HOVERING CRAFT & HYDROFOIL

THE INTERNATIONAL REVIEW OF AIR CUSHION VEHICLES AND HYDROFOILS

Volume 6 Number 5

FEBRUARY 1967

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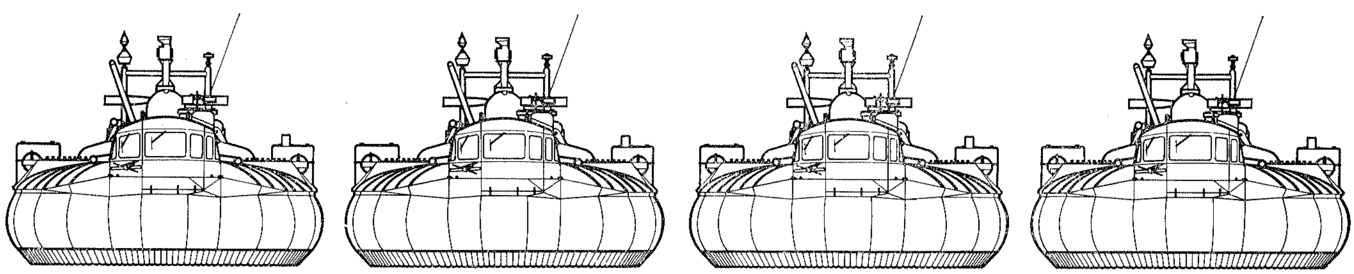


BHC hovercraft have now joined the forces – as regulars enlisted for active service, at home and abroad, with the Royal Corps of Transport Hovercraft Squadron. This vital decision by the British Government to purchase BHC SR.N6's for the world's first fully-operational hovercraft squadron, marks the full establishment of hovercraft as front-line vehicles with a vital role in military operations and will undoubtedly influence defence planning throughout the world.

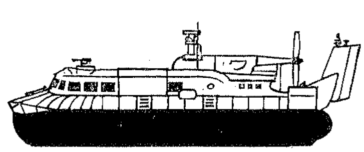
BHC hovercraft lead the world. Incorporating systems and components proven in over 20,000 hours of operation all over the world, the 10-ton SR.N6 carries 30 fully-equipped troops or over 3 tons of freight, and is able to mount the latest weapons systems. It cruises at 56 knots and is unrestricted by reefs, sandbanks, underwater defences, ice, tide state or shallows, giving military forces a freedom and speed of movement by day or night far in advance of anything feasible for conventional craft.

BHC hovercraft are the only hovercraft that have been used on military operations – both by British Defence Forces and by the U.S. Navy. They have proved themselves in extremes of climatic conditions, from tropical jungles and deserts to the frozen arctic – from Sweden to Sarawak, from Thailand to the far north of Canada.
BHC strength is further emphasised by the recent Government decision to order the larger 40-ton BH.7 in both the patrol boat version and the logistics support version.
The 10-ton SR.N6 is in full production with the 40-ton BH.7 to follow shortly.

BRITISH HOVERCRAFT–WORLD LEADERS IN THE HOVER TRANSPORT REVOLUTION

BHC

1966
WESTLAND AIRCRAFT LIMITED
SAUNDERS-ROE DIVISION



YEOVIL ENGLAND **british hovercraft corporation limited**

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JUANITA KALERGHI

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A Task for Britain's Youngest Ministry

THE news that a few of the latest emigrants bound for the United States are from the hovercraft industry comes as no surprise. What does surprise is the fact that such news has only just started to attract the attention of Parliament and the national Press. As is usual in cases of industrially important matters, the Press is a long way behind on the story and has presented an incomplete picture of the true situation to the public.

The journalistic term "brain drain" which has been devised for the situation is insufficient and misleading. "Talent wastage" would be better. The westward trek of manpower may be said to involve three classes. One comprises the academicians, or "way-out" men who think ten or twenty years ahead. Then there are the engineers, designers and design draughtsmen — real industrial talent and know-how is invested in this category, and they represent the most immediately serious loss. Thirdly, there is the important group of men who work with their hands, and of whom a considerable number have gone into Europe.

Using the bait of higher salaries and supervisory posts, it has been possible to entice home a few disillusioned and possibly homesick migrants. But it is only a very few, and the majority remain.

Obviously the task is to find the reason for the rot and stop it. In this direction the politically obsessed newspapers can always find a scapegoat in this or that government policy — or the lack of it. In this case they are wrong.

The first murmurings of discontent arise in a man who is dissatisfied with the management under which he works, the promotion schemes or absence of them. Poor management, lack of quality leadership, square pegs in round holes — these are the real instigators. To this must be added the alacrity with which some firms will take up licence production of a foreign component rather than develop their own design.

It was largely for these reasons that thousands left the British aircraft industry during the pinnacle years 1948 to 1958. Whilst trained men, many with apprenticeships behind them, left, others came in from milk rounds, garages, tailoring and many other walks of life. These were the days of full employment, no mergers, a surfeit of projects and full order books. Not all the leavers went abroad. Then, as now, many stayed in this country to enter more general industry.

The ladies and gentlemen of the Press and the Society of British Aerospace Constructors who have been concerning themselves with the problem of late, should note that it is one of over twenty years' standing. Only the degree has changed and this has now reached the stage where practically every major industry in the country is beginning to feel the effect.

It would be nice to know what measures the self-appointed experts on the problem envisage. How anything short of a complete reorganisation of the structure and status of technical staffs and pruning amongst senior executives will suffice, is hard to see. The operation is long overdue. Most certainly the use of semi- or complete nationalisation to impose Civil Service status upon technical staffs will not work towards the national interest. Men who think and venture ahead seldom enjoy working in a fettered environment.

There are, of course, some who take solace in nationalistic pride. For their benefit we would point out that the work of some of the earlier emigrants from this country appears in current British hovercraft and aerospace products. We refer, of course, to the American General Electric T.58 gas turbine produced over here as the "Gnome", the various constant-speed alternator drives that can go with this and other engines, and also fuel tank and hull sealants. In addition, there are all the major electrical and electro-mechanical components on the VC-10 and BAC One-Eleven airliners, as well as the complete APU of the latter. To these must be added the American propellers that are available through British licensees for future hovercraft.

It is our solemn belief that (under the leadership and guidance of Mr Wedgwood Benn) Britain's youngest Government Department, the Ministry of Technology, which may well have to face conflict and opposition from older-established departments, will nevertheless succeed in banishing the stultifying effects of "talent wastage" by reshaping the long-term development of British industry along productively efficient lines.

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COVER PICTURE: *A hoverterminal night scene. An SR.N6 hovercraft makes a smooth transition from water to land*

Hovercraft trial held in a playground. The boys of Barnstaple Secondary Modern School, Devonshire, give a push off to their hovercraft built by them as part of the School's applied science and technology activities. Barnstaple School is one of 60 involved in an applied science and technology project intended to develop the active ability and initiative in pupils which many educationalists feel is stifled by the academic strait-jacket of existing curricula. Most of the boys in the scheme are at public, grammar or technical schools

People and Projects

Öresundsbolagen have ordered another hydrofoil from **Cantiere Navale Leopoldo Rodriquez,** Messina. The craft will be a PT 20S type and will carry 110 passengers. Next summer Öresundsbolagen will operate six of these hydrofoils between Malmö and Copenhagen.

★ ★ ★

Mr Frank A. Dobson of California has patented an air car — a small vehicle with a fan that lifts it slightly above land, water, snow or ice on the "ground effect" principle. His company, Dobson Products, will sell the complete plans and operating instructions for $25. The cost of materials is estimated at $200, exclusive of the engine. The motor can be a unit of from 7 to 15 hp such as used in miniature cars.

The company will also supply a complete single-seater with engine for $1,500, and can furnish the fan and other parts for those who build their own vehicle.

The air car has a light wooden, plastic-covered frame, with the fan set in the front end at about 45° and a rudder at the stern. The slant of the fan provides both lift and propulsion. The pilot controls the air car with a stick.

Mr Dobson received his BSc degree in Electrical Engineering from Queen's University, Kingston, Ontario, and began his first work in the air cushion field in 1957 after many years spent on aircraft design for American companies.

In 1964, his Air Dart (which he designed for Air Cars Inc of Los Angeles) won the first air cushion vehicle race at Canberra, Australia. He subsequently founded his own company.

★ ★ ★

Societe Bertin of 28 rue la Boetie, Paris, builders of the Aerotrain, have developed a new hybrid vehicle for which they expect to find wide application in civil engineering jobs.

Caterpillar tracks are combined with an air cushion system in a vehicle intended for farming use. It is said to have excellent steering characteristics and to be designed to prevent soil erosion from the air blast.

The invention is the subject of British Patent No 1,053,394, published on December 30th, 1966.

★ ★ ★

Mr Basil Hurle-Hobbs, a former test pilot, has stated that his company will build a special pneumatic hydrocraft for an attempt on Donald Campbell's world water speed record of 276.3 mph. The craft uses a system of air lubrication to reduce friction and drag.

★ ★ ★

Two engineers from **Hovercraft Development Ltd,** Mr Michael Johnston and Mr Robert Moore, are leaving for jobs with Bell Aerosystems in the United States. They have been preceded by four others.

Bell Aerosystems already employ Mr John Chaplin, chief engineer for air cushion design, who went to America in 1962, and Mr Wilfred Egginton, chief of air cushion design technology, who arrived in America in 1963, as well as Mr Vernon Griffiths and Mr Reginald Page.

★ ★ ★

Hoverwork Ltd, the Isle of Wight hovercraft charter and training organisation, is one of the two companies to have been awarded a Ministry of Defence contract to train six officers and NCOs of the Royal Corps of Transport to operate British Hovercraft Corporation SR.N6 machines. The Army recently announced its intention to purchase four of these machines in the new year.

The course, which is the first of its kind for the Ministry of Defence, started on January 23rd and will continue for six weeks. Theoretical and practical training is being held in and around the Isle of Wight. On completion the personnel involved will undergo further training with the No 200 Hovercraft Trials Squadron — the first military hovercraft squadron to be formed.

Crew training for hovercraft operators is a particularly specialised field and Hoverwork Ltd is one of the few companies to exploit it. To date, it has trained personnel from both the Air Registration Board and Hovercraft Development Ltd, part of the National Research Development Corporation. In addition, the company recently chartered three craft and crew to Columbia Pictures for an exciting hovercraft sequence in the latest Dean Martin/Matt Helm epic, *Murderer's Row* — due to be screened early this year.

