserve. This is the condition in which river hydrofoil vessels with similar engines and propellers normally work.

Case 2 :

Two hundred and sixty passengers aboard; propellers not cavitating; no waves; deposits on the foils of 1-2 mm of salt; and on the hull, of 8-10 mm of barnacles and weed.

Deposits of this nature occur during June, July and August if the vessel is running for eight hours in twenty-four, or lies at anchor for a fortnight.

The effect of these conditions on the normal working of the power unit can be discovered by adding the propeller characteristic for a foul condition to the normal characteristic.

Fig. 3 shows that the propeller characteristic is considerably steeper than usual and that at 1,600 rev/min it reaches the outer characteristic. The point 0_1 at which the propeller characteristic intersects the limiting characteristic, lies to the left of the point 0, which means that overloading occurs earlier, and at a smaller number of revolutions per minute, than it does in the conditions described in Case 1. The power overloading in this case is

$$q\% = \frac{N_D - N_A}{N_A}\, 100\% = 25.6\%$$

where N_D is the limiting power in foul conditions, and N_A is the nominal power.

Working in such conditions is not permissible.

Bearing in mind the high degree of forcing of the type of engine with which we are here concerned (its specific weight g 1.7 kg/hp), it is essential to be particularly careful to avoid any overloading.

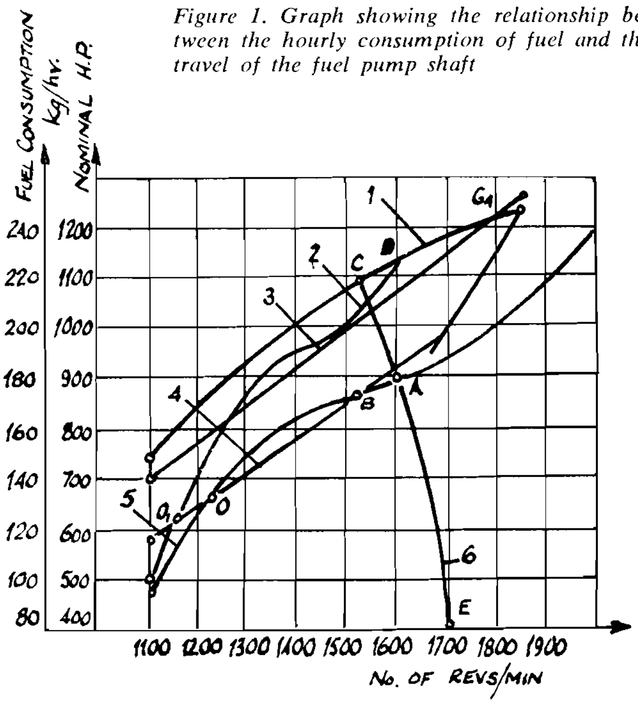


Figure 1. Graph showing the relationship between the hourly consumption of fuel and the travel of the fuel pump shaft

1 — 1850; 2 — 1700; 3 — 1600; 4 — 1500; 5 — 1400; 6 — 1300; 7 — 1200; 8 — 1100. The figures 1 — 8 relate to revolutions per minute

The method indicated of determining the load by the position of the shaft of the fuel pump makes it possible to choose a working regime which does not overload the engine. It is a particularly good thing to determine the weighting of the propeller characteristic on account of fouling of the foils. Fig. 1 shows the point at which nominal working — the position of the fuel pump shaft and the number of revolutions per minute — is regained after cleaning (with no waves).

Comparison should be made, with the engines running at the same number of revolutions per minute, between the positions of the fuel pump shaft before and after the foils have been cleaned, and if any overload is observed, the power unit should not be run until the periodical cleaning of the foils has been carried out.

Case 3 :

Hull and foils clean; 260 passengers aboard; propellers not cavitating; waves force 5, with 3% security.

In these conditions, the propeller characteristic will be heavier than usual. It will be impossible, however, to construct this on account of constant changes in the position of the fuel pump shaft. The analysis must therefore be done by comparison.

Let us assume that the vessel has risen on her foils inside the harbour and is proceeding to sea. The regime of the power unit is shown by point A on the normal propeller characteristic. Draw through this point the regular characteristic CE (see Fig. 3). Suppose now that the vessel has experienced a momentary shock from a wave of force 5 (while running, such shocks were of a more or less periodical character, according to the character of the waves). In such circumstances since the position of the organ for tuning the corrector remains unaltered, point A on the propeller characteristic moves along the correcting curve to point C on the outer characteristic.

