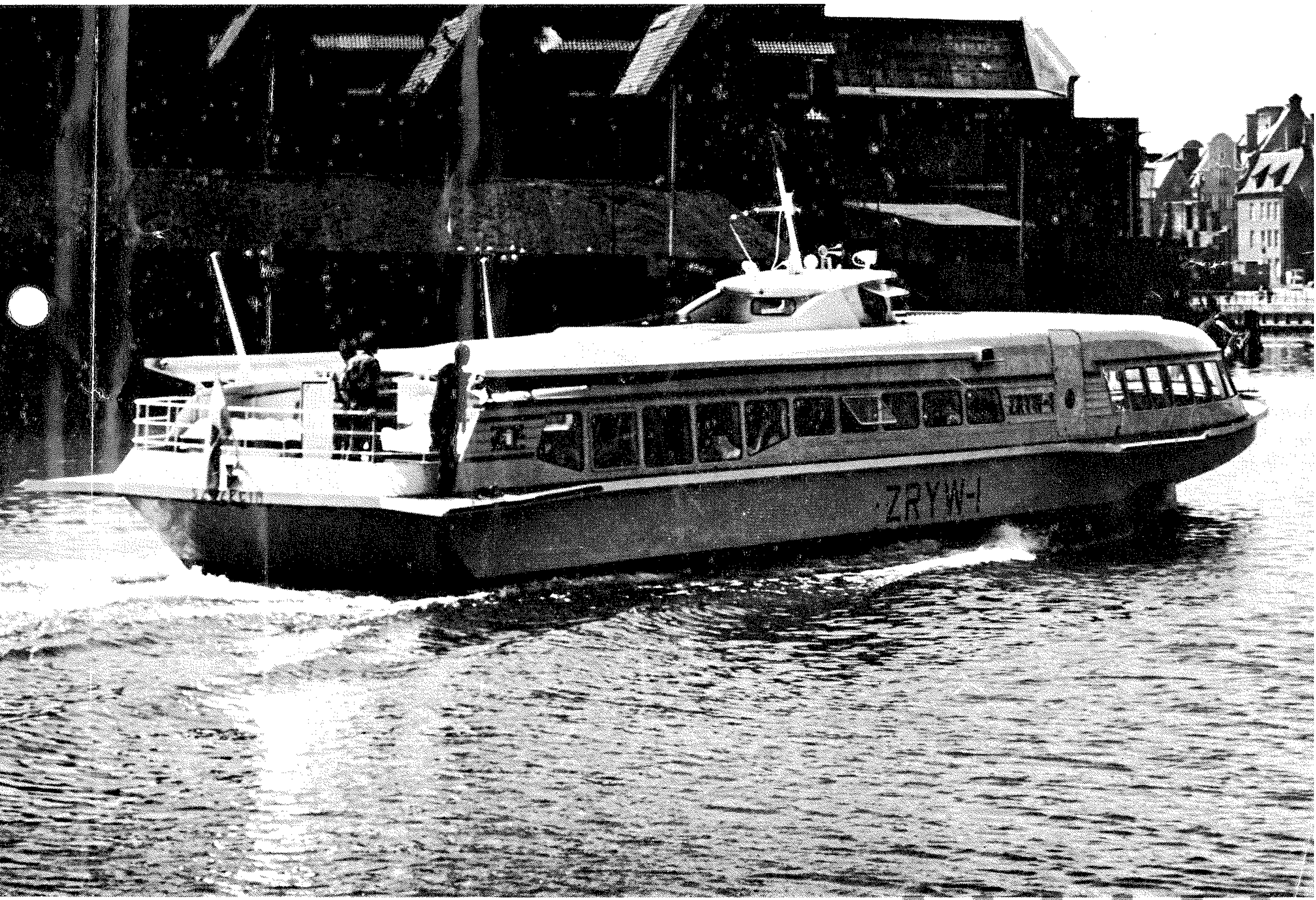
HOVERING CRAFT & HYDROFOIL

THE INTERNATIONAL REVIEW OF AIR CUSHION VEHICLES AND HYDROFOILS

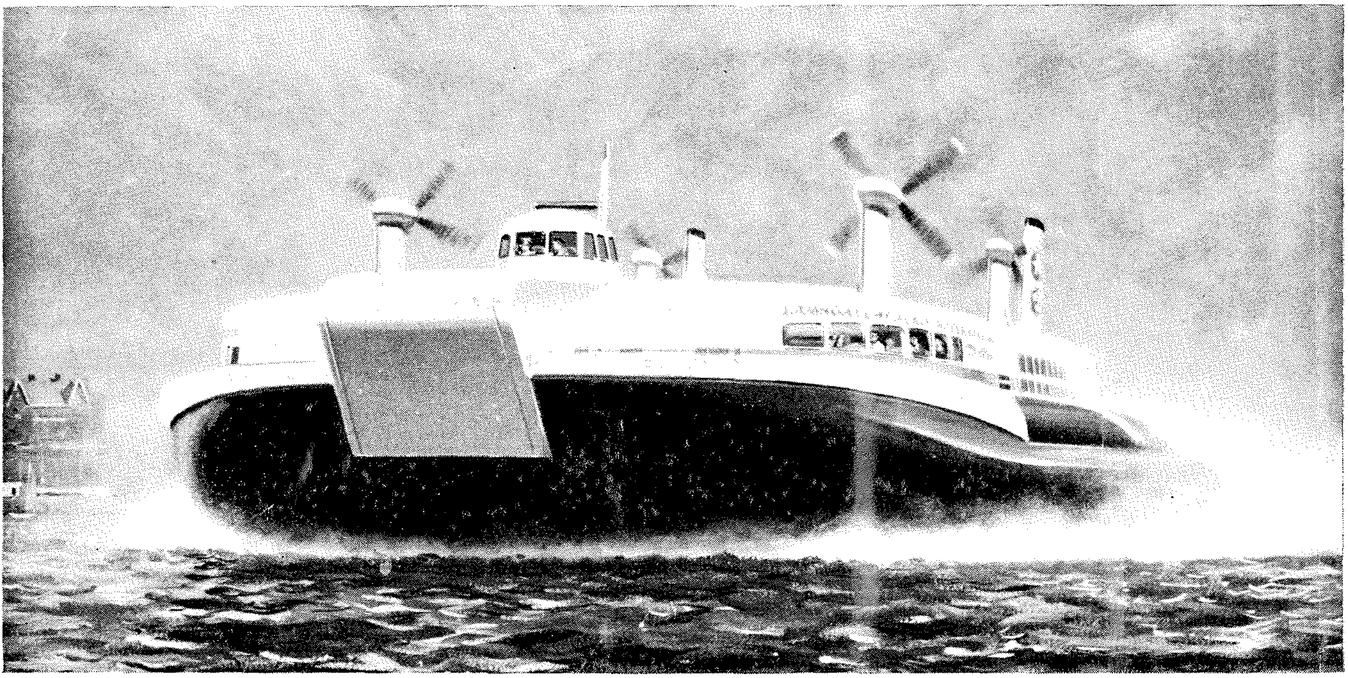


Volume 5 Number 2

NOVEMBER 1965

KALERGHI PUBLICATIONS

SR.N4
is the choice



For their passenger/vehicle hovercraft ferry service across the English Channel – which is due to open in 1968, and will be the first such service – Swedish Lloyd Steamship Company and Swedish American Line have chosen the 160-ton Westland SR.N4. The particular version ordered has room for 250 passengers and 30 cars.