The Canadian subsidiary, Hoverwork Canada Ltd, will be operating two SR.N6 machines under contract to Expo '67, carrying passengers on a twelve-hour-per-day, seven-day-per-week service. Operating and maintenance personnel are currently being trained in England for the Canadian exercise. Expo '67, which opens in April in Montreal, will be the world's largest international exhibition ever staged. Hoverwork Canada's undertaking is being supported by the National Research Development Corporation, British Hovercraft Corporation — the manufacturers — and BP Canada.

★ ★ ★

Following one and a half years of regular operation, **Hovertravel Ltd,** the first-ever commercially successful hovercraft ferry service, is instituting a number of important internal company changes. It has been decided that more responsibility and authority should be given to local company executives. As a result, from January 1st, 1967, the following changes are announced:

Mr John S. Watford, formerly manager of Hovertravel's cross-Solent operation, has been appointed General Manager (Solent Operations).

Mr A. Smith has been appointed Senior Captain and Chief Instructor.

To date, Hovertravel has carried almost half a million people on its Gosport–Ryde–Southsea routes.

☆ ☆ ☆

Hoverwork Ltd, which was formed early last year to provide a charter and training service, is also consolidating authority in the Solent area.

From January 1st, Mr Christopher Bland, a Director of Hoverwork, becomes Managing Director.

Captain Peter Ayles, already a Director of Hoverwork, becomes Director of Operating Personnel. This will mean that he will devote more time to Hoverwork's activities.

Mr R. B. Stratton has been appointed Executive Engineer of both Hovertravel Ltd and Hoverwork Ltd.

☆ ☆ ★

British Hovercraft Corporation Ltd (BHC) has acquired the whole of the share capital of FPT Industries Ltd, The Airport, Portsmouth.

Mr W. F. Locke will continue as Managing Director. Mr D. C. Collins has been appointed Chairman, and Mr W. Oppenheimer and Mr L. Boddington have been appointed Directors. Mr Collins is Managing Director of BHC; Mr Oppenheimer, Assistant Managing Director (Finance); and Mr Boddington, Assistant Managing Director (Technical).

FPT Industries' general business is rubber processing and the manufacture of a variety of rubber extrusions and mouldings. The company also specialises in the development and manufacture of flexible sheet materials and their use in flexible self-sealing fuel cells for aircraft, marine craft, and wheeled and tracked military vehicles. Among these specialised products is the rubber/nylon laminate Hycaflex, which is currently used for the flexible skirts on BHC hovercraft.

FPT Industries has, for some time past, undertaken substantial business for both the British Hovercraft Corporation and Westland Aircraft Ltd, which has the major share holding (65%) in the corporation.

★ ☆ ☆

Men from Transport Command disembarking from one of Hoverwork Ltd's SR.N6 hovercraft. Six men will be chosen from this contingent to undergo crew training by Hoverwork Ltd. The course will last six weeks. Theoretical and practical training will take place in and around the Isle of Wight

Mr W. H. Fröbel, a mechanical engineer living in Johannesburg, South Africa, has recently built two hydrofoil models. The smaller one is driven by a propeller and works on diesel principles; the larger has a conventional spark-driven engine with propeller shaft, and has done 15 knots on Germiston Lake. At full speed the hull is completely out of the water.

Mr Fröbel started on the first German experiments in 1928 at Wiesbaden on underwater wings with new hydrofoils designed by Baron von Schertel. He accompanied him to Dessau-Rosslau in 1940, and there they constructed and built more than a dozen hydrofoils of different types.

Mr Fröbel was one of the men not captured by the Russians in 1945, and he still possesses two models of the hydrofoils.

★ ★ ★

Among the innovations to be introduced in the course of execution of the current Five-Year Plan in the USSR is a general **speed-up of coastal passenger services.** According to *Pravda* of December 11th, 1966, the average speed of these is to be increased one and a half times by the replacement of half of the existing vessels employed on inter-urban and pleasure cruising services. Express vessels, carrying 150 passengers at a speed of 25 knots, will be the new norm, the only type named, however, being the *Raduga*, which carries 40 more passengers than her predecessor, the *Arkadiva*, than which she is "considerably faster". Mentioned specifically is also a 200-passenger vessel for short-distance services, which is one and a half times faster than her predecessor and which can stand up to waves of Force 4.

★ ★ ★

A motor-cyclist, fifty-two-year-old **Mr Ernest Heffer,** of Gosport, Hants, was riding along the seafront at Lee-on-Solent, when an SR.N5 hovercraft, from the Inter-Services Trials Unit at HMS *Daedalus*, started to cross the road.

A Royal Navy sentry had already held up four cars to allow the hovercraft across, but Mr Heffer went past them and cut in front of the craft. He was summoned to appear in court and the case, at Gosport, was the first time a hovercraft had been involved in a *road traffic hearing*.

Captain Stuart Syrad of the Royal Marines, who had been behind the controls of the hovercraft, told the court that he was travelling at 10 mph. Mr Heffer claimed that there were no warning lights near the slipway and alleged that the Royal Navy sentry was too late in giving a halt sign.

Mr Heffer was found guilty of driving without due care and attention, and fined £10.

★ ★ ★

The formation of a **Hover Club of Canada,** with its head office in Fredericton, New Brunswick, was announced in January by the Honorary Secretary for 1967, Major Peter H. Rubie. The club will give assistance to hovercraft enthusiasts throughout Canada with designing, construction and handling of light air cushion vehicles, and through rallies and competitions will promote ownership of small sporting ACVs.

The Hover Club of Canada will be affiliated with the Hover Club of Great Britain, which will give Canadian members the advantage of the experience of the many home builders in the United Kingdom, and the benefit of practical advice from the club's Technical Advisory Panel.

Initially the Hover Club of Canada will operate on a national basis, with each Province represented on the executive committee. As membership grows, regional branches will be formed for competition purposes. Lord Brassey has graciously accepted the Honorary Presidency.

The address of the Hover Club is PO Box 341, Fredericton, New Brunswick, Canada.

★ ★ ★

Mr Leslie Colquhoun, chief of operations of **Hoverlloyd,** has been appointed managing director of the company. He joined Hoverlloyd in 1965 from Vickers Armstrongs (Engineers) where he was a test pilot, chief production test pilot and operations manager of the Vickers hovercraft division.

★ ★ ★

Vice-Admiral Ralph E. Wilson, USN (Retd), has been appointed Chairman of the Maritime Transportation Research Board (MTRB) of the National Research Council, succeeding Vice-Admiral William M. Callaghan, USN (Retd), who retired from the Board on September 30th, 1966.

Admiral Wilson is Vice-President of the J. J. Henry Company, naval architects and marine engineers. A graduate of the US Naval Academy, class of 1924, he served as Deputy Chief of Naval Operations from 1958 to 1960. Following his retirement from the Navy he was appointed Maritime Administrator and Chairman of the Federal Maritime Board by President Eisenhower.

The MRTB operates as an advisory group within the NRC Division of Engineering to stimulate research and the application of new knowledge in the field of maritime transportation. In seeking acceptable solutions to problems of water transportation, the Board works through special committees and panels comprising representatives of management, labour, government and academic institutions. The Board was established in October 1965 as a more broadly based successor to the Maritime Cargo Transportation Conference which was formed in September 1953.

The National Research Council is the operating agency of the National Academy of Sciences and the National Academy of Engineering. The two academies are private organisations devoted to the furtherance of science and engineering and their use for human welfare. They also serve as official advisers to the Federal Government in science and technology.

★ ★ ★

Rotork Marine Ltd, Bath, Somerset, sharing a stand with **G. Ruston & Son,** will exhibit for the first time at the International Boat Show at Earls Court on January 14th, 1967, the standard version of the Sea Truck which began production in July this year.

Best described as the marine equivalent to a lorry, with a flat load-carrying deck area of 170 sq ft (20 ft × 9 ft less control pedestal), it is said to be able to carry a one-ton load for seven miles at 20 knots in less than 2 ft of water on one gallon of petrol.

Its exceptional load/speed characteristics are derived from the air-lubricated hull principle developed in this form by Mr Jeremy Fry and first introduced in an "Aquaglider" sport version at the previous Boat Show.

The hull is constructed of fibreglass, in "eggbox" fashion, with built-in foam buoyancy, and complete with Volvo Penta Aquamatic 110/100 engine and all controls, the Sea Truck costs £1,875. The finished hull can be purchased without engine or controls for £990. A special export version, complete with all controls for the Volvo engine but without the engine, is also available at £1,150. A number of extra fittings such as helmsman's seat, windscreen, roof, navigation lights and passenger benches are available at extra cost.

★ ★ ★

On December 23rd, 1966, the **Berlin Aerotrain** test vehicle completed the first phase of its tests along a 4.17 mile track between Limours and Gometz. During the test a SEPR powder rocket was used to confer additional power which greatly increased speed. Two hundred km/hr were obtained with the 240 hp piston engine, but once the 1.2 m rocket was ignited speed raced to 303 km/hr.

★ ★ ★

A symposium on **High Speed Guided Transport** will be held at the Borough Polytechnic, Borough Road, London, SE1, on March 1st, 1967.

The problems to be reviewed are: Radar location of vehicles; signalling and traffic control; communications with moving vehicles; automation; application of computers to train movement.

Power requirements; suspension (wheeled vehicles/**hover-vehicles**); linear motor; current collection.

Mr S. F. Smith (British Railways Board) and Professor E. R. Laithwaite (Imperial College, London) will take the chair at the morning and afternoon sessions respectively.

The speakers will be Professor H. M. Barlow, FRS (University College, London), Professor F. T. Barwell (University of Wales), Dr L. L. Alston (British Railways Board), Mr R. B. Morris (Clare College, Cambridge) and Mr E. A. Rogers (British Railways Board).

Registration forms and the detailed programme for the symposium may be obtained by application to the Secretary, Borough Polytechnic, Borough Road, London, SE1.

★ ★ ★

The **"Third International Fair of Communications"** will be held in Genoa from October 12th to 22nd, 1967.

The classified list of sections for the exhibition includes the following :—

Sea, river and road communications
Energy for communications
Air communications
Telecommunications

Further details may be obtained from Comm. Dott. Carlo Pastorino, Piazzale J. F. Kennedy, Genoa, Italy.

★ ★ ★

From April 1st, 1967, the **National Physical Laboratory** at Teddington is to take over the Hovercraft Technical Group at Hythe as part of moves to strengthen Government-financed research into hovercraft.

Mr Anthony Wedgwood Benn, Minister of Technology, stated in the Commons that the Hythe technical group would come under a new Hovercraft Unit being set up at NPL. A section of the new unit would be attached to the Inter-Services Hovercraft Trials Unit of the Ministry of Defence.