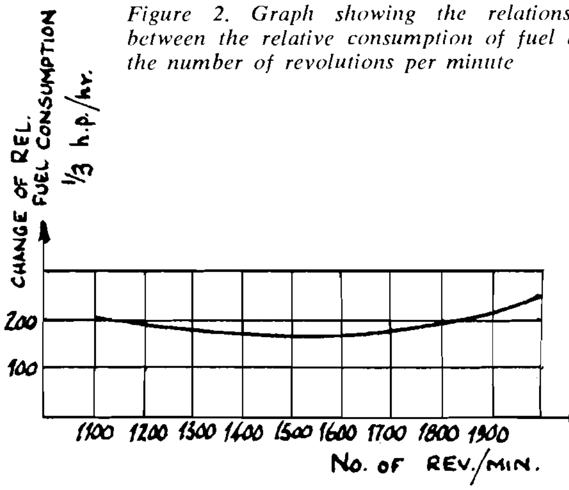


Figure 2. Graph showing the relationship between the relative consumption of fuel and the number of revolutions per minute

If the effect of the wave is more prolonged, the engine will begin to lose revolutions along the outer chracteristic until the vessel becomes a displacement vessel.

The overload due to the shock of a force 5 wave is

$$q\% = \frac{N_C - N_A}{N_A} 100\% = 20\%$$

where N_C is the maximum power under the shock of the wave, and N_A is the nominal power.

Such conditions very seriously reduce the reserve of power, since the overloading is of a cyclic character. The foregoing analysis affords a fairly clear picture of the regimes of the power unit of the motorboat *Vikhr* and makes it possible to arrive at the conclusion that sea-going hydrofoil vessels must have a power unit of sufficient power to be able to work at regimes below the limiting characteristic.

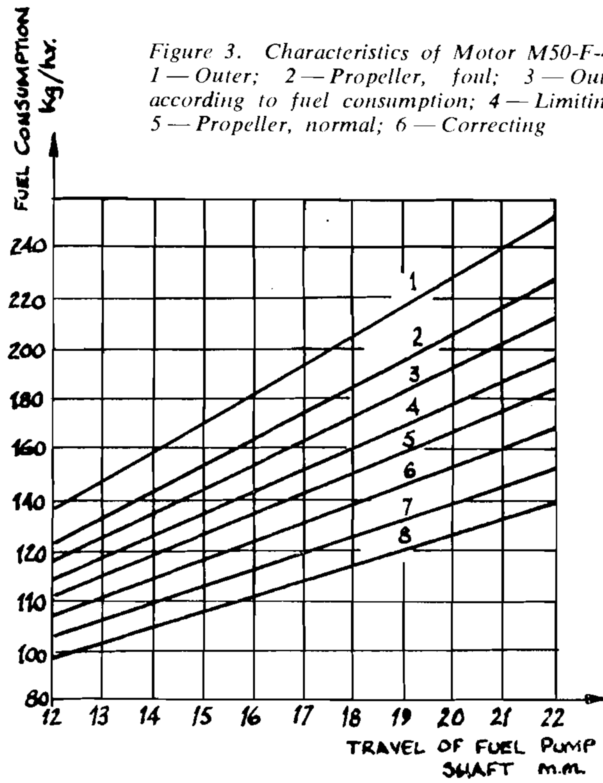


Figure 3. Characteristics of Motor M50-F-4 : 1 — Outer; 2 — Propeller, foul; 3 — Outer according to fuel consumption; 4 — Limiting; 5 — Propeller, normal; 6 — Correcting

Adapted translation from the Russian of an article in the Soviet Journal "Morskoy Flot", No 9, 1964

The Determination of the Stability of Vessels on Shallow-Submerged Foils

Engineer B. A. Tsarev

The hydrodynamic righting moments on submerged hydrofoils result from the increase of the lifting power of the foil subject to the following conditions:-

(1) If the relative depth of immersion is increased, $\bar{H} = H/b$ where H is the immersion, and b is the chord of the foil (Fig.1a). In practice, this concerns only shallow-immersed foils, with $\bar{H} \leq 1$ (Fig.2);

(2) If the submerged area of the foil, S, is increased on the side to which it heels, and is reduced on the opposite side (Fig. 1b) in vessels whose foils cut the surface of the water (this relates principally to V-shaped and "stepped" foils, though in the latter case the relative depth plays an essential role);

(3) If the angle of attack (a) of different parts of the foil or the flaps is altered (Figs. 1c and d).