This advanced, third-generation hovercraft embodies a wealth of operational experience unrivalled by any other manufacturer. As a passenger carrier, it can accommodate up to 500 seated passengers, or up to 800 with an 'all-commuter' interior layout.

To initiate their cross-Channel operations, the Companies have ordered the smaller, 38-seat SR.N6, which will enter service in 1966. The SR.N6 and SR.N4 services will bring Calais within half an hour's journey of Ramsgate. On business or pleasure, passengers will travel in smooth comfort, even in stormy winter seas.

Both SR.N4 and SR.N6 are powered by Bristol Siddeley gas turbines.

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HOVERCRAFT LEADERSHIP

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WESTLAND AIRCRAFT LIMITED YEOVIL SOMERSET

HOVERING CRAFT & HYDROFOIL

FOUNDED OCTOBER 1961

First Hovering Craft & Hydrofoil Monthly in the World

Interior of the passenger compartment in "Zryw-1"

"ZRYW-1" PROTOTYPE POLISH PASSENGER HYDROFOIL

In recent years express hydrofoil passenger service has aroused considerable interest in Poland. During the period 1956-61 practical and theoretical tests with models of various types of hydrofoil were carried out by the department of naval architecture of the Gdansk Technical University. As a result the basic construction principles have been elaborated and preliminary models of foils with advantageous hydrodynamic characteristics have been tested.

In 1961 the Polish Central Board of Inland Navigation and Gdansk River Shipyard asked the Gdansk Technical University to design a hydrofoil boat for use in the Firth of Szczecin. An order was placed accepting the "Zryw"-type hydrofoil boat, which had been designed during 1962-1963. In 1964 the Gdansk River Shipyard undertook the construction of the prototype hydrofoil boat named *Zryw-1*, which was built under the supervision of the Polish Register of Shipping.

The *Zryw-1* hydrofoil is provided with two shallow-submerged foils with a longitudinal and transverse dihedral in a tandem system. The fore foil is of surface piercing type, the after foil being fully submerged. The profile of foils is ogival with a sharp leading edge. The hull has a sharply raked stem with a highly raised bend in the forepart. The frames in the forepart are concave, those amidships and aft being straight. There are two oblique steps in the bottom. The hull's sides are vertical.

The hydrofoil has two passenger compartments, one for forty passengers forward, the other for thirty-six passengers aft. The engine room is located amidships, the wheelhouse, crew accommodation and toilet facilities being situated forward. The passenger compartments are connected by a passage running along the port side. Main entrances for passengers are at both sides, leading to a small vestibule forward of the engine room and crew's cabin. An emergency exit leads from the after compartment to a small stern deck.

The wheelhouse, engine room and crew cabin are interconnected, while the main engine room entrance is in the crew cabin. The emergency exit leads to the corridor joining the passenger compartment. The entrance to the wheelhouse is by a stairway in the crew cabin.

The space under the bulkhead deck is divided by eight water-tight bulkheads into nine watertight compartments, thus assuring the hydrofoil boat two-compartment unsinkability. Each of the watertight compartments can be entered through a manhole. The fuel-oil tank is set in the eighth compartment.

Constructed of light alloys, the hydrofoil's hull is of almost fully welded construction, riveting being applied only for the joints of the longitudinal and transverse framings with the outer plating of the vessel's roof, partition walls with the bulkhead deck and roof, and for the joining of steel elements (foil foundations, stern tube) with light-alloy elements. The

(*Continued on page* 28)

IN THIS ISSUE

COVER PICTURE : *The seventy-six passenger Polish hydrofoil "Zryw-1". See page 3 for further details*

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JUANITA KALERGHI

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People and Projects

Mr Peter Fielding, who wrote the article "Twentieth Century Yankee Clippers" which appears on page 6 of this issue, has been concerned with the design, development and operations of fixed and rotary wing aircraft, hydrofoils, displacement craft, hovercraft and off-road vehicle systems since 1939. He is currently a Vice-President and Director of Research at Booz, Allen Applied Research Inc in the USA, and is directing a systems analysis of the functions of US transportation, a two-year, two million dollar research programme for the US Department of Commerce.

Mr Fielding is an Associate Fellow of the Royal Aeronautical Society, Associate Fellow of the American Institute of Aeronautics and Astronautics, and a Member of the Society of Naval Architects and Marine Engineers. He holds a number of US and UK patents in the transportation field and was elected to the Honour Roll of Inventors (Lockheed Georgia) in 1961. He is listed in "American Men of Science" and is a frequent contributor to the technical press. He has in the last six years acted as a senior consultant in Hovercraft matters to the US Office of Naval Research, the US Army Transportation Corp, the Department of Commerce, the US Maritime Administration, and also to a number of industrial undertakings in the US and abroad.

★ ★ ★

A. J. McLellan Ltd, Gibraltar, and its associate company **Hercules SA,** Tangier, are two newly-formed companies who will operate a regular and frequent hydrofoil passenger service between Gibraltar and Tangier. The distance of thirty-two nautical miles will be covered in one hour. The normal time taken by a commercial craft is two and a half hours, and by an aircraft (from city centre to city centre) one hour twenty-five minutes.

★ ★ ★

Mr Donald Shelley, a director of Shelley Electric Furnaces, of Stoke-on-Trent, has worked with a team of five technicians for three years on the development of a "hoverkiln" which uses a conveyor belt system based on the hovercraft principle. At present pottery manufacturers have to collect all unfinished goods from every department of the factory and place them in one large kiln for eighteen to twenty-four hours. With the new kiln, which measures 40 ft in length, single items can be floated on a cushion of air straight from the production line and fired in only twenty minutes.

£50,000 has been spent on developing the kiln and it will go into full production in five months' time. Each machine will cost about £30,000 but the firm believes that it will pay for itself within three years.

★ ★ ★

Inchcape and Co is disposing of its interests in International Aquavion (GB), the hydrofoil builders. In a statement to shareholders at the annual general meeting held in London, Lord Inchcape said: "Unfortunately, one of the new developments on which we had been working over the last five years [hydrofoils] has not been successful and we are now disposing of our investment in International Aquavion."

Inchcape is at present in joint control with Wallace Brothers (Holdings) of International Aquavion (GB) through a subsidiary, Duncan Macneill and Co. This came about in 1962 when International Aquavion (GB) was registered as a British company to take over the Dutch hydrofoil concern of the same name together with rights to develop patented hydrofoil craft in the UK and internationally. The total investment by Inchcape is believed to be about £40,000.

★ ★ ★

Mr Frank Cousins, Minister of Technology, announced in a written reply in the House of Commons on November 11th that the Government have given **British Railways** authority to operate a Westland SR.N4 hovercraft between Portsmouth and the Isle of Wight early in 1968.

Mr Cousins, who had been questioned by Sir Barnett Janner, MP for North-West Leicester, said that the development of the hovercraft had reached an advanced stage and that the Government intended to do everything they could to ensure the continuation of the pre-eminence Britain enjoyed, and to promote the growth of the industry and the development of exports for which the potential demand was large and widespread.

He said that over 100,000 passengers had been carried across the Solent in little more than three months, and because of its convenience and time-saving, the hovercraft was becoming the preferred method of travel on this route for many businessmen.