Until now, the Hythe group has been part of Hovercraft Development Ltd. (HDL) a subsidiary of the Government-sponsored National Research Development Corporation (NRDC).

NRDC will continue, through HDL, to control patent rights for hovercraft and hovertrain inventions, and to consider applications for licences.

★ ★ ★

A spokesman for NRDC, commenting on the news that the technical group of Hovercraft Development Ltd is to be transferred to the National Physical Laboratory, Ministry of Technology, has stated :

"Two years ago, i.e. long before the merger of the hovercraft interests (last year there was a merger of the hovercraft interests of Westland Aircraft Ltd, Vickers Ltd, in British Hovercraft Corporation Ltd in which NRDC has a 10% interest) NRDC had concluded that in due time it would be better for the hovercraft research and development facilities of its subsidiary HDL Ltd to be sustained on a national basis, and we therefore requested the Ministry to take over these facilities. It was recognized by the Corporation when it made the proposal that it would require to continue to support the technical group until the Minister of Technology decided that the time for the handover was opportune."

★ ★ ★

On January 24th, 1967, a consignment of Atlas lamps and fluorescent tubes was loaded on board an SR.N6 hovercraft at Ramsgate Harbour, Kent, and crossed the Channel to France.

The cargo was the first ever to be shipped by this means, and the crossing was an exploratory one in view of the **Thorn Electrical Industries'** increasing business with Common Market countries.

★ ★ ★

In a supplementary statement by the Chairman of **Vosper Ltd** at the Annual General Meeting, the following was said :—

"In recent months there has been considerable speculation as to our position in the hovercraft field; we already have technicians who have started work on hovercraft and who will form the nucleus of our hovercraft team, and negotiations are at an advanced stage for us to assist as main sub-contractors to Cushioncraft Ltd in the design and construction of a hovercraft passenger/car ferry known as the CC.6.

"In the circumstances we are in touch with the National Research and Development Corporation in regard to our being licensed by Hovercraft Development Ltd, which we believe to be essential at this stage."

★ ★ ★

London may soon have **fire-fighting hovercraft** to tackle riverside blazes and ship fires, and the first of these hovercraft fire floats may operate from a new fire station at Upper Thames Street, near Cannon Street Station, equipped with a special slipway.

A London Fire Brigade spokesman said that officials had been watching demonstrations on the Solent. Two problems have to be worked out — whether they can be built large enough to carry the equipment, and whether craft of this size will be able to pass safely under the Thames bridges, whatever the tide.

★ ★ ★

A Theory Concerning the Dynamics of Hovercraft Lift

R. A. COLE

THIS article will be of most interest to aerodynamicists and others who may have a keen appreciation of the flow around aircraft wings and the associated air circulation. It is to be understood that unless otherwise stated everything in this article concerns a hovercraft in the stationary hovering condition. No translational effects are to be considered except towards the end of the article where acceleration from rest is specifically mentioned.

An inviscid perfect fluid has been assumed; the usual assumption in theoretical aerodynamics.

The concept was founded when the author tried to draw parallels between the lift mechanisms of aircraft and hovercraft. Very little has been written on the aerodynamics of hovercraft and it wculd appear that a concise theory has not yet been developed. Of course it may well be that an encompassing theory does exist under a classified heading.

Overall the approach has been biased from the start by the author's contention and pet theory that nothing lifts without some form of circulation. Thus in the case of an aircraft wing the lift is asscciated with a circulation of air. The well-known expression —

$$\text{Lift} = \Gamma \rho V$$

where

Γ = the circulation
ρ = the density
V = the velocity

ties them together.

Moving to other things one finds that a lift rises only when a cable drum is rotated, therefore a mass of metal is circulated. An escalator works in a similar manner. Hot air currents describe a spiral path as they ascend and in still air the smoke from a cigarette demonstrates this. So far as animal life is concerned, climbing a hill calls for increased heart action and hence an increased blood circulation.

Before leaving this fascinating subject it is worth mentioning that circulation appears to be associated with controlled descent also. Mechanical appliances such as the lift and escalator are obvious, while the vortex formed by water flowing down a plug-hole represents a natural physical phenomenon. From all the examples given it appears that in what plane the circulation takes place does not matter, but that it takes place does matter.

With all this in mind it is worth investigating the hovercraft to seek possibilities and proof as to where air circulation may take place. Again it must be emphasised that only the stationary hovering condition is to be considered. There is ample evidence of circulation taking place both as a part of and as an adjunct to the lifting system. Furthermore, such circulation appears to give rise to effects which are closely paralleled in aircraft aerodynamics. Of these the author's concept of an "induced weight" is closely analogous to the "induced drag" of an aircraft wing.

Vortices

If one considers the well-known air curtain which is developed around the periphery of a hovercraft it can be seen that an exterior vortex is formed by the escaping air. Additionally, the larger proportion of the air curtain which is directed under the hovercraft can form another vortex or a mass of smaller vortices. Fig 2 shows both possible systems.

Since air is continuously being fed into the internal vortex pattern a similar amount of air must escape from it; the theory of continuity dictates this. Thus it is reasonable to assume that air enters the inner chamber and rotates under the action of its energy. As the energy of the individual particles is dissipated they will move to the periphery of the chamber. Flowing towards the centre line, they will then pass along the only escape path, which is under the main vortex close and parallel to the terrain surface.

This outflowing air will interact with the vortex and produce an area of positive pressure beneath the platform. Diagrammatically it is seen that a system of contra-flow equivalent to that taking place beneath a lifting aerofoil is set up. Also it wculd appear that if the total circulation, the density of the air and the mean velocity of the escaping air are known, then the lift can be calculated. Fig 1 shows the flow and circulation around a lifting aerofoil.

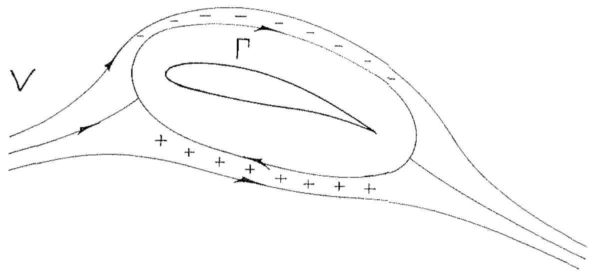


FIG. 1

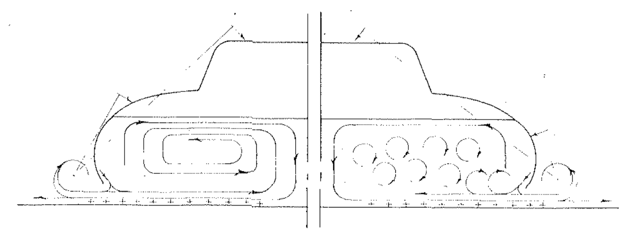


FIG. 2

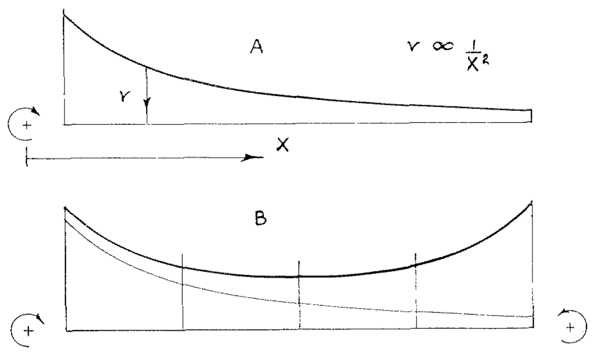


FIG.3

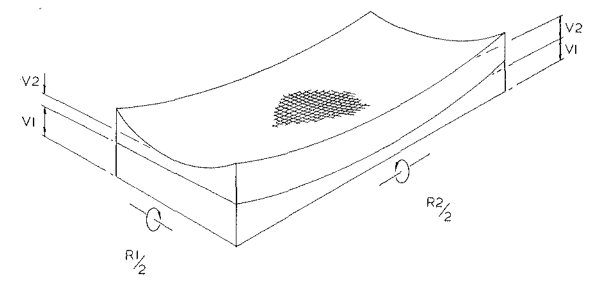


FIG.4.

Circumstantial Proof

If a hovercraft develops a pronounced list, or the surface were abruptly to change to give the same effect, then serious instability can develop, capsizing being the worst possible result. It is of some interest to examine the circulation theory to see if it can explain the phenomena.

Considering a full cross-section through a hovercraft in a canted condition, it can be seen that the lowest side will contact the surface and close the air escape path. Thus momentarily twice the amount of air will follow the escape path beneath the vortex on the raised side. The consequent increased lift from that side will combine with the loss of lift from the lowered side to create a powerful turning moment about the CG. This at least gives some validation to the theory that lifting vortices exist under a hovercraft.

Induced Effects

The external vortex system formed by the air which does not go under the platform will have an action similar to that of the trailing vortices at the tips of a finite wing. If we consider just one vortex at the end of a simple lamina it will give rise to a vertical air velocity all over the surface. The vertical velocity distribution is shown in Fig 3A. Adding a second vortex to the other end gives a similar pattern which can be added to that of the first, and this is shown in Fig 3B.

Naturally this vertical velocity will come to rest on the surface and give rise to a stagnation pressure $P = \frac{1}{2} \rho v^2$ Since its value will be additional to atmospheric pressure it will be equivalent to an added load and may be termed "induced weight". Very obviously it arises from similar circumstances to those which produce induced incidence and induced drag on a finite aircraft wing.

Efficient Planforms

To complete the picture one has to consider that a hovering platform occupies three dimensions and there will be additional vertical velocity components contributed by the vortices attached to the other two sides. Hence a 3-D model can be constructed as shown in Fig 4. In this the vertical velocity distribution due to the end vortices is seen at the bottom and that due to the edge vortices has been added on top. The uppermost and shaded plane describes the total vertical velocity everywhere across the platform.

All this suggests that a criterion somewhat analogous to the aspect ratio of an aircraft wing has some importance in deciding the efficiency of a lifting system. To minimise induced weight one obviously needs the maximum amount of area for the minimum length of peripheral curtain. It is an informative exercise to work out values for some basic shapes using a unit area. It is found that a circular planform is the most efficient for a peripheral curtain and here the ratio of peripheral length divided by unit area is approximately 3.54 : 1. Other shapes give higher values and are consequently not so efficient.

Sidewall Craft

Going back to Fig 4, one can see that if the sidewalls are employed to suppress the side vortex, then the velocity pattern is reduced to that of the lower part of the model. Since pressure is a function of v^2 the smaller the velocity then the smaller the induced weight. From this it is evident that the analysis agrees with what has been found in practice: that is, that sidewall craft require a smaller power for levitation.