From a theoretical point of view, the most interesting problem to be studied is that of the righting moments on shallow-immersed foils. Since the absolute value of these is less than those on foils which cut the surface, the methods of calculating them must be more accurate. The practical importance of having reliable methods of calculation arises from the fact that all our (Soviet) hydrofoil vessels use shallow-immersed foils, either alone, or in combination with various auxiliary devices, such as elements of V-shaped foils.

Practical formulae for estimating the stability of systems of shallow-submerged foils are given below.

The lifting force of a foil (or of part of a foil) which is slightly submerged may be determined by the following equation

$$Y = C_y(a, \bar{H})\, q \frac{V^2}{2} S \qquad (1)$$

where q is the density of the water;

v is the speed of the vessel;

S = l x b is the area of the foil (or part of the foil);

l is the span of the foil;

b is the chord of the foil.

Formula (1) shows that at a constant speed the change of lifting force depends on $\bar{H}$, S and A. Moreover, in systems without artificial control, it is possible to change H only, in the case of shallow-immersed foils, and S only in the case of foils cutting the surface of the water.

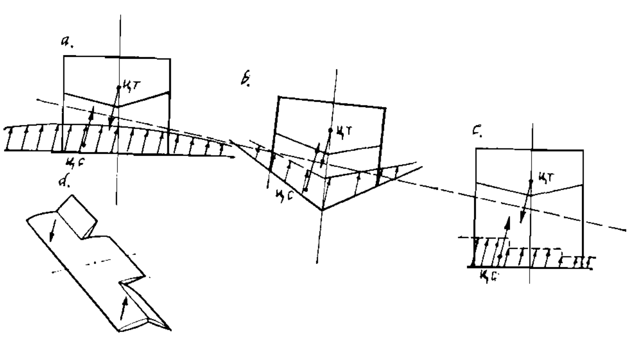


Figure 1. Drawings showing the development of righting moments for different foil systems

The Lift Coefficient at a given relative depth of immersion of the foil $C_{Y\bar{H}}$ is linked up with that of the same foil at an infinite depth by the following formula

$$C_{Y\bar{H}} = \int_{\bar{H}} C_{Y\infty} \qquad (2)$$

The magnitude of the coefficient $\int_{\bar{H}}$ found by experiment, is shown in Fig.2. The actual formulae (1) and (2) lead to a somewhat cumbersome solution, for which the following, more simple, alternative is recommended.

$$\int_{\bar{H}} = 1 - \frac{0.5}{10^{\bar{H}}} \qquad (3)$$

The proposed formula (3) is convenient for making calculations and alterations and requires no supplementary materials other than the two lower scales of an ordinary logarithmic slide-rule (the bottom scale showing the values of $\bar{H}$ and the second from the bottom, those of $10^{\bar{H}}$).

Research work in relation to the transverse stability of shallow-submerged foils has been done by G.A. Goshev (3) who has proposed the following formula for a stipulated metacentric radius, ensured by a separate foil or element of a foil

$$Q_i = \frac{Y_i}{D} \frac{5}{6} \frac{(1/2)^2}{b} \varphi_{\bar{H}} \qquad (4)$$

where Q and Y_i are the metacentric radius and the lifting force of a separate foil or element of a foil;

D is the total weight of the hydrofoil vessel.

The coefficient $\varphi_{\bar{H}}$ is worked out in his treatment (3) in the form of a graph. Analysis of the numerical values of various points on this graph shows that the coefficient $\varphi_{\bar{H}}$ is linked constantly with the magnitude of $\int_{\bar{H}}$ in the relation