The 150 ton SR.N4 will carry up to 700 passengers, or 250 passengers and 30 cars at 70 knots. Westland have started production at Cowes of four craft worth about £1,500,000 each. Two have been ordered by a Swedish consortium for use between Ramsgate and Calais in the early summer of 1968; British Railways will take one; and Townsend Ferries are believed to be negotiating for the other.

★ ★ ★

A paper entitled "Gas Turbine Engines in the Royal Canadian Navy Prototype Hydrofoil Vessels" by **S. E. Hopkins,** Commander, RCN, and **G. L. Amundrud,** Canadian Forces, Ottawa, will be presented at the meeting of the Gas Turbine Division of ASME at Zurich, March 13-17th, 1966. This is the first time that this Conference has been held outside the United States.

★ ★ ★

A contract to supply a Westland 9 ton 38 seat SR.N6 hovercraft costing about £100,000 has been signed between Westland Aircraft and **George Nott Industries Ltd** of Coventry and Dover. The craft will be used on local and cross-Channel services and will be operated by Townsend Car Ferries Ltd and P. and A. Campbell Ltd in the Dover, Deal and Folkestone areas. It is due for delivery in February 1966.

★ ★ ★

On November 12th thirty-five officers of Flag rank including the **Chiefs of Naval Staff** of seven North European Navies, and the Supreme Allied Commander, Atlantic, Admiral T. H. Moorer, who were attending staff talks at Greenwich, made a trip from Greenwich Watergate to Tower Pier in a Westland SR.N6 hovercraft.

★ ★ ★

Clyde Hover Ferries have decided to cut their fares which have been running at 11d to 1s 6d per mile, to the 4d to 9d per mile which is charged by the Clyde steamers. They will also issue season and concession tickets to encourage regular travellers to use the craft, rather than the casual visitor. It is also planned to transfer their base to a point (possibly Gourock) nearer the main area of operation than Tarbert. Only one craft will be utilized for the winter service with the second craft as a standby. The summer travel experience of the craft has provided a useful picture of the difficulties inherent in operation from piers or jetties rather than from a beach where buffeting is avoided.

★ ★ ★

G. Ruston and Sons, boatbuilders, of Mylor, Falmouth, will show the "Aquaglider", a new type of fast water craft combining hydroplane and hovercraft features, at the Boat Show in January, 1966. The craft is 22 ft overall by 9 ft 6 in and rides on a cushion of air pumped under the bows. It can be used as a passenger or vehicle ferry and has a high door at the side which allows 5 ft 6 in passage. It has a load capacity of 1½ tons (small car) or twenty people and a top speed of about forty knots. It is driven by a 110 hp Volvo Penta engine. It is believed that the fundamental concept of the craft can readily be applied to much larger vessels such as civil or military ferries, pontoons and patrol boats.

★ ★ ★

A **Bristol Siddeley** Gnome engine in a Westland SR.N6 thirty-eight passenger hovercraft which has been operating a ferry service in the Solent has completed over 1,000 hours running.

The 1,050 hp Gnome is installed in the SR.N3, SR.N5 and SR.N6 hovercraft, and the twenty-six engines at sea have a cumulative total of 8,000 hours operation. The Westland SR.N4 700 passenger hovercraft cross-Channel ferry will be equipped with the more powerful 4,250 hp Proteus. Proteus engines at sea have a cumulative total of more than 25,000 hours' operation.

★ ★ ★

A hovercraft built in 1964 by engineering students at **Natal University,** with the financial backing of an oil company, has been presented to No 5 Squadron of the South African Air Force. The aluminium craft measuring 21 ft by 11 ft named "Progress" can rise to a height of eight inches, and has been flown at more than 50 mph.

★ ★ ★

Princess Margaret, accompanied by her husband, Lord Snowdon, made a trip in a hovercraft from San Francisco to Oakland on Saturday, November 6th, 1965. After completing the crossing, the Princess told Oakland's Mayor and Mrs John Houlihan: "It was like a deflated bug, like something out of Jules Verne."

★ ★ ★

Scanhover (Scandinavian Hovercraft Promotion), Oslo, have received a permit from the Ministry of Trade allowing them to use their two SR.N6 hovercraft for day and night operations. The service between Arhus and Kalundborg (Copenhagen) has been extended to six return trips per day. The Danish permit is based on regulations which have been set up by the British Air Registration Board for hovercraft—especially for service during the hours of darkness. The limits in Danish waters are 3 ft high waves and winds up to 15 knots. So far the service has been used mainly for sightseers but the new schedule offers prospects for competition with the railways.

★ ★ ★

The Channel Islands hydrofoil Condor I owned by **Condor Ltd, Guernsey,** and built at the Rodriquez Shipyard, Messina, Italy, has recently completed its second season of operation, and has carried nearly 54,000 passengers on scheduled services between Jersey and Guernsey and to St Malo, as compared with 31,000 in 1964. During the winter certain parts of the craft will be redesigned or modified in the light of two years' experience in Channel waters.

★ ★ ★

Westermoen Hydrofoil A/S, Mandal, Norway, is negotiating with the Danish State Railways for delivery of two hydrofoil craft which may be put into operation between Denmark and Sweden. Westermoen has already supplied four hydrofoils for service between these two countries.

★ ★ ★

Installation and trials of the **Decca D202 transistorised marine radar** on the Westland SR.N6.012, operated by Clyde Hover Ferries Ltd, Tarbert, Scotland, have now been successfully completed and approved by the Air Registration Board.

Clyde Hover Ferries Service, which started operations in late June this year, was equipped and fitted with the D202 by the Glasgow Department of Decca Radar Ltd in October, and is currently operating on a winter timetable between 6.30 am and 8 pm.

One of the directors of Clyde Hover Ferries Ltd has expressed great satisfaction with the Decca equipment, especially during fog when other transport was at a standstill. He has stated that without radar the craft would be restricted to daylight operation, and only with good visibility, but with radar they sometimes get an extra eight hours or more operating time.

During the winter extensive use is made of the hovercraft service by workers commuting between their homes in Dunoon and the Isle of Bute and work in Glasgow. In addition, many US Service personnel from Holy Loch travel to and from Gourock on the mainland during their off-duty hours. Clyde Hover Ferries Ltd will be operating two SR.N6 craft each capable of carrying thirty-eight passengers, in the Firth of Clyde and Loch Fyne. Certificated master mariners, recruited from leading British Shipping Companies, pilot the craft and they have all had extensive experience of marine radar during their previous sea-going service.

The D202 was installed in the smaller SR.N5, two of which have undergone extensive trials in the Far East manned by Army and Navy personnel. Other hovercraft which have been equipped with Decca Radar are the SR.N2 and SR.N3. The radar equipment for Clyde Hover Ferries Ltd has been fitted with north stabilisation from a Sperry gyro/magnetic compass and draws all its power from the general 24 v supply.

★ ★ ★

The **British Inter-Services Hovercraft trials unit** will be returning to Britain in December after a year's trials with the two Westland SR.N5 hovercraft in Borneo. Major Roger Hiams, of Portsmouth, commanding the test unit, has said that the craft had proved themselves in every way in their off-shore infiltration role.

★ ★ ★

Hovertravel Ltd, who operate the cross-Solent Hovercraft service which has carried 120,000 passengers since the end of July, have formed a wholly-owned subsidiary—Hoverwork Ltd. The company has been formed to train future Hovercraft captains and engineers and to act in an advisory capacity in all matters concerned with hovercraft and the development of new routes. The company has already received enquiries from potential overseas operators for training facilities.