For a design producing no side vortex and having a length of twice the beam, the ratio of curtain length divided by unit area is just over 1.4 : 1, and if the length is four times the beam then the ratio is 1 : 1. Of course, the ratio decreases still further with higher length-to-beam ratios.

Going back to wing systems, one may liken the front and rear vortices existing under the platform to the bound vortex on a model wing spanning the walls of a wind tunnel. In both cases the vortices end on a wall and are considered to be of infinite length — a situation that gives nil induced drag on an aircraft. Where a peripheral air curtain exists the internal vortex forms a collar under the platform and can be likened to the bound and horse-shoe vortex system of a lifting wing.

Although such analogies may be tenuous, the fact that they can be made is surprising.

Practical Considerations

Before leaving the subject of induced effects one or two remarks and observations must be made. Returning to Fig 4, it is to be noted that the velocity distribution surface as drawn applies to an infinitely thin platform. Practical depth combined with rounding of the edges of a typical hovercraft will modify this considerably. Velocity peaks at the corners would occur more inboard and have somewhat reduced values. It is of some interest to note that the fan intakes on the SR.N4 are near the apices of its plan at points where maximum induced velocity and hence stagnation pressure would occur.

At the intakes air will not come to rest and hence stagnation pressure will not arise there. A type of regenerative effect will be obtained with the air passing back into the circulatory system. An ideal arrangement would be for the entire top surface to be an intake.

Again in the case of practical craft the effect of depth also minimises the induced weight effect. This is seen from Fig 2, where some generator arms are drawn together with their normal velocity component. Thus, what is direct downward velocity and pressure in the case of a simple lamina becomes side pressure and reduced downward velocities in a real case.

It is in the realm of induced effects that the French Bertin system appears to be very efficient. Their unique arrangement employs a number of tuyeres protruding from the underside of a platform. Looking at a typical cross-section as shown in Fig 5, one sees that the generator arms from the exterior vortices will give rise to pressures tending to support the craft.

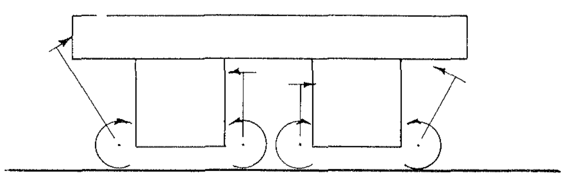


FIG. 5

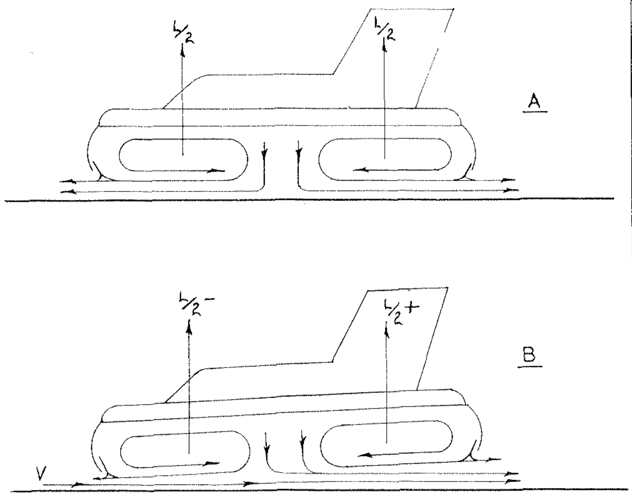


FIG. 6

Trim Change

Earlier the lateral instability condition of a hovercraft was invoked as circumstantial proof of the existence of internal circulation. The known trim change as a hovercraft accelerates from rest will be invoked as further proof.

The fore and aft situation with the craft stationary is shown in Fig 6A. Once it gets under way the outflow beneath the forward vortex is suppressed by the natural airflow. This volume of air, plus that flowing into the system from outside, must escape from the rear of the craft (theory of continuity). Hence the lift of the forward vortex is destroyed while that of the rear one is increased, and as a result the craft pitches nose down. In practice this action is trimmed out by the horizontal stabilisers, which have to produce a negative lift and so act against the positive lift.

Summary and Note

If the theory that there is a circulation is accepted, then its ramifications and impact upon hovercraft design could be enormous. A concept could be built up which together with basic formulae would allow rapid appraisal of many variations. In particular the effects of planform on the efficiency of levitation and the effects of motion could be more readily envisaged. At least one shape that deserves much attention comes to mind.

Everything tends to suggest that an important parameter could be the shape of the vortex chamber. With a suitable vortex theory it should be possible to derive chamber contours for maximum efficiency and for particular purposes in the same way that aerofoil profiles can be derived. In this direction it is worth noting that some skirts have an internal catenary.

At first sight a problem may be to get compatibility with the momentum curtain theory, which by the way is not invalidated by the suggested circulation theory. The momentum curtain is seen as part of the circulatory system. Levitation pressure exists within the boundaries of the outflowing air stream which passes beneath the curtain.

Furthermore, such an approach to the aerodynamics of the system may well lead to a much better understanding of vortices, their effect and techniques. Thus we may learn how to handle them better and use them to best advantage in both aircraft and hovercraft.

Finally, the ideas expressed here are entirely those of the author. He is in no way connected with any firm engaged on hovercraft manufacture or research, nor yet any institute, seat of learning or Government agency. Comment is invited.

LETTERS TO THE EDITOR

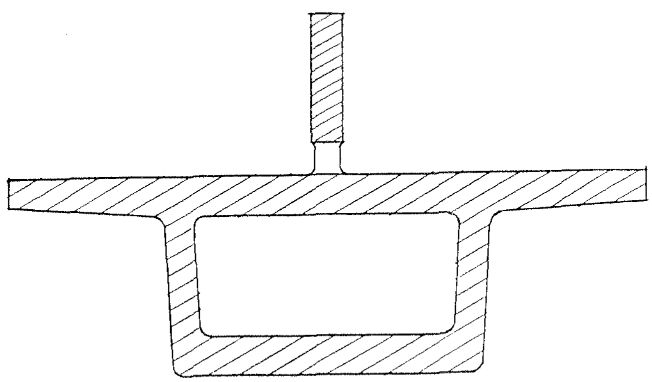
University of Leeds.

Dear Editor,

Hovertrains — Inverted T versus Rectangular Section Track

A point in favour of the "Inverted T" section, which does not appear to have been specifically raised in previous discussion on the subject, involves the manoeuvring of hovercars at terminal and other facilities.

It would seem that any hovercar with a body cross-section which is devoid of projections extending below the level of its main lift pads is inherently superior in this respect. Such a hovercar, designed to operate normally on an inverted T type of track, would, in the absence of the vertical part of the T section, possess complete freedom to move laterally in a two-dimensional plane. Thus, all that would be required in the form of track at a terminal or other facility would be a flat concrete apron. With the addition of steerable and retractable wheels, taking perhaps 10% of the total weight, the hovercar would then become more manoeuvrable than a conventional road bus.



Hovertrack — Inverted T combined with box sections

On the other hand, a hovercar with a body cross-section which extends down both sides of a rectangular section track would certainly require the provision of more complex switching arrangements. In fact, some type of traversing action in which a complete section of the track is slewed sideways would appear to be necessary. The need for unadaptable set-piece switching arrangements is one of the fundamental drawbacks of conventional railways and should be avoided if possible in a new system. In this respect at least, therefore, the inverted T holds an advantage over the rectangular section.

One of the disadvantages of the inverted T is that it is a poor beam section and thus relatively more expensive for the purpose than a rectangular box section. The accompanying sketch, based on the overhead concrete girders designed for the BARTD system in San Francisco, suggests how a track section might be designed which combines the advantages of both the inverted T and rectangular sections. The problem of debris collection could be avoided by providing a series of gaps through the base of the vertical guide. In fact the vertical guide might well be manufactured as a separate piece altogether.

Yours sincerely,

C. D. English

* * *

Nicholson House
High Street
Maidenhead
Berks.

Dear Editor,

The letter from Mr Gresham Cooke in your October issue has raised some interesting points concerning the development of hydrofoils in British waters. However, the possibility of developing new hydrofoil designs in the United Kingdom must have been under consideration repeatedly over many years in our own shipbuilding industry.

Our own experience in this field is limited to the economics of transport and studies recently undertaken for private sponsors in this country to establish the probable commercial prospects for hydrofoils and hovercraft in competition with established conventional ships. Using current designs of hydrofoils, some of which are in operation in many countries in Europe and also outside Europe, it is becoming clear that a strong economic basis does exist for hydrofoil services, when traffic justifies it and when the time advantage can be made to work favourably as a sales factor in those waters where harbours of the right type are available and where sea conditions are not too extreme.

The hovercraft, however, while holding out probably greater expectation for long-term economic advantage, especially in the larger sizes which will soon be available, is not an immediate commercial prospect and in many categories is not available immediately to offer direct competition.

As we see it, the hydrofoil and hovercraft potential will lie in different areas and in most cases, when it is quite clear what the operational objective is, research into the requirement will indicate the optimum vehicle to meet economic objectives.

Unfortunately, far too little research of this kind, combining engineering, economic and operational factors, has been done in this country. Fuller studies in this field are now surely required, if our ship builders and aircraft manufacturers are to concentrate on the best types for wide commercial sale.

Yours sincerely,

Alan H. Stafford

34 Waterside,
Martham, Gt Yarmouth

January 26th, 1967

Dear Editor,

For the apparent reasons of popularity and profit, the odd editor and writer continually hawk around the old potboiler that we are on the verge of sailing at twice wind speed by using hydrofoils. Thus I would tend to say to such as your last issue correspondent, Mr T. James, not to be too readily lulled into this well-worn trap.

By dint of long practical experiments, years ago I succeeded in getting lifted up on sailing hydrofoils, propelled only by wind velocity reacting on an aerofoil. This is a very much more difficult achievement than is the relative ease of lifting up on foils when due to the constant level mechanical thrust provided by an engine powered propeller or jet.

Therefore, whilst it certainly can be done by sailing, it only happens as a spasmodic occurrence. The process seems entirely too dependent on the inconstant fickleness of suitable wind and water conditions. In outcome, the opinion of some members of the Hydrofoil and Multihull Society and myself is that hydrofoil sailing is not within the accepted requirements of the vast majority of yachtsmen who usually want to sail sufficiently at any time for their pleasure and recreation.