$$\varphi_{\bar{H}} = \frac{1 - \int \bar{H}}{\int \bar{H}} \qquad (5)$$

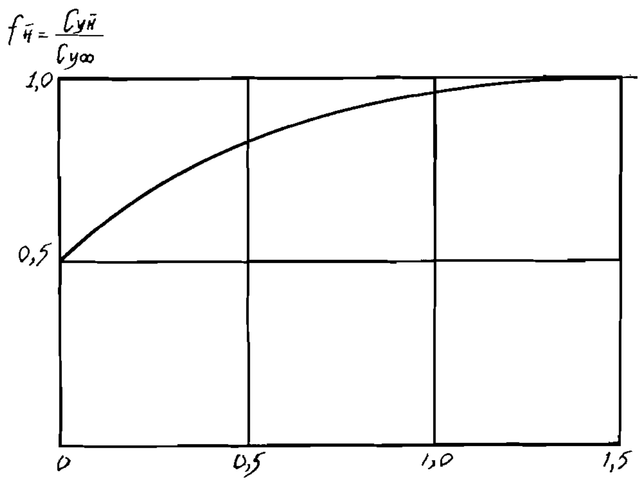


Figure 2. The effect of relative immersion on the coefficient of lifting force

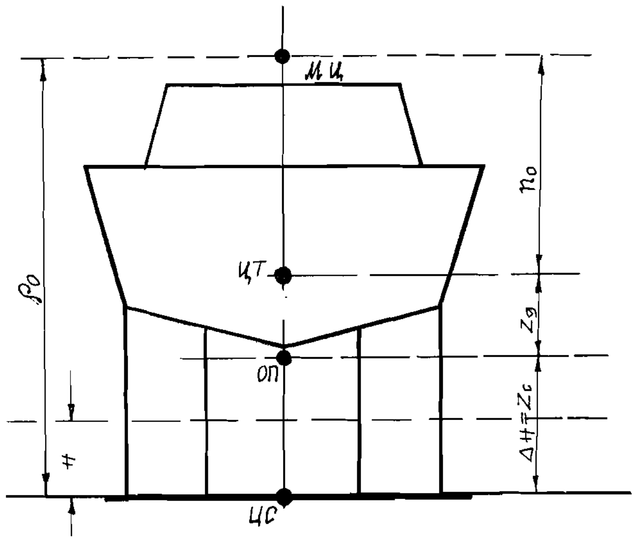


Figure 3. Plan for the determination of metacentric height of hydrofoil vessels

Thanks to equation (5) it is possible to find Q_i without reference to G.A. Goshev's graph. In particular, by using formula (5) one can arrive at

$$Q_i = \frac{Y_i}{D}\frac{5}{48}\frac{l^2}{b}\frac{1}{10\bar{H} - 0.5} \qquad (6)$$

It is reasonably safe to assume that $5/48 \approx 0.1$ and then

$$Q_i = 0.1\frac{Y_i}{D}\frac{l^2}{b(10\bar{H} - 0.5)} \qquad (7)$$

The points of application of the lifting forces of the foils (Fig.3) are in most cases situated below the reference plane and in practice are characterized by the distance from the plane ΔH or from the fixed point ΔH_i of the foil (for non-horizontal foils) from the reference plane of the vessel.

$$\Delta H = \sum \frac{Y_i}{D}\Delta H_i = Z_c \qquad (8)$$

ΔH belongs to the foil system as a whole, ΔH_i to a separate foil (or part of a foil). Thus the formula for calculating the initial stability

$$h_o = q_o + z_o - z_g \qquad (9)$$

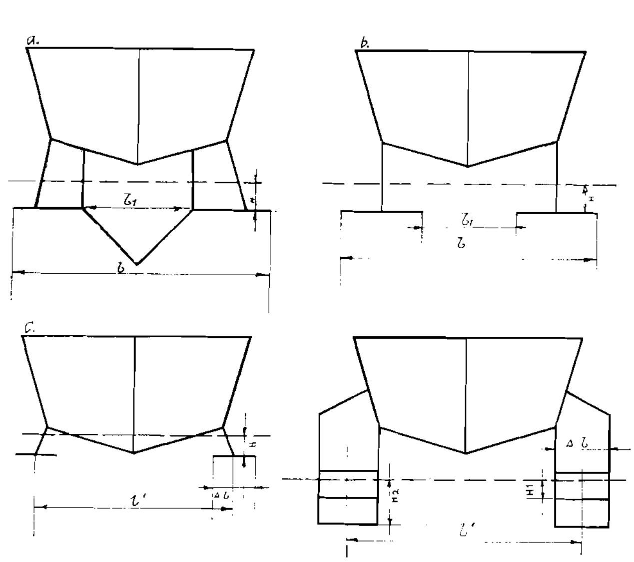


Figure 4. Variety of types of shallow-submerged foils

becomes

$$h_o = \sum \overset{o}{q}_i - \sum \frac{Y_i}{D}\Delta H_i - z_g \qquad (10)$$

The magnitude of Z_g is found from calculating the load, those of ΔH are geometrical characteristics and are determined by the drawing of the deposition of the foil structure. The magnitude of q_i for an ordinary flat, undivided foil is determined by formula (7).