★ ★ ★

Officials of the **Royal National Lifeboat Institution flew** in a hovercraft recently in a gale in the Solent. The Institution is considering hovercraft for sea rescue work.

★ ★ ★

M. Dossier, director of the **French Society for Aerotrain Research,** has announced that the first full-scale trials with an experimental model of a "hover-train" designed by the Society will be started next spring near Gallardon (Seine-et-Oise). The details now given of this prototype air-cushion vehicle are slightly different from those announced at the end of October, and are as follows: It will measure about 12 metres (nearly 40 ft) in length by 2 metres (about 6 ft 6 in) in breadth, and will carry four passengers in addition to the driver and the engineer mechanic. It will be of the side-wall type with an air-cushion produced by fans driven by a 150 hp Renault-Gordini motor, and will be propelled by an aircraft-type Continental motor developing 150 hp, driving an airscrew 2 metres (about 6 ft 6 in) in diameter mounted above the after part of the body. It is expected to develop a speed of about 200 km/hr (124 m/hr), running along a concrete rail, shaped like an inverted T 1 m 20 wide (5 ft 11 in) and 0 m 55 high (1 ft 9½ in), mounted on pylon suports, which need not be very substantial, since they will experience little strain. The trial runway will be about 8 km (5 miles) long. Later models are to be fitted with variable pitch propellers for trial purposes, and may be powered by a jet-propulsion unit, or by an electric motor.

This trial vehicle will doubtless be developed into an actual "hover-train", travelling at twice the speed, eg 400 km/hr (250 m/hr), used for suburban and inter-urban passenger services. The reduction of noise to a minimum is therefore most important, and to this end it is intended to try using horizontal wheels with pneumatic tyres which pinch against

Continued on page 30

TWENTIETH CENTURY YANKEE CLIPPERS

Peter G. Fielding A.F.R.Ae.S., A.F.I.A.A., M.S.N.A.M.E.

Vice-President and Director of Research BOOZ, Allen Applied Research, Inc. U.S.A.

This paper is based upon research carried out by Booz, Allen Applied Research, Inc, over a period of two years for the Maritime Administration. The research is aimed at providing the American Merchant Marine with a fast transoceanic freight transport over the next decade

Rich awards await the country that can revolutionize its inter-continental cargo shipping industry in the same way that the jet transport revolutionized intercontinental passenger service.

Wanted — A Marine Revolution!

The most urgent need for drastic improvement lies in the area of cargo shipments covering the 10 to 30 lb/cu ft range. To date, ship speeds, cargo handling, and terminal facilities have all been studied with a view toward improving their overall effectiveness. This has resulted in raising ship speeds a few knots, automating cargo handling, advancing the use of containerized cargo, and improving terminal facilities. Other progress has been made by successfully incorporating nuclear power in a merchant ship and in the building and testing of some advanced marine concepts, such as the Hydrofoil ship *Denison*.

However, the total of all these improvements and advances do not nearly approach the giant step made by the jet transport in doubling speed and keeping operating costs constant.

In comparing the type and density of overseas shipment by all carriers against the cost of such shipment in dollars per ton-mile, it is clearly indicated that there is a great need for faster ships that are economically competitive with the jet transport. Figure 1 presents in a crude, and perhaps over-generalized, form the range of cargo densities (total annual tonnage) versus operating costs and speed ranges of current carriers.

If left unchallenged, such new aircraft as the C-5A and the C-141 will move into the shipping field in the near future and take over the bulk of manufactured and high-value overseas cargo, leaving the ship in its primary role as the carrier of bulk cargoes, such as grain, oil and ore.

From this it is readily apparent that there is a definite need for a fast carrier of ocean freight in the $500/ton category and up, and in the range of operating costs of five to fifteen cents per ton per nautical mile.

Technology has Produced Five Contenders for the Marine Gap

Although a number of advanced concepts have been suggested for the past hundred years, they have been limited by the technology of the times. Today, however, lightweight materials, new structural forms, lightweight power plants and improved fuels make it possible to develop these concepts and, perhaps, to achieve the goals set by their inventors.

Hydrofoils, hovercraft, and lifting-effect aircraft flying close to the surface are all possible contenders in the race to fill the "marine gap".

Variations of each concept should also bring a host of feasible alternates to the fore, and result in additional concepts. Currently, there are at least five concepts that have been studied in depth for long-range, high-speed transportation of people and freight.

Ignoring the possibility of using nuclear power as the prime source of power, because of the current state-of-the-art in lightweight and low-cost reactors, the five basic, chemically-powered concepts may be broken down into two categories:

- Those which require little or no aerodynamic lift; and
- Those which require aerodynamic lift.

In the first category we find the plenum chamber, the annular jet, and the sidewall ground effect machines; in the second, the ram-wing and aircraft-type flying in ground effect. Perhaps the best known in the first category are the Westland series of annular jet hovercraft, the Denny sidewalls, the NADC's captured air bubble concept, and Bell Aerosystem's plenums and hydrokeels. In the second category are such well known craft as Vehicle Research's channel flow, and Douglas Aircraft's Weiland. In each of these detailed studies, nan-carrying scale models and, in some cases, full-scale production craft, have been made and successfully operated.

Substantial effort has been expended in the operational and feasibility aspects of these concepts, to keep pace with the physical developments made in each of them. This effort has been largely supported by funds from the Maritime Admini-

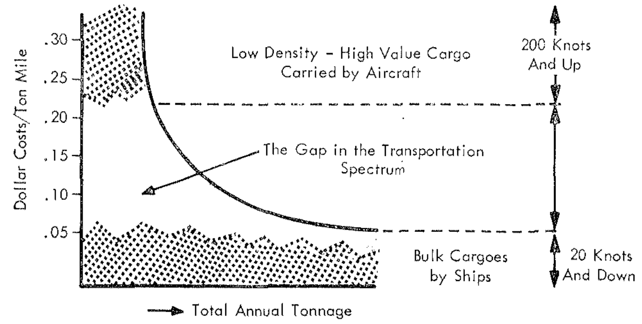

Figure 1. The gap in overseas transportation

stration of the United States Department of Commerce, and has been going on for several years. This activity has culminated in a detailed economic model of advanced marine concepts which are capable of operating within the charter of the United States Merchant Marine.

An Economic Model for Evaluating Advanced Marine Concepts

Simulation of a conventional mercantile fleet operation has been accomplished with some success for the Maritime Administration, and is now being used for a variety of operational problems. However, the dearth of operational data available on advanced marine concepts prevents a detailed appraisal of the operational and economic characteristics. Therefore, a special model programme (REFI) has been developed and programmed for the CDC-160A. This model is capable of evaluating alternate designs over a wide range of routes and environments, based on a common background of performance and cost data. One feature of the model is its ability to assess any of the major variables with respect to changes in values of the variable. Effects of wind speed, wind direction, visibility, harbour restrictions on speed, wave height, cargo handling, maintenance, manning and utilization, to name a few, can be systematically evaluated against the capabilities associated with research and development, production and operation.

This feature permits a particular concept to be evaluated by using a range of performance and cost above and below the manufacturer's claimed performance and cost structure. Such parametric analysis provides a sound basis for evaluating the relative merits of each concept long before it is necessary to commit funds for hardware development.