Accordingly we went on to carefully develop the first classes of shallow draft advanced sailing yacht, such as Trifoil and Triforms, to embody an especially designed new form of hydrofoil. These configurations purposely affording only modified or partial lifts for improved stabilisation and superior seakindliness, besides entirely replacing the appreciable weight and high costs attendent in otherwise providing essential forms of keel.

Based on the aeronautical work of the Americans Wilbur and Orville Wright, these present British inventions have long since been fully proved by many independent people at home and abroad. The operative conclusion of these delighted users infers a bird in the hand is better than a dream in the bush.

Intended as a big advance on run-of-the-mill orthodox trimarans, the concepts of the Trifoil and Triforms alternately supported by one of their asymmetric working "Hydrowings", attached through streamlined " Storkcons" and low resistance "Meroloa" arms, are the synthesis of the progressive sailing yacht. A faster yet cheaper yacht, developed to obtain a wholly practical wind propelled hydrofoil system. Still to be fully appreciated, but in a variety of ways a distinct improvement on the basically unchanged yacht of tradition, yet enough like it to be capable of immediate use from the faintest breeze up to a gale.

The technology was explained in the paper entitled *Practical Hydrofoil Sailing versus Flights of Fancy,* by the H & MS in the March 1965 issue of *Hovering Craft & Hydrofoil,* Vol 4, No 6.

Rather than the sensationalism of extravagent prophecies of sailing at double wind speed, one must regard such realities as: (a) The wind, even when adequately present, seldom stays constant enough in velocity. (b) On open water when hydrofoil sailing winds blow, the water surface gets too rough to initially get something approaching a comfortable passenger hull accommodation up on to foils. (c) The hydromechanical couple of reaching has the fastest sailing potential, yet the resultant heel does not assist a full hydrofoil lift configuration. (d) Unlike the reserve power and (e) multidirectional ability of a motorboat, we found even a bit of seaweed would spoil sailing foil lift, as would much in the way of a change of course, (f) hardly to mention close tacking requirements.

This and more, direct information was presented many years ago to the editor of a specialist magazine, but he could hardly be expected to disseminate such findings when his publications invariably indicate their next issue may tell the reader just how to sail at 24 knots in a 12 knot wind?

Regrettably, additional to such natural obstacles as herein mentioned, it should also be considered, compared to the trifling resistance of a blade on hard ice, or even friction from

(*Continued on page* 13)

A single-seat Hoverbat was constructed on Hover-Air Ltd's stand at the International Boat Show at Earl's Court, London, which ended on January 14th, 1967

HOVER-AIR'S HOVERBAT

by our Special Correspondent

THOSE who lead busy lives centred on full-size hovercraft may well be excused for pursuing other hobbies in their spare time. Active people whose lives revolve around different spheres may well take an interest in the new mode of transportation for fun, and this could be a good thing for the industry. The Hover-Air Ltd Hoverbat which has been promoted nationally by the *Daily Express* has been designed for the adventurous handyman. It can be purchased complete or in kit form.

Purchasing the kit of ready-formed parts and building the craft will enhance the interest and education to be derived from such a project. So far as size is concerned, the basic hull structure could be assembled in any small garage that will accommodate a mini car, a bedroom or dining alcove. The forty manhours required could be accounted for in a week or two so that the prevailing domestic situation need not be disrupted for long. Attachment of the engines, lift fan, skirt and propellers will require further time and is perhaps better done out of doors unless more generous accommodation is available.

Costs

As purchased from Hover-Air Ltd, the basic kit of parts costs £65 and for this one gets all the necessary timber, ready-cut keel members, formers, ribs, spars, seat and control column. A ready-assembled kit including Perspex canopy costs £125 and of course the engines, propellers, fan, fuel tank and instruments have to be added. The fully comprehensive kit containing every item including the engines sells for around £550.

Of course, the engines — of which there are three — are expensive new items and the constructor can do a lot better for himself by adapting used units. Ingenuity and initiative will be required but this adds still further interest to the exercise. It is possible to employ a wide range of motor-cycle or even car engines, none of which is expensive in the used condition. In this way it seems possible that a Hoverbat could be built and tested for inside £125.

Assembly

The constructional task is very simple so far as the hull is concerned. It is held together in the main with Cascamite glue, which has excellent weathering properties and is universally employed by small boat builders. Most members are of plywood 9 mm thick, while a few are of 6 mm material. The assembly is self-jigging, being built around the base-board and two large internal keel members. An average handyman's range of tools is all that is required, although it appears that several pairs of "G" cramps are needed during the initial gluing phase.

All the metal fittings are simple and not beyond the scope of a local garage mechanic and his welding equipment. Their quality or lack of it is not going to make a scrap of difference to the performance so long as they are strong enough and not too heavy.

At the *Daily Express* Boat Show it was possible to inspect the prototype machine, its details, typical power plant installations and propellers. On the opposite side of the stand the work of building up a kit progressed, and it was hoped to hover it out at the end of the show — probably straight on to a customer's transport.

Even before the Boat Show numerous inquiries had been received from sources at home and abroad and still more were received during the show. Current kit production is at the rate of forty per week. It appears that there is a bottleneck in the distribution and in dealing with all the inquiries at this time. All quite understandable when one considers the small size of the organisation.

Technical Details

It is of some interest to view the technical characteristics and merits of the craft; they are quite surprising. In the current developed form which employs three Velocette two-cylinder horizontally opposed engines, fuel in the tank and ready to go, it turns the scales at a nominal 400 lb (181 kg). The single occupant must be added to this, so that the minimum all-up weight is in the region of 560 lb (254 kg). Total output from the three engines is 45 bhp, which means that the power ratio realised is in the region of 180 hp per ton. By comparison, the experimental HD.1 attained the lowest known value of 19 hp/ton and the SR.N5 requires about 33 hp/ton.

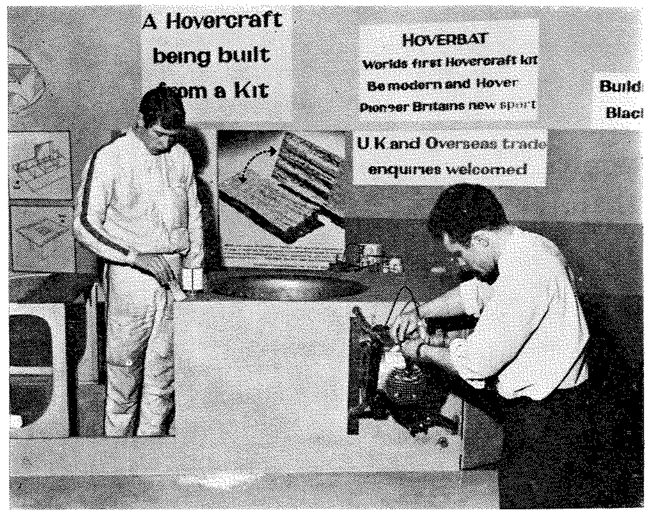
However, the situation is not quite as poor as would seem at first sight. First, the Hoverbat can lift the weight of four persons, so that at maximum load the power requirement is about halved. Second, the design is very fast and even the prototype has attained 50 knots (92.8 km/hr), so that further development can be expected to improve the picture still further.

Obviously a lot can be done on the power plant side, and it is in this sphere that the amateur constructor can make some experiments. The Velocette is ungeared and produces its maximum power at approximately 6,000 rpm. As a result of this high rotational speed the airscrew diameters have to be kept very low. Larger diameter airscrews would work at a higher efficiency but some form of gearing would have to be introduced if compressibility drag at the blade tips is to be avoided. The adoption of a single engine and reducing drives to the propellers would appear worth consideration.

The positioning of the two propulsive engines with their fibreglass propellers on outrigger arms allows differential thrust to be employed for turning when static or travelling slowly. Twin rudders of generous area are effective when under way. The third engine is mounted in a fibreglass funnel-like intake amidships and drives a multi-blade fan which supplies air for the cushion.

Performance

Hoverheight is quoted at 10 in (254 mm), but it is in fact slightly greater than this at maximum value. But it must be made clear that this figure does not represent daylight clearance but rather the depth of the skirt plus clearance. As already mentioned, one result of the high power loading is the very fast speed and it can be made to go faster yet. Dan Reece, the designer, is looking forward to testing one powered by the well-known Volkswagen car engine.



Michael Childs is seen painting the Hoverbat whilst Colin Neale attends to the fitting

Experienced hoverpilots say that there is nothing like it for thrills, and the training value of developed versions is thought to be considerable. Overland it was found to be faster than one of the military SR.N5 vehicles. It is also hoped that development will give even better hovering performance, and already a two-place version with side-by-side seating is being built in small numbers.

At this time Hover-Air Ltd is engaged in the construction of a five-place craft for Commander Costeau and it is intended for use in a film. A large proportion of the basic hull structure which incorporates the cabin has been completed. Three Volkswagen engines will be fitted and the propulsion arrangement will be somewhat similar to that seen on the Hoverbat. An early date in 1967 will see its completion. Further examples of this basic design are foreseen for use at coast resorts to give the public joy-rides along the sands and foreshore.

(*Continued from page* 11)

the ballbearings of a pneumatic wheel on hard smooth concrete or sand. There remains a rather different drag proposition for even small hydrofoils running in dense water.

All this is quite aside from the problem of initially getting enough speed to surmount the lift barrier hump. As a practical and academic teacher of sailing seamanship, I should finally mention terra firma testing situations may be a safer suggestion than the intolerance of the sea to the impractical.

Needless to say, the opportunity remains wide open for some free publicity seeker to perform on sailing hydrofoils before TV cameras. These will need to patiently wait for suitable freak conditions. In actuality it is much more likely he will stoop to resorting to the artificiality of being intially towed up like a glider, which is all a very different arrangement. Out of camera view, doubtless this daring exploit will be surrounded by rescue launches, as with the abnormally developed C-Class Catamaran out-and-out racing machines. He will be instantly acclaimed the patron saint of all yachtsmen, yet time is likely to show the vast majority of yachtsmen will not have benefited in the slightest degree. In any case, most sailing men are not the least interested in even using established advanced improvement in practical form, never mind about buying impractical freaks.

Yours truly,

ERICK J. MANNERS, MIN, AMBIM

Multihull Designer

From Ferry Boats to Hovercraft—Some Aspects of Economics and Operation

An analysis of operational factors, crew requirements and future prospects

by R. L. Trillo, CEng, AMIMechE, AFRAeS
Chief Development Engineer, Hovermarine Ltd.