For other types of shallow-immersed foils the following formulae for q may be obtained.

(a) for a foil with a dihedral (see Fig.4a) if a small allowance for safety is made, and if the effect of the dihedral on stability is ignored

$$q_i = 0.1\frac{Y_i}{D}\frac{l^3 - l_1^3}{l b(10\bar{H} - 0.5)} \qquad (11)$$

(b) for a divided foil (see Fig.4b)

$$q_i = 0.1\frac{Y_i}{D}\frac{l^2 + l l_1 + l_1^2}{b(10\bar{H} - 0.5)} \qquad (12)$$

For divided foils, the supplementary role of the small flaps under the foils (see Fig.4c) is quite in conformity with formula (12), but for practical purposes it is more convenient to express q_i by means of other characteristics (the dimensions of the foil)

$$q_i = 0.1\frac{Y_i}{D}\frac{(l')^2 + \Delta l^2}{b(10\bar{H} - 0.5)} \qquad (12')$$

Formula (12) may be used also for calculating the areas of the horizontal elements of twin ladder foils (see Fig.4d).

CONCLUSIONS

1. The formulae proposed make it possible to calculate simply and rapidly the characteristics of initial stability of a vessel with any system of shallow-submerged foils, and thus to establish the disposition of the foil structure from the point of view of stability in the preliminary stages of design.

2. Making calculations by means of these formulae requires no auxiliary materials, and the data for a foil structure may be given in the form of preliminary sketches, so that the method of calculation which has been described in appropriate for the variational analysis of any number of variants of foil structure and its position in relation to the hull.

3. If a series of calculations is made for various displacements, one can obtain a curve of the dependence of the initial metacentric height on the draught of the vessel T (see Fig.5a). In as much as each draught of a hydrofoil vessel T corresponds with a given speed v (see Fig.5c) the curve in Fig.5a may be reconstructed to show the dependence of h_o on the speed (see Fig.5b). The dependence $h_o = f(v)$ for many hydrofoil vessels may be evaluated by experimentl Comparison of what is found by such experiment with what is arrived at by calculation will confirm the reliability of the formulae given.

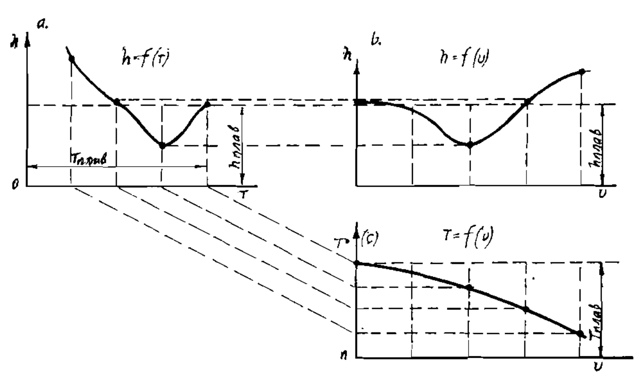


Figure 5. Graphs for the determination of the dependence of the metacentric height on the speed

Adapted translation from Russian of an article in "Sudostroyeniye", No 3, 1964

Stability of the Terraplane on the Ground

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The following is an annexure to Monsieur Bertin's paper presented to the Research Symposium on Air Cushion Craft held in the Department of Engineering, University College of Swansea, from July 21st to July 23rd, 1964, and published in "Hovering Craft and Hydrofoil" in the July 1964 issue

1. STIFFNESS OF A CUSHION-COMPRESSOR SYSTEM

Characteristic of a compressor:

$$p = f(Q) \quad \text{with} \quad \begin{array}{l} p = \text{relative pressure} \\ Q = \text{volume flow} \end{array}$$

hence:

$$dp = f'_Q dQ \qquad (f'_Q \text{ is } < 0) \tag{1}$$

In the plenum chamber exit, the jet velocity V_j is given by:

$$p_c = \frac{1}{2}\rho V_j^2 . \qquad \begin{array}{l} p_c = \text{chamber pressure} \\ \rho = \text{jet fluid density} \end{array} \tag{2}$$

Volume flow:

$$Q = S_j V_j \tag{3}$$

where $: S_j = \pi D h$.

with $: D$ = cushion diameter
h = cushion height.