Initiated early in 1963, this programme has been substantially modified and upgraded in order to keep pace with the rapid progress made in air cushion technology. Since early 1965, the model has been used to evaluate five advanced marine concepts:

- The planing air-lubricated hull (Fig 2)
- The captured air bubble (CAB) (Fig 3)
- The annular jet with flexible extensions (Fig 4)
- The ram-wing annular jet (Fig 5)
- The aircraft in ground effect (Fig 6).

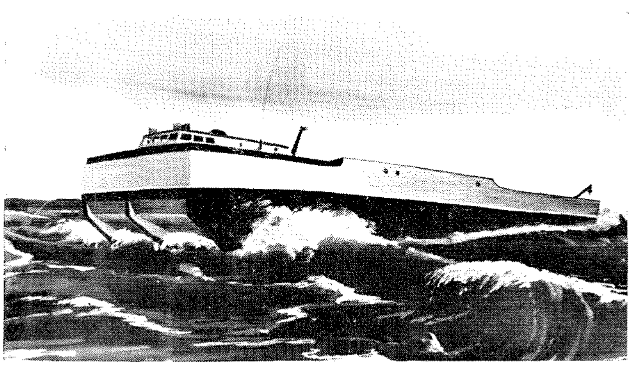

Figure 2. The planing air-lubricated hull

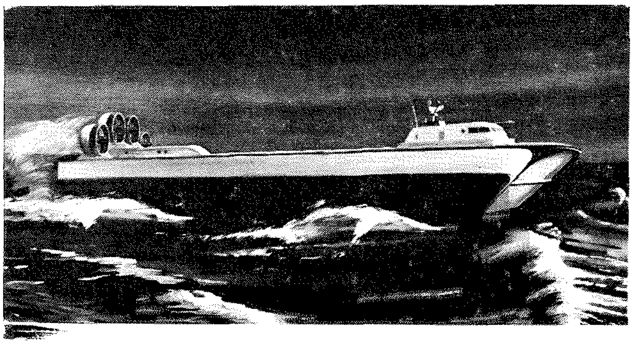

Figure 3. The captured air bubble

The evaluations were geared to isolate the concept most suited to the declared policy of the American Merchant Marine:

> "Section 101. It is necessary for the national defence and development of its foreign and domestic commerce that the United States shall have a merchant marine: (a) sufficient to carry its domestic water-borne commerce, and a substantial portion of the water-borne export and import foreign commerce of the United States, and to provide shipping service on all routes essential for maintaining the flow of such domestic and foreign water-borne commerce at all times; (b) capable of serving as a naval and military auxiliary in time of war or national emergency; (c) owned and operated under the United States flag by citizens of the United States in so far as may be practicable; and (d) composed of the best-equipped, safest, and most suitable types of vessels, constructed in the United States and manned with a trained and efficient citizen personnel. It is hereby declared to be the policy of the United States to foster the development and encourage the maintenance of such a merchant marine."

Physical Characteristics of the Five Concepts

As indicated by its name, the *planing air-lubricated hull* gets its lift by planing. The hull bottom is designed to trap air pumped into a cavity formed by longitudinal side skegs and the stern of the hull. This layer of air reduces water friction between the hull and the water, thus allowing the ship to hit higher speeds at relatively low power. A marine propulsion system is being considered.

The *captured air bubble* (*CAB*) resembles the Denny sidewall craft in that air is pumped into a cavity bounded by longitudinal skegs and fore and aft planing surfaces capable of moving with the motion of the surface. Combined air and marine propulsion systems are projected. Speeds in excess of 100 knots in calm water at relatively low installed power are expected.

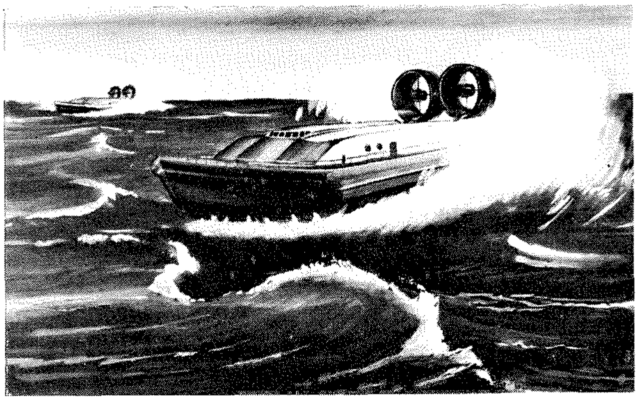

Figure 4. The annular jet with flexible extensions

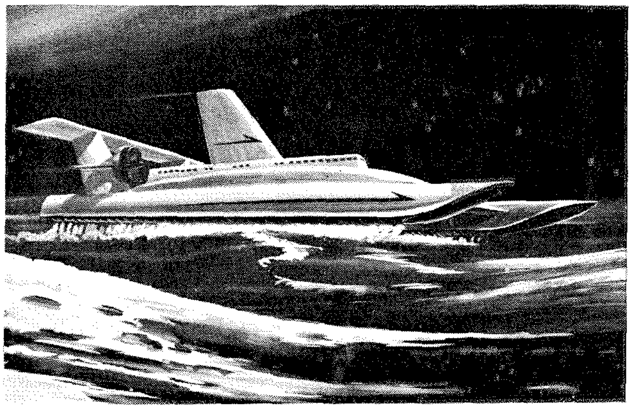

Figure 5. The ram-wing annular jet

The *annular jet with flexible extensions* maintains an air wall to retain its air cushion. In many ways this concept is somewhat similar to the CAB, with the exception that higher installed power is needed due to the need for a continuous flow of air. No surface contact is required, however, thus making air propulsion feasible at considerably lower installed power.

To reduce the power requirements for lift of the annular jet, the *ram-wing* concept uses the longitudinal sidewalls of air and an aerodynamic lifting body to support the ship at high forward speeds. Power requirements for the air cushion mode of operation are the same for this concept as for the annular jet; however, as speed increases the fore and aft jets are swept rearward and eventually shut off. Air propulsion is contemplated for this concept.

Surface Skimmer Studies Soar

From the early days of man's first attempts at flight, he has been aware of the powerful effect of flying in close proximity to the surface. In the 1930's a Dornier flying boat crossed the Atlantic Ocean by "flying" almost continually in ground effect to save fuel. Today, serious attention has been given by a number of aerospace companies to designing large *aircraft that fly at all times in ground effect*. One such concept, developed by Douglas Aircraft Corporation, resembles a tandem-wing monoplane with twin hulls at the wing extremities.

The size and characteristics of the five concepts selected for analysis are shown in Table 1. It should be noted that the disposable load includes fuel, crew and cargo, and that the maximum power is based upon achieving speeds of 100 knots for the annular jet, ram-wing, and aircraft in ground effect at constant operating heights (4 ft); whereas, power for the planing air-lubricated hull and the CAB ship is based upon the optimum speed for operating conditions dictated by winds and waves. For comparative purposes, maximum and normal power requirements for each concept are shown in Figures 7 and 8 respectively.

The derivation of the empty weights of each concept may be obtained from current state-of-the-art capability in materials, structures, power plants and marine/air propulsion systems. Figures 9, 10, 11 and 12 show, respectively, the machinery, equipment, structural, and empty weights of the five concepts used for gross weights ranging from 100 to 10,000 tons. These estimates, to a large extent, are based upon data supplied by the equipment developers and manufacturers, and constitute realizable state-of-the-art weights. However, they are not the result of detailed analyses of each size and should, therefore, be considered as a basis for establishing comparative performance only. Later in the analysis the sensitivity of varying these parameters with respect to operating costs will be reviewed.