This article is based on a paper presented to the Institution of Mechanical Engineers, Rugby Sub Branch, and the Coventry AD Graduates' and Students' Section at Coventry on December 13th, 1966

A FERRY operator contemplating the introduction of hovercraft on his services is confronted with a radical change in marine transport. This change from the ship demands the most careful study of the factors involved. A preliminary examination of the merits of hovercraft as opposed to conventional ferry boats need not be complicated, however, but must at least be on a rational basis. This article is intended to summarise a few of the main factors which have a bearing on the suitability of hovercraft in ferry operation.

As the hovercraft industry grows, many types of craft will become available and specific designs will appear for specific applications. As ferries, these craft will all possess a common property, the ability to carry a payload at a certain cruise speed. The product of this payload and speed, which may be called the potential work capacity, is the essence of the purpose of the craft and is, therefore, a logical basis upon which to examine other aspects of the craft, such as power and capital cost.

Comparative Payload

A modern ferry, having a service speed of 20 knots and weighing 3,000 tons, may be designed to carry 210 tons of that weight in payload, ie 7%. In comparison, a hovercraft ferry of the SR.N4 type, weighing 160 tons, can carry up to 37½% of its weight in payload, ie 60 tons. Consequently, it is seen in this example that 60 tons carried at 70 knots is equal in work capacity to 210 tons carried at 20 knots = 4,200 ton knots. As will be shown later, the actual work achieved in a day's operation will depend upon turnround time, block speed and utilisation.

The overall efficiency in terms of transport capability may be judged by the amount of installed power required per unit of work capacity. Fig 1 shows this parameter for a number of European ferry boats (as listed in *The Motor Ship*, December 1965), and for the SR.N4. It can be seen that for ferry boats operating on crossings of less than one hour duration, the horse-power per ton knot values (E_T) are mostly between one and two and the highest service speed is 17 knots. For longer

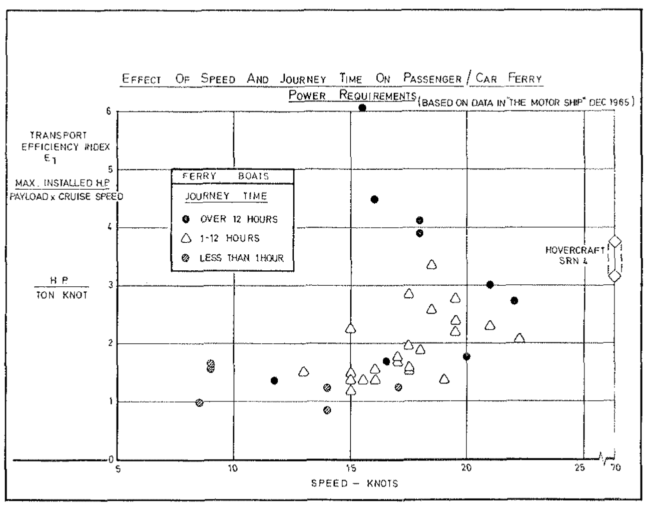


Figure 1

crossings of up to twelve hours, E_T reaches a value of 3.5 and speeds rise as high as 22 knots. For the longer journey more accommodation volume per passenger is provided and so relatively fewer passengers can be carried and sea states are higher so that the power-to-payload ratio increases. Overnight boats show even higher E_T values, reflecting the drop in payload carried as a result of providing overnight accommodation. The E_T level of the SR.N4 hovercraft is seen to be well placed, especially bearing in mind the speed of 70 knots. At 3.5 it is a little higher than the short-duration boats but since the craft is some three to four times faster than a conventional ferry boat this means that some overnight trips can become day trips.

* Formerly of Hovercraft Development Ltd.

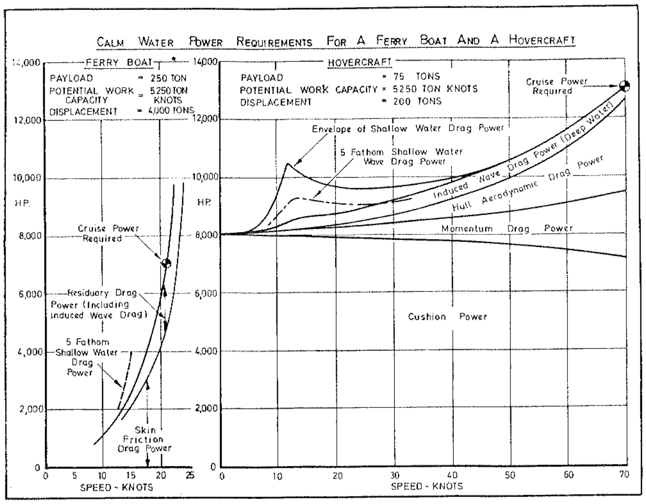


Figure 2

Observing from Fig 1 that the installed power requirements related to work capacity are not dissimilar for ferry boats and hovercraft, it is interesting to examine how the power requirements arise for the two types of craft. Fig 2 shows the breakdown of power for a hypothetical 4,000 ton displacement ferry boat and a hypothetical 200 ton displacement hovercraft of comparable work capacity. The boat is supported by buoyancy, travels through the water and incurs rapidly rising skin friction drag with increase in speed. Also rising rapidly and becoming a greater percentage of the resistance is the induced wave drag which manifests itself as the familiar wash. The hovercraft produces no such wash, but, as Fig 2 shows, a large percentage of the total power is used to support the craft on its air cushion. A hump drag condition is reached at a relatively low speed, around 15 knots in the example shown, at which the maximum water disturbance is reached, becoming negligible at cruising speed. The momentum drag power arises from the change of momentum given to the cushion air as it is accelerated to craft speed *en route* to the cushion. Some reduction in the level of power required for hovercraft cushion systems may be expected as development proceeds. Also, improvement in fan and ducting efficiency will come and the ability of skirts to follow closely the sea's surface. With such improvements the aerodynamic drag component will tend to become a larger percentage of the total so that more attention can be expected to be paid to hull form. Ferry boats, although experiencing only a few per cent of their cruise resistance as aerodynamic drag, are occasionally severely embarrassed by aerodynamic forces in gale conditions, tending to have rather high superstructure in comparison with other ships.

Effect of Shallow Water

Shallow-water effects on power required differ considerably for ferry boats and hovercraft. Some very thorough measurements on a Belgian Marine ferry boat provide sufficient data with which to predict the probable power rise incurred by shallow water of five fathoms, as shown in the example of Fig 2. The increased power needed arises from changes in the induced wave pattern, an increase of local velocities beneath the ship and a reduction in propulsive efficiency. It is apparent that the effect of shallow water on the power required is large and where such conditions are encountered in practice the boats concerned are either provided with sufficient margin of installed power to maintain normal speed, or are routed around the shallow water areas. In contrast, the hovercraft suffers no such penalty at its cruising conditions — in fact, for water depths less than craft length a very slight reduction in induced wave drag is predicted at cruising speed.

There is, however, an accentuation of the low-speed hump drag in shallow water conditions, although in the example shown this does not present a serious threat to performance. As hovercraft size decreases, hump drag does become a greater percentage of the total, and in the early days of hovercraft development some of the smaller craft experienced difficulty in "getting over the hump", aggravated by reduced thrust and increased aerodynamic drag in a head-wind condition.

Underwater Fouling

A power increment which has to be considered in the provision of adequate installed power for ferry boats is that due to marine growth fouling. One aspect of marine growth fouling which is pertinent to hovercraft is that of slipway fouling, which could presumably make some small contribution towards minimising skirt wear over the slip at low tide. Marine fouling on a boat may cause, over a twelve-month period, up to a 30% increase in power to propel it at the same speed as in its clean condition. There is no corresponding problem with hovercraft. On the other hand, hovercraft are more sensitive to waves and wind than ferry boats and consequently sufficient installed power must be provided to give the desired cruise speed under the majority of weather conditions during operation.

Capital Cost

The capital cost or first cost of a craft has a significant effect on the overall operating costs of a transport system. In judgment of whether a craft is expensive or cheap, it is all too often clear that the basis of reckoning is at fault. One hears that hovercraft are more expensive than hydrofoil craft or that aircraft are more expensive than ships — such statements seldom being accompanied by any basis for the comparison. When hovercraft first appeared on the transport scene it was common practice to say that, on a pound for pound basis, they would rest somewhere between ships and aircraft. The transport operator is not interested in a pound for pound figure (unless possibly he is selling for scrap); he is much more likely to be concerned with the capital investment in relation to the transport productivity of the craft. In practice, the productivity will depend not only upon speed and payload but also craft life, block speeds, practical scheduling and load factors. Despite these factors, a useful way of putting first costs in perspective is to relate them to the potential work capacity. When this is done, as in Fig 3, it is found that ferry boats and aircraft are on similar levels at somewhere between £200 and £400 per ton knot. At the present time, hovercraft tend to be a little above these figures, though the SR.N4 is in keeping with a number of current ferry boats, which is a considerable achievement when the very short period of development is considered in comparison with that of the ferry boat. With ever-increasing competition on sea ferry operations, we can expect to see conventional ferry boats becoming more complex in design to secure higher rates of working, leading to a higher escalation of costs than would normally be expected. In contrast, we would expect the hovercraft first costs to be a little eased as production in numbers increases.