From (3), neglecting the variation of ρ and volume of air in the plenum chamber

$$dQ = S_j\, dV_j + V_j\, dS_j \tag{4}$$

With (1):

$$dQ = \frac{dp}{f'Q} \tag{4a}$$

and (2):

$$d\,V_j = \frac{dp}{\rho V_j} \tag{4b}$$

the equation (4) becomes:

$$\frac{dp}{f'Q} = S_j \frac{dp}{\rho V_j} + V_j\, dS_j \tag{5}$$

Neglecting the pressure loss we have:

$$dp\left(\frac{1}{f'Q} - \frac{S_j}{\rho V_j}\right) = V_j\, dS_j$$

$$\frac{S_j\, dp}{\rho V_j}\left(\frac{\rho V_j}{S_j\, f'_Q} - 1\right) = V_j\, dS_j$$

or:

$$\frac{dp}{\frac{1}{2}\rho V_j^2} \times \left(\frac{\rho V_j}{S_j\, f'_Q} - 1\right) = 2\,\frac{d\,S_j}{S_j} \tag{5'}$$

With (2):

$$\frac{dp}{p_c} = \frac{2}{\dfrac{\rho V_j}{S_j\, f'_Q} - 1}\,\frac{d\,S_j}{S_j} \tag{6}$$

Putting:

$$C_K = \frac{2}{\dfrac{\rho V_j}{S_j\, f'_Q} - 1} \tag{7}$$

we have:

$$\frac{dp}{p_c} = C_K \frac{d\,S_j}{S_j} \tag{8}$$

C_K is the stiffness coefficient; the lift of the cushion is:

$$L = S\, p_c$$

where S is the basic area of the cushion. Hence:

$$dL = S\, dp_c \quad \text{if} \quad p = p_c \quad \text{as stated before}$$

Multiplying the first member of equation (8) by S, and with $S_j = kh$, hence $dS_j = k\,dh$, we have:

$$\frac{dL}{L} = C_K \frac{dh}{h} \tag{9}$$

2. STABILITY OF A PAIR OF CUSHION

Let a small incidence: $d\theta$ with respect to the equilibrum position, in bidimensional, the variation of average h corresponding to $d\theta$ is:

$$dh = \pm\, a\, d\theta \tag{10}$$

This relation is also true for circular cushions.

M : rolling (or pitching) moment:

$$dM = 2\,a\,dL = 2\,a\,L\,C_K \frac{dh}{h}$$

With (10), and weight W lifted by the 2 cushions : W = 2 L

$$dM_2 = a\,W\,C_K \frac{a\,d\theta}{h} = C_K\,W \frac{a^2}{h}\,d\theta \qquad (11)$$

Gravity moment:

$$dM_1 = W\,l \sin d\theta \approx W\,l\,d\theta \text{ (if } d\theta \text{ is small } \sin d\theta \approx d\theta) \qquad (12)$$

$$dM_1 + dM_2 = dM = \left(Wl + C_K\,W \frac{a^2}{h}\right) d\theta$$

Total moment (pressure center):

$$\frac{dM}{d\theta} = \left(C_K\,W \frac{a^2}{h} + Wl\right). \qquad (13)$$

Stability condition : $\frac{dM}{d\theta} < 0$, or :

$$C_K \frac{a}{h} + \frac{l}{a} < 0$$

C_K is < 0 [see (1a) and (2)]; hence we write preferably:

$$\frac{l}{a} < - C_K \frac{a}{h} \qquad (14)$$

Stability coefficient:

Putting $C_M = \frac{M}{a\,W}$,

we have, from (13):