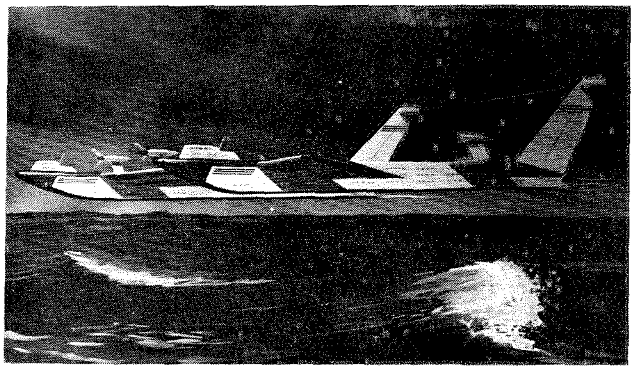

Figure 6. The aircraft in ground effect

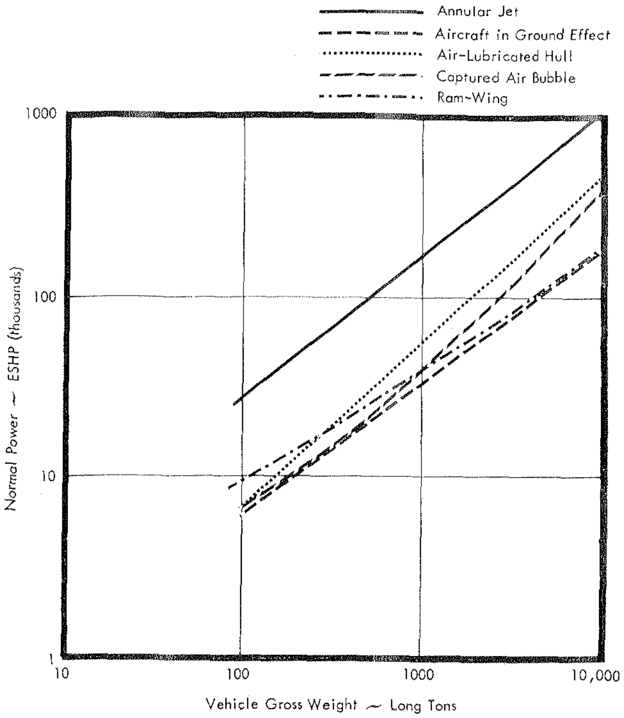

Figure 7. Normal power requirements

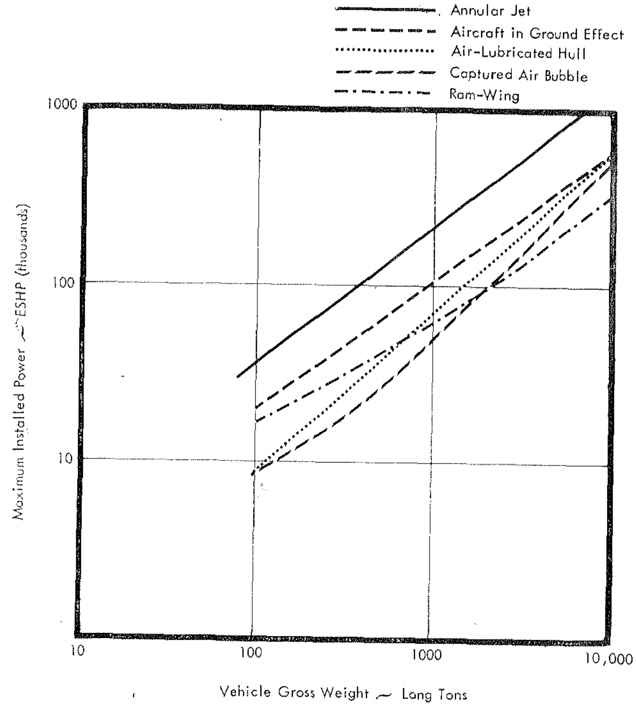

Figure 8. Maximum installed horsepower

Table 1
SIZES AND CHARACTERISTICS

Concept	Gross Weight (Long Tons)	Dimensions LxBxH(feet)	Maximum Horsepower	Disposable Load Tons*
Air-Lubricated Hull	100	90 x 20 x 20	8,500	55.4
	500	160 x 30 x 30	36,000	291.2
	1,000	205 x 37 x 40	70,000	627.2
Captured Air Bubble	100	100 x 40 x 25	8,500	68.9
	500	200 x 70 x 45	26,000	386.4
	1,000	270 x 110 x 65	50,000	805.2
	2,500	352 x 149 x 80	125,000	2017.0
	5,000	445 x 188 x 90	250,000	4062.0
	10,000	500 x 215 x 100	500,000	8124.0
Annular Jet	100	77 x 38 x 21	35,000	56.0
	400	122 x 61 x 35	105,000	268.8
	1,000	166 x 83 x 40	214,500	716.8
Ram-Wing	100	140 x 110 x 62	16,900	56.0
	500	310 x 156 x 80	40,500	324.8
	1,000	440 x 220 x 100	63,500	674.2
	2,000	620 x 310 x 120	99,700	1388.8
Aircraft in Ground Effect	100	215 x 150 x 48	19,500	56.0
	500	370 x 280 x 68	63,100	314.7
	1,000	600 x 500 x 100	105,000	761.6

Includes fuel, crew, and cargo.

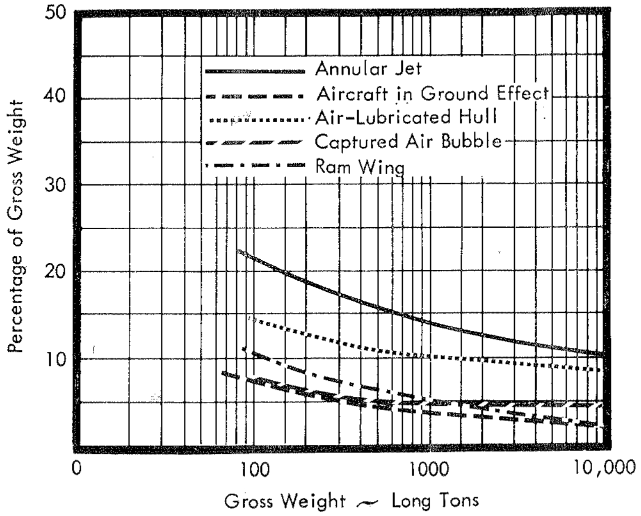

Figure 9. Machinery weight

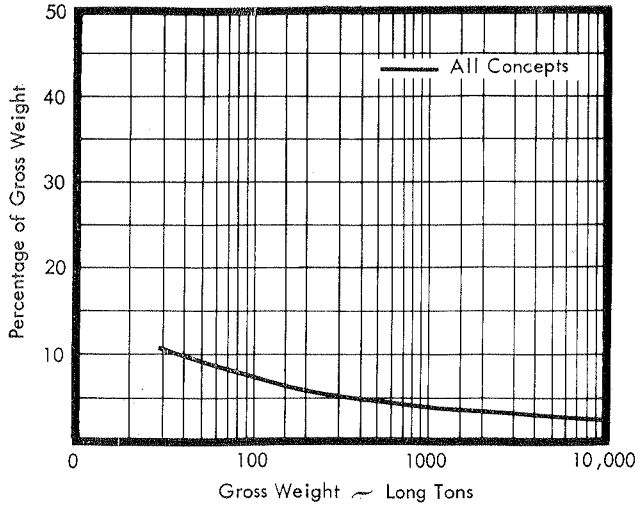

Figure 10. Equipment weight

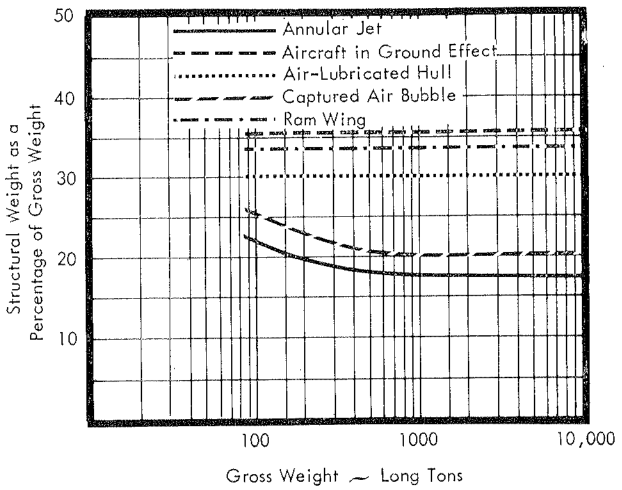

Figure 11. Structural weight

Cost Characteristics of the Five Concepts

A consistent cost methodology does not exist at the present time. The cost of developing and manufacturing air cushion craft vary between 75% and 200% of the values consistent with airframe industry production of low-performance aircraft of similar complexity. Much remains to be accomplished in this area. For the purpose of this analysis, the variable and non-variable data used in the economic model will be as shown in Tables 2 and 3. These tables cover the annular jet, ram-wing and aircraft in ground effect concepts. It should be noted that Figure 10 covers the 100-ton variations only, similar tabulations apply to the other sizes when the stipulated costs are multiplied by the weight items shown in Figures 9, 10, 11 and 12. The variable and non-variable data covering the air-lubricated hull and the CAB are given in Tables 4, 5 and 6.

It should be noted that as each of the concepts grows larger, the dock time, crew costs and number of engines with respect to cost, will be increased. For this analysis, it has been assumed that 0.4 hours/100 tons gross will be required to load and unload cargo. Crew costs will increase, as shown in Figure 13 and the number of engines will be based on multiples rounded out to a maximum of 20,000 hp per engine.

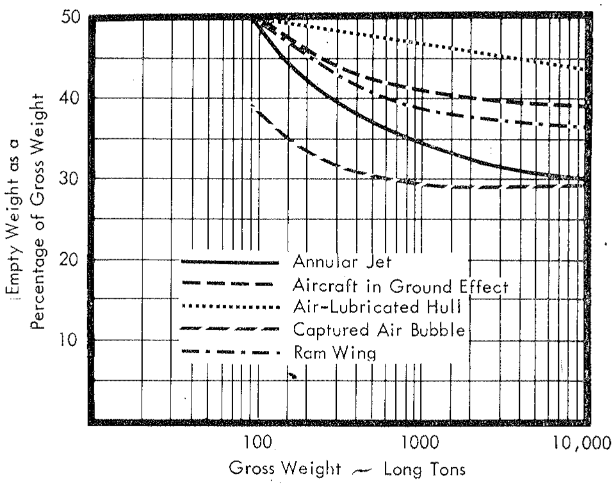

Figure 12. Empty weight

Table 2
BASIC NON-VARIABLE INPUT DATA

Route: Hypothetical with waves greater than five feet 10 percent of the time and restrictions due to visibility five percent of the time with a route temperature of 60 degrees Fahrenheit. No reduction in speed has been used for the traffic consideration.
Time in the confined harbor = .25 hour
Specific fuel consumption = .6 lb/hp-hr
Performance reduction due to salt water = 6 percent
Fuel reserve = 10 percent
Utilization per year (max. possible) = 2,500 hours
Cargo and passenger load factor = 100 percent
RDT&E costs = 100 dollars/lb.
Number of vehicles purchased = 10
Cost of structure = 10.60 dollars/lb.
Cost of equipment = 10.00 dollars/lb.
Cost of propulsion hardware = 19.00 dollars/lb.
Maintenance labor rate = 3.00 dollars/lb.
Time between engine overhauls = 2,000 hours
Attained period between overhaul factor = 1.22
Insurance cost = 4 percent of the initial investment (flyaway) cost
Fuel cost = 12 cents/gallon at 6.4 pounds/gallon
Passenger service cost = 6.2 percent of direct operating cost (DOC)
Ship and traffice service cost = 12.3 percent of DOC
Promotion and sales cost = 17.0 percent of DOC
General and administration cost = 18.5 percent of DOC
Ship, engine, and spare parts depreciation factor = .85
Ship depreciation period = 10 years
Engine depreciation period = 7 years
Ship spare parts factor = .10
Engine spare parts factor = .50
Engine spare parts price factor = 1.5
Nonrevenue factor = 1.03

Table 3
VARIABLE INPUT DATA
(Data for the 100 ton Machines)

			Annular Jet	Ram-Wing	Aircraft in Ground Effect
Run number			301	205	401
Route length		n.m.	100	100	100
Dock time per port		hr.	.4	.4	.4
Percent useful load			50	50	50
Power requirements at 100 knots					
Operating hp =	1 ft	hp	13,000	3,500	4,300
	2 ft	hp	18,000	5,200	4,550
	3 ft	hp	23,000	7,100	4,800
	4 ft	hp	28,000	9,300	5,000
Power requirements at one foot (in the water for the airfoil ship)					
Velocity	0 knots	hp	5,000	3,300	--
	5 knots	hp	5,000	3,300	100
	20 knots	hp	5,100	3,300	4,900
	50 knots	hp	6,800	3,500	7,800
Crew costs		dollars per hr.	34.33	34.33	34.33
Nominal empty weight		lb	112,000	112,000	112,000
Equipment weight - % empty weight			14	14	14
Propulsion system wt. - empty wt.			44	20	15
Structure weight - empty weight			42	66	71
Number of engines			4	6	3
Horsepower per engine			7,000	2,250	5,200
Engine cost (dollars per hp)			21	39.5	24

Table 4
BASIC NON-VARIABLE INPUT DATA
(100 ton Crafts)

Route: Hypothetical with waves greater than five feet ten percent of the time and restrictions due to visibility five percent of the time with a route temperature of 60 degrees Fahrenheit. No reduction in speed has been used for the traffic consideration.

Time in the confined harbor	0.50 hour
Specific fuel consumption	0.6 pound per horsepower-hour
Performance réduction due to salt water	6 percent
Fuel reserve	10 percent
Utilization per year (max. possible)	2,500 hours
Cargo and passenger load factor	100 percent
RDT&E costs	$85.00 per pound
Number of vehicles purchased	10
Cost of structure	$8.00 per pound
Cost of equipment	$10.00 per pound
Cost of propulsion hardware	$19.00 per pound
Maintenance labor rate	$3.00 per pound
Time between engine overhauls	2,000 hours
Attained period between overhaul factor	1.22
Insurance cost	4 percent of the initial investment (flyaway) cost
Fuel cost	$0.12 per gallon at 6.4 pounds per gallon
Passenger service cost	6.2 percent of direct operating cost (DOC)
Ship and traffic service cost	12.3 percent of DOC
Promotion and sales cost	17.0 percent of DOC
General and administration cost	18.5 percent of DOC
Ship, engine, and spare parts depreciation factor	0.85
Ship depreciation period	10 years
Engine depreciation period	7 years
Ship spare parts factor	0.10
Engine spare parts factor	0.50
Engine spare parts price factor	1.5
Non-revenue factor	1.03

Table 5
VARIABLE INPUT DATA
(Data for the 100 ton Air-Lubricated Hull)

Run number		601
Route length		100 n.m.
Dock time per port		0.4
Percent useful load		49.5
Power requirements at 34 knots		
Operating height	1 foot	4150 horsepower
	2 feet	5250 horsepower
	3 feet	--
	4 feet	--
Power requirements at one foot		
Velocity	10 knots	2600 horsepower
	20 knots	4000 horsepower
	30 knots	3950 horsepower
	34 knots	4150 horsepower
Crew costs		$34.33 per hour
Nominal empty weight		113,120 pounds
Equipment weight		12.9 percent of empty weight
Propulsion system weight		27.7 percent of empty weight
Structure system weight		59.4 percent of empty weight
Number of engines		3
Horsepower per engine		2850
Engine cost*		$35.00 per horsepower

* Included in investment cost when using Bell Aerosystem Corporation data.

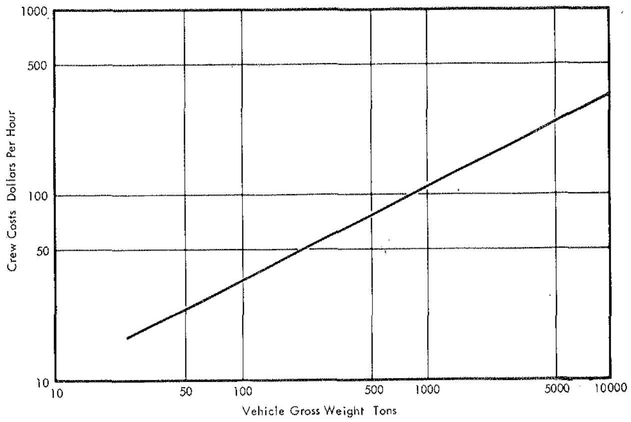

Figure 13. Typical crew costs

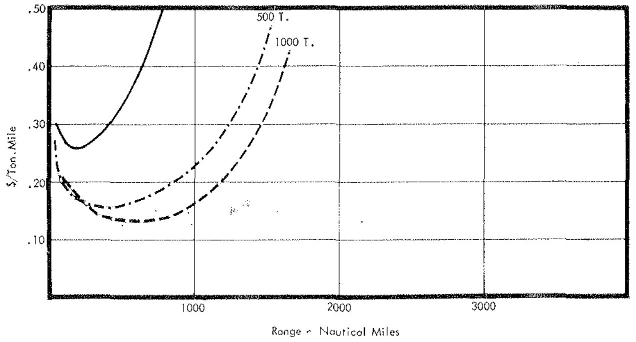

Figure 14. Growth potential air-lubricated hull

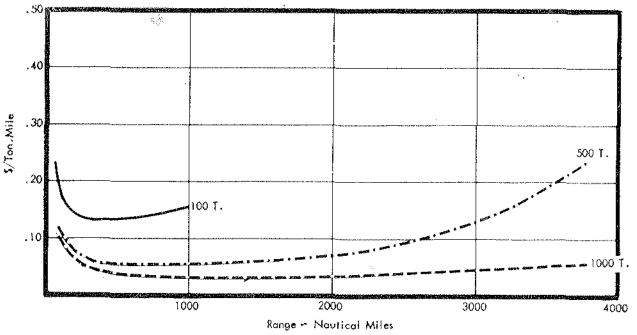

Figure 15. Growth potential captured air bubble

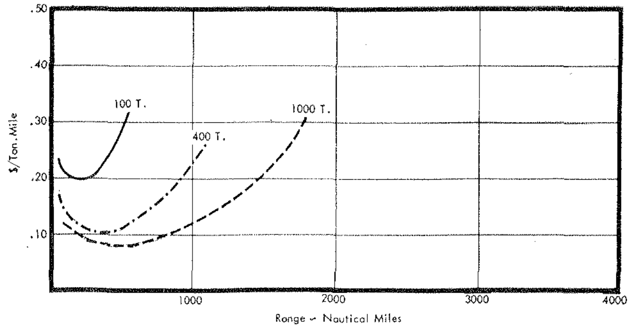

Figure 16. Growth potential annular jet

Growth Potential of the Five Concepts

The results of the model programme based on the preceding physical and cost characteristics are shown in Figures 14, 15, 16, 17 and 18.

- **The Air-Lubricated Hull Concept** (Figure 14)
  The moderate speed for the relatively high power required results in a comparatively high transport cost. The maximum range at reasonable operating costs is seen to be less than 1,000 nm's. This limit on range arises from the power required to sustain a cruise speed of 50 knots. The marked increase in transport cost with range results from diminishing payload as fuel is consumed. The limits at the shorter ranges is a direct result of the high turn-around times required for the larger sizes which, in turn, prevent high utilization rates.
- **The CAB Concept** (Figure 15)
  The overall picture here represents considerable benefits with respect to growth in size, with transport costs consistent with displacement ships in the 1,000 to 2,000 nm range for 1,000 ton craft.
- **The Annular Jet Concept** (Figure 16)
  As expected, the relatively high transport costs associated with ranges in excess of 1,000 nm's preclude the chemically powered annular jet craft from consideration as a valid contender for the American Merchant Marine.
- **The Aircraft in Ground Effect** (Figure 17)
  The outstanding range characteristics of this concept are borne out by this figure. This is particularly true in the 1,000 ton size. Excellent growth potential is apparent.
- **The Ram-Wing Annular Jet** (Figure 18)
  There can be little doubt of the superiority of this concept over the other four concepts. The overall flatness of transport costs with range is almost independent of range in the 1,000 ton size.

Comparative Analysis of the Five Concepts

To establish the concepts with the most growth potential in the American Merchant Marine, it is necessary to compare each concept over a range of sizes at the range where transport costs are minimum. Figure 19 shows the total transport costs (no return on investment) against size for each concept. It is apparent that little change in operating costs can be expected in sizes over 1,000 tons for the air-lubricated hull and the annular jet, whereas the remaining three concepts all have considerable potential. To complete the comparison, it is necessary to evaluate the payload/range characteristics of the five concepts. Figure 20 shows the payload and range capabilities for the five concepts configured in the 1,000 long ton gross weight category. Again, the air-lubricated hull and the annular jet show to some disadvantage, thus eliminating these two concepts from further analysis

Consideration of operational and developmental questions governing the CAB, the ram-wing annular jet, and the aircraft in ground effect, is the next step, as each appears to have similar transport costs and suitable range capability.

The CAB, of all the other concepts, is most like a ship. Further, little or no major development would be required except for the propulsion system and fore and aft sealing of the bubble. Both of these are considered to be well within the state-of-the-art by the developers of this concept. Construction techniques would be simple and straightforward.

The ram-wing annular jet, however, would require considerable research to perfect the aerodynamics associated with high-speed operation and satisfactory wave clearance. As a third generation project, it undoubtedly has considerable merit, and is probably the ultimate in long-range marine transportation.

The aircraft flying in