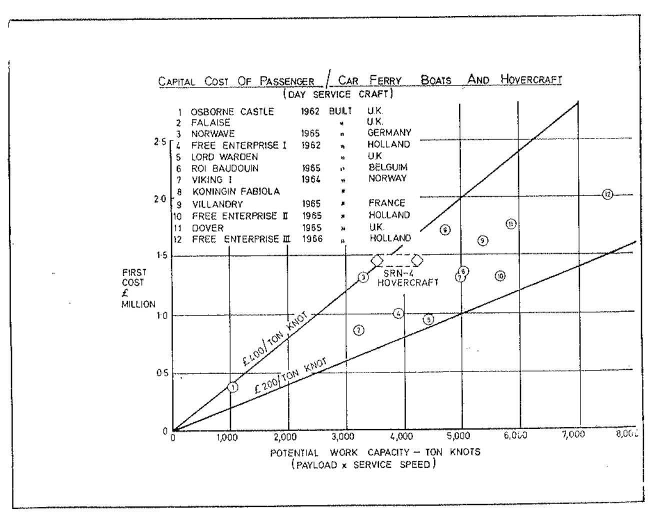


Figure 3

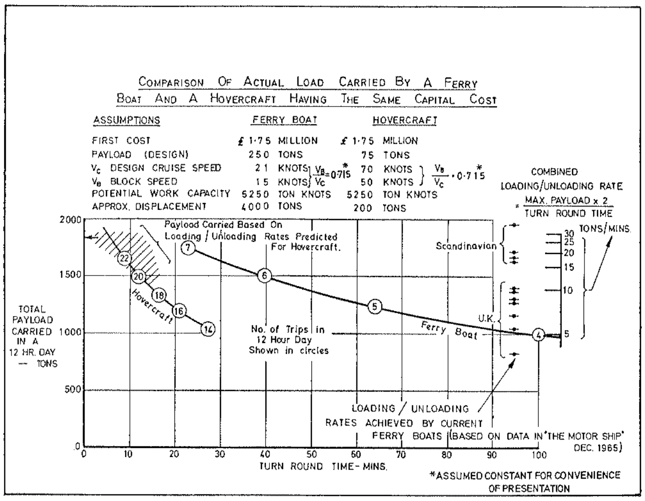


Figure 4

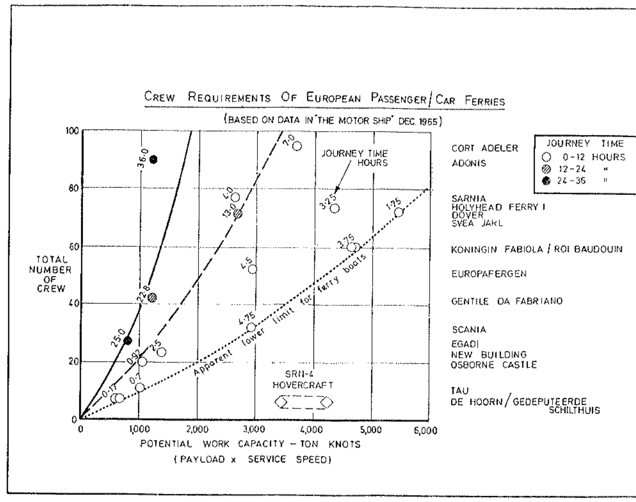


Figure 5

Turnround Time

Fundamentally, a transport craft is of no value while stationary — it has no earning capacity while stationary. In practice there are times when services have to stop for lack of people wishing to travel. During peak traffic periods, however, it is obviously desirable to reduce turnround time to the minimum. The particular operations required during turnround are considered during the design of the craft and in this respect the hovercraft basic shape, an almost rectangular planform, is of considerable assistance. For car ferries a straight lane, drive-on/drive-off system is possible. Many ferry boats are now designed in this way since the additional revenue earned, resulting from the quick turnround, more than offsets the slight increase in capital cost. Scandinavian ferry operators are achieving loading and unloading rates on a level with those expected for large hovercraft such as the SR.N4. Fig 4 shows the effect of turnround on the total load carried by a hovercraft and a ferry boat in twelve hours of operation. The two hypothetical craft have the same potential work capacity, 5,250 ton knots, and the same capital cost, £1,750,000. It is seen that for the same load transported, the hovercraft offers over three times the frequency of service. Even if a substantial reduction in turnround time is achieved for the ferry boat, at the very best it would probably only offer an additional two services in a twelve-hour day. Alternatively, it could mean the same number of services but at reduced service speed, requiring less installed power. At the present time, loading and unloading rates on UK services are below Scandinavian levels and current hovercraft thinking. Consequently, by introducing hovercraft on these routes, having the same potential work capacity as the ferry boats, we might expect, during peak traffic periods, a 30% increase in productivity resulting directly from savings in turnround time.

Crew Requirements

A review of current passenger/car ferry boats showed that a boat having the work capacity of the SR.N4 hovercraft would have at least eight times the number of crew members, ie forty-eight as against six. Fig 5 shows the effect of journey time on crew numbers required, from which the penalty of providing overnight accommodation is obvious. With manpower costs always tending to increase, the possibility as shown by the SR.N4 of a large reduction in this component of operating costs is a very attractive feature. Catering crews are carried on many ferry boats but are not yet contemplated for hovercraft, the one-third to one-quarter journey time being a decisive factor here. It is interesting to see, though, that on two Baltic ferry boats, the *Visby* and *Gotland*, pre-packaged meals are being served, avoiding the use of highly qualified kitchen staff and achieving a considerable and important saving in space. Developments such as this and the use of aircraft-type seating on ferry boats seem to point to passenger facilities approaching those in air transport as competition with hovercraft begins.

Environmental Capability

Wind and waves remain as two of the most important factors affecting the installed power requirements and, indeed, many other aspects of ferry boats and hovercraft. It might seem at first that the ferry boat has a distinct advantage over the hovercraft when operating in an environment of wind and waves. On closer examination, though, it is found that the hovercraft is not at all unfavourably placed in comparison.

It is convenient to assess wind and wave situation in terms of cumulative frequency of occurrence plots such as are shown in Fig 6. Such plots may be drawn, of course, for yearly, monthly or seasonal distributions. In our work on hover ferries at Hovercraft Development Ltd we have thought it sensible to select two frequency-of-occurrence levels for design purposes. We consider that for 85% of the year a hover ferry should be capable of operating without any restrictions. This would mean in relation to the sample wind and wave conditions shown in Fig 6 that on a cross-Channel route in the area shown, a craft would be designed to operate efficiently and comfortably in waves up to 6 ft in height and in mean winds up to 20 knots, together with an allowance for short-duration gusts of up to perhaps 35 knots. For more severe conditions, up to 98% or 99% of the time the craft would be capable of operating, but, if necessary, a reduced speed and/or a reduction in payload would be accepted. These conditions would imply operations continuing in wave heights of up to 10 ft and steady winds up to 30 knots. Experience with the 9 ton SR.N6 on the Solent would suggest that the above figures are very conservative. Despite this evidence, the hovercraft is more sensitive to wind and waves in terms of speed than is the comparable ferry boat.

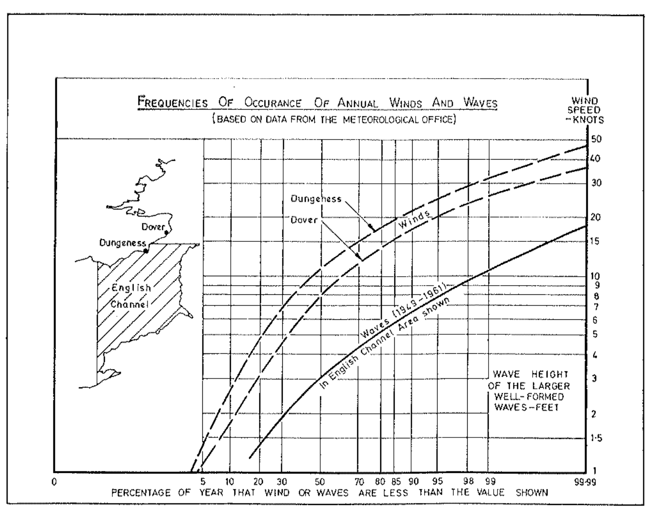


Figure 6

At a wave height of 6 ft and a wind of 17 knots (approximately the 85% conditions for the English Channel area), the worst penalty produced by a head sea on a ferry boat is only a 4% loss in speed from the calm-water, still-air condition. Although 4% may only represent about a 1 knot drop in service speed, to regain this speed would require about a 14% increase in power, hence the need for a good installed power margin.

A hovercraft, by virtue of its greater speed and greater percentage payload carrying ability, is about one-third of the length of a ferry boat having the same work capacity. Consequently, on this basis the waves are physically of much greater significance to the hovercraft.

Controlling the hovercraft speed/wave height relationship as much as resistance, is a consideration of an acceptable acceleration boundary, and of how the craft will ride over the infinitely varying sea surface. From experience gained to date with hovercraft, the frequency of motion is higher than that encountered in normal passenger-carrying ships such as ferry boats. From the passenger comfort point of view, this is a good result, moving away from motions liable to cause seasickness. The design aim, of course, is to reduce to the minimum the acceleration felt by the passengers. The frequency of acceleration is is very much dependent upon the length of the hovercraft and the waves over which it is travelling.

Although it is true that only a handful of passengers out of something like 500,000 who have travelled on hovercraft have been seasick, it would be a most worth-while accomplishment if this unpleasant business could be avoided completely. The hovercraft may well provide the opportunity to achieve this result for overwater travel.

Noise Effects

A hovercraft uses power for propulsion and support; the noise of amphibious hovercraft, as generally referred to, has been the external noise arising from the two main machinery components used for propulsion: the air propeller and the engine. Of these two sources, the air propeller has been found to be dominant. This situation has been due solely to the economic necessity of using existing aircraft-type propellers. Such propellers are designed to provide a good performance under aircraft flight conditions, which means, in most instances, a rotational tip speed of between 800 and 900 ft/sec. When used on hovercraft these propellers must still be operated at this speed in order to secure an efficient thrust level for the power input. All evidence of propeller noise points to relatively high noise levels being inevitable at such tip speeds even at distances from the propeller which may be considered excessive, for instance 500 to 1,000 ft. Without these readily available propellers, however, hovercraft progress would have been slowed considerably, awaiting the development of an improved design requiring considerable development effort. Development work is now in hand with the propeller manufacturers which will lead to the provision of low-tip-speed, large-blade-area propellers which should be very quiet in relation to present levels.

Non-amphibious sidewall hovercraft can be driven, of course, by conventional marine screws, and in this respect are as silent as ships. Development of this type of hovercraft has now been taken up in the UK by Hovermarine Ltd of Southampton. Britten-Norman Ltd has sought another solution to the air-propeller noise problem by driving the CC-4 and CC-5 hovercraft with centrifugal fan efflux, and the result has shown an appreciable reduction in noise, though at some unavoidable loss in propulsive efficiency.

Reprinted from "The Motor Ship", November 1966

Hovercraft in the USSR

by

Commander Edgar Young, RN(Retd)

INTERESTING revelations about the development of hovercraft in the USSR were made in *Pravda* of December 7th, 1966, by their Special Correspondent, K. Raspyevin, as the result of a visit to the laboratories of the Central Institute of Aerodynamics at Leningrad, where the fundamental research work in connection with these vehicles would appear to be conducted, and of a trial run on the River Neva aboard the fifty-seater *Sormovich* on or about December 6th, 1966, when the river was on the point of freezing-up for the winter. This trial run is described as "one of the last to be carried out this year", and one gathers that there has been some kind of hitch with this prototype fifty-seater, as it is stated that it had been intended that she should be on trial in actual operation, presumably on the River Volga, during the past summer, but no details of this have been published.

The trial was attended by Vladimir Borisovich Lyetistkiy, representing the Krasnoye Sormovo shipyard, at Gor'ki, where the *Sormovich* was designed and built, Mr Al'bert Abramovich Zhivotovskiy, chief constructor of that yard, and Mr Valeriy Romanovich Shevberg, who designed the vessel and supervised her building, the pilot and engineer being Messrs Min Alekseyevich Semyonov and Vitaliy Georgiyevich Savinovskiy. Much of the theoretical work would appear to have been done, however, by Mr Valentin Ivanovich Khanzhonkov, Candidate in Technical Science, shown in a photograph carrying out research with a scale model of the *Sormovich* in the wind tunnel at the Leningrad Central Institute of Aerodynamics, where he was interviewed by the correspondent, who described him as "the father of contemporary hovercraft", of which he is "keenly enthusiastic". It was on the basis of data derived from such tests in this wind tunnel that the early Soviet hovercraft, the thirty-eight-seater *Neva*, built in Leningrad, and the smaller *Raduga*, built at Gor'ki, as well as the *Sormovich*, here in consideration, were designed.

Mr Valentine Ivanovich Khanzhonkov carrying out research with a scale model of the "Sormovich" in the wind tunnel at Leningrad Central Institute of Aerodynamics

Little is written about the actual trial of the *Sormovich*, but it would appear that it passed off satisfactorily and that she will really be in service, on probation, next summer. What is of interest, however, is the correspondent's description of a documentary film which he claims to be the first man to have seen, apart from the research workers at the Institute of Aerodynamics. It would appear from this film that Soviet research workers, acting on an idea advanced as early as 1927 by Konstantin Eduardovich Tsiolkovksiy, better known for his work on rockets, for an air cushion train (such as is now in development in France), actually built and did trials with a hovercraft, the two-seater *L-1*, as far back as 1934. This vehicle is shown in the film running at high speed along a river, doubtless the Neva, down to the sea, where she beached herself and displayed her manoeuvrability on dry land by turning round on a very small patch of the shore. The film also showed a later model, the *L-5*, considerably larger and evidently much faster than the *L-1*, travelling over swamps and sand spits, etc.

"Sormovich" Specifications

Fifty passengers.

Maximum speed of 64.5 knots.

Hull made of light aluminium alloy consists of separate units and blocks welded together.

Length overall, 26.5 m (101.85 ft).

Beam, 10 m (32.81 ft).

Moulded depth of 4 m (13.12 ft).

An aviation-type Ivchenko A1-24 gas turbine of 1,800 shp is installed in the stern, driving the single lift fan and two shrouded propellers. The air cushion developed through the fan by peripheral jets totals 165 sq m (1,775 sq ft) and a height of 20.30 cm (7.87-11.81 in).

The *Sormovich* is steered by two air rudders installed directly behind the propulsion airscrews and is claimed to be highly manoeuvrable even at speeds of 100 km/hr (about 53 knots). The power unit, rudders and auxiliary system controls are operated automatically from the bow wheelhouse. Turbine noise has been controlled by isolating the engine from the passenger cabin by a soundproof bulkhead. The passenger cabin partitions have been lined with soundproof plastic material.

"Taiga"

A general purpose craft for operation on rivers running through virgin forests. Developed from an earlier craft, the *Raduga*, the *Taiga* has been designed specifically for the Soviet logging industry. She may be used for clearing jammed logs and rafts during timber flotage as well as for refloating logs thrown out on to the banks. As she will be equipped with a powerful winch, it will also be possible to use the *Taiga* as a tug. A passenger version for short local services and an ambulance version are also being developed. In all versions power will be provided by an unspecified gas turbine driving two lift fans developing a 12 in cushion. The *Taiga*'s overall length is 42 ft 8 in, her beam 19 ft 8 in and her speed 26 knots.

With an inland waterways system of 300,000 km (187,500 miles) with depths below 1 m, which cannot be negotiated by conventional or hydrofoil craft, the Soviet Union offers splendid prospects for ACVs and the current Five-Year Plan provides for the development and construction of twenty- to thirty-seater ACVs with speeds of up to 35-40 km/hr (19-21.5 knots). Icebound rivers will become navigable the year round. Trials are proceeding with experimental cross-country ACVs.

The History of Hydrofoils

(Part XIII)

by Leslie Hayward

U S S R

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

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

Raketa

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

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

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

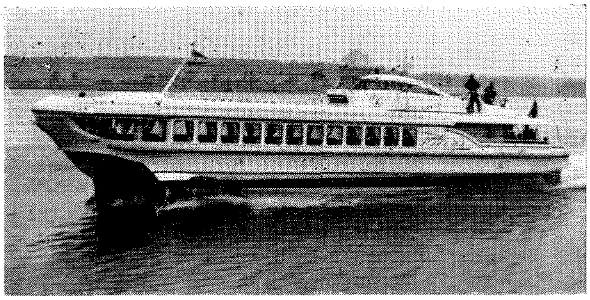


Figure 91. "Raketa"

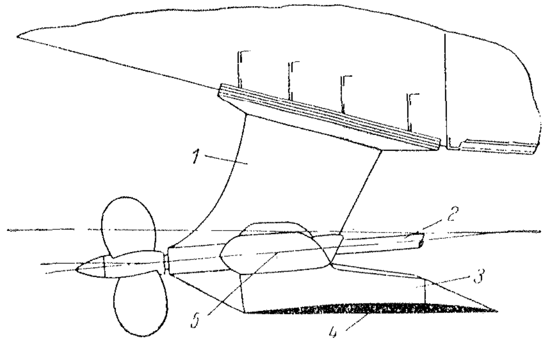


Figure 92. Construction of the after bracket after modification to the "Raketa"

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

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

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

Meteor

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

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

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

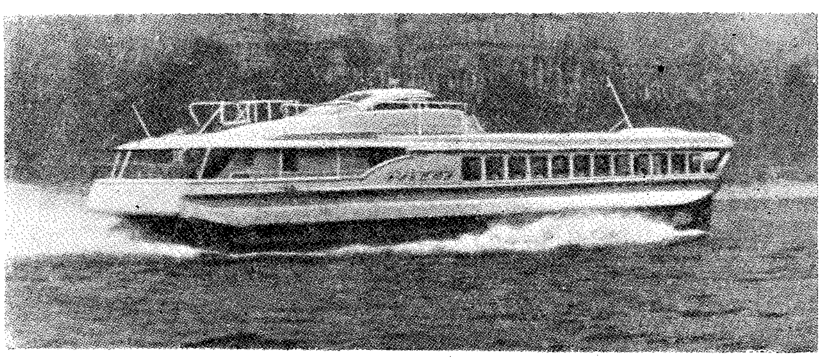


Figure 93. The modified "Raketa"

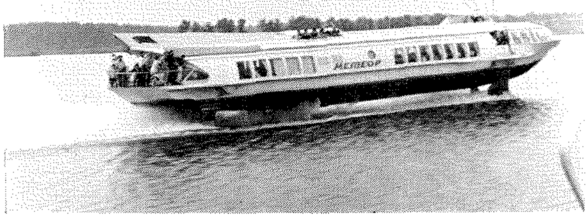


Figure 94. "Meteor"

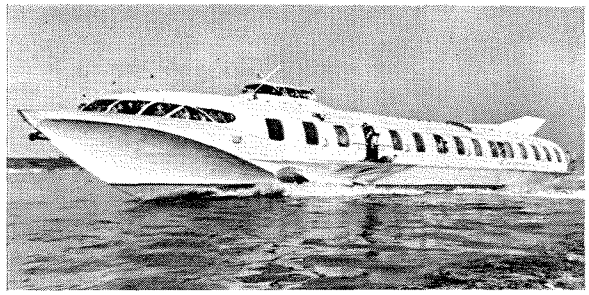


Figure 96. "Sputnik"

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

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

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

MIR

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

Cosmos

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

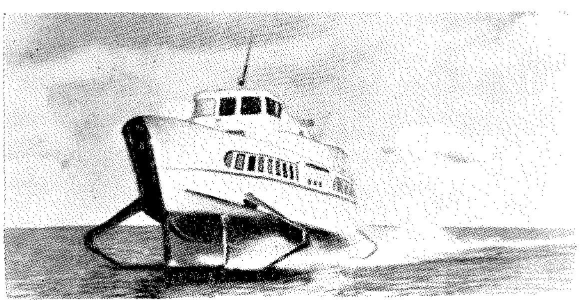


Figure 95. "Mir"

Sputnik

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

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

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

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

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

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

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

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

Molnia

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

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

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

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

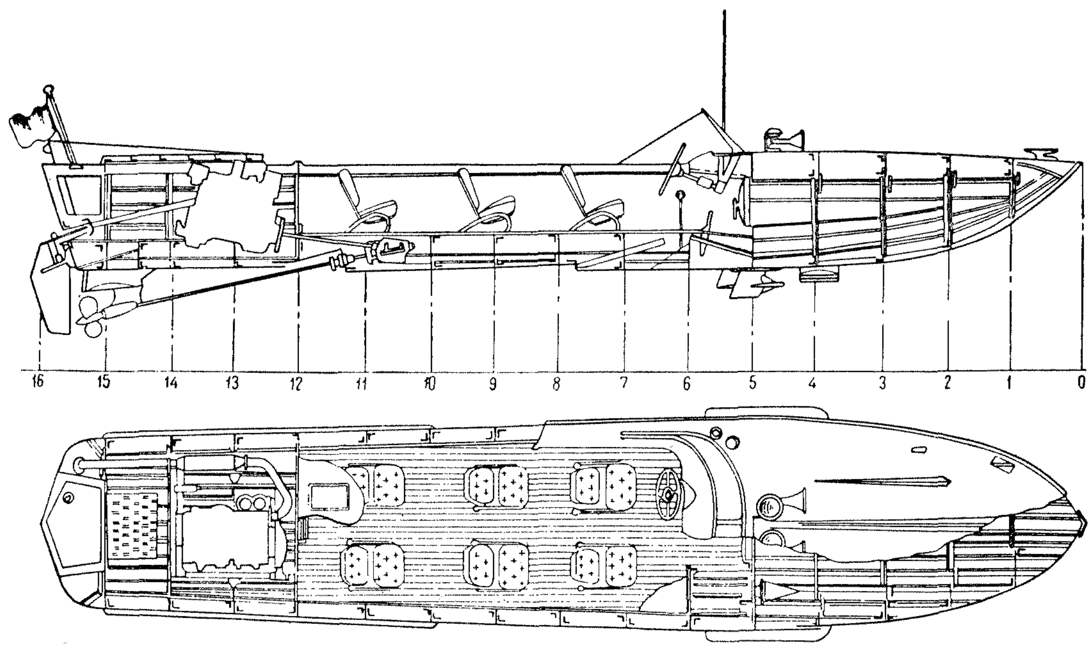


Figure 97. "Molnia"