$$C_M = \left(C_K \frac{a}{h} + \frac{l}{a}\right)\theta \qquad (15)$$

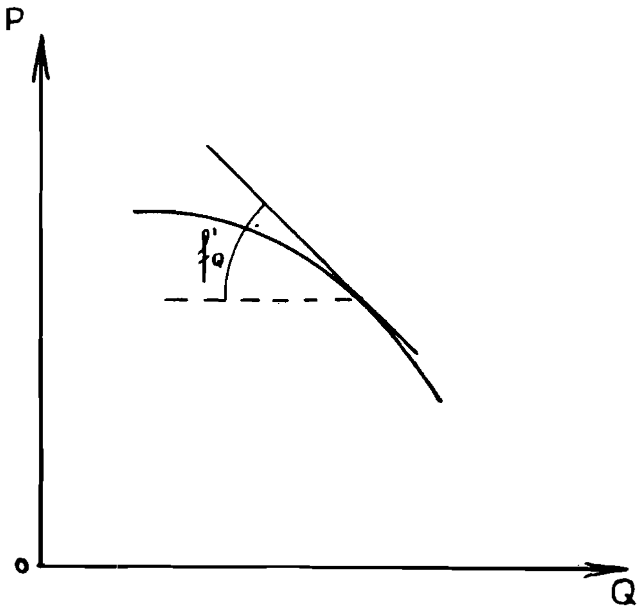

Figure 1

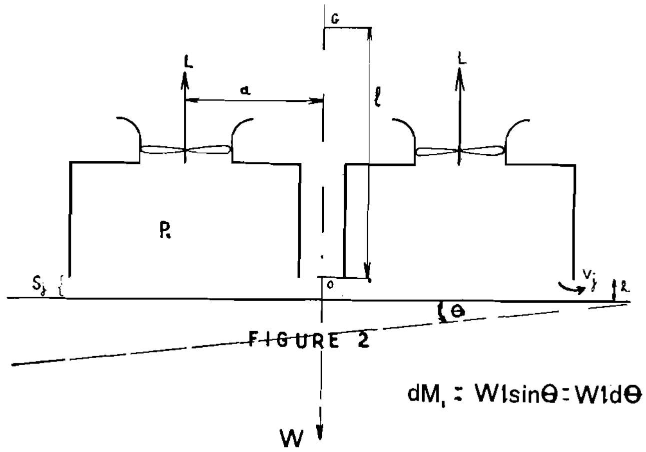

FIGURE 2

Numerical values for the Terraplane -

C_K is near - 1 (it varies very little with compressor)

We have : l = 2 m - a = 0,75 m - h = 0,05 m

hence : $\frac{l}{a} = 2{,}7$ et $C_K \frac{a}{h} \approx -15$

hence : $C_M = (-15 + 2{,}7)\theta = -12{,}3\,\theta$

The span is b = 4 a, hence is equivalent to a 6% shift of the C.P. per degree:

$$\frac{M}{bW} = -\frac{12{,}3}{4 \times 57{,}3} \approx 0{,}06 \quad \text{in rolling}$$

In pitching, this value is ≈ 0,12 (per cent of the length).

These values are very large, compared with those of peripherical jet GEM.

Obviously, this analysis is based on simplified assumptions, and is valuable only for the dimensions of the Terraplane. The experiments have entirely confirmed this conclusion.

3. DYNAMIC STABILITY

Dynamic beheaviour was studied theoretically and experimentally.

Dynamic stability is excellent. It decreases when h decreases, (tendency opposite of the one corresponding to the static stability), but it depends on other factors which are at our convenience.

Commercial Breakthrough

Westland has secured the first commercial orders to be placed anywhere for high-speed, amphibious hovercraft. First commercial sale of the 7-ton SR.N5—the world's first production-line hovercraft—was to Bell Aerosystems Company of Buffalo, N.Y. Orders have also been received from Scandinavian Hovercraft Promotion Limited A/S of Oslo, Autair Helicopter Services Limited of Montreal and Mitsubishi Heavy Industries Ltd., of Tokyo. "Off-the-shelf" delivery was assured by the Company's decision, in August 1963, to lay down a production line without waiting for orders.

Earlier this year, it was announced that the Ministry of Defence had decided, subject to contract negotiations, to order two of these very versatile small hovercraft for military evaluation. In making the announcement, the Minister of Aviation stressed that Westland had carried out the design and development of SR.N5 as a private venture. The Government were coming in after 'private initiative has shown the value of the project.' Only days before, the Company had delivered the $37\frac{1}{4}$-ton SR.N3—currently the world's largest hovercraft—to the British Armed Services, completing the only order so far placed for so large a craft.

Backing up these successes, sales negotiations are already well advanced with other possible customers in several parts of the world.

Twin sales successes. A 7-ton SR.N5 (foreground) keeps high-speed company with the $37\frac{1}{4}$-ton SR.N3 in the Solent

sustained
HOVERCRAFT LEADERSHIP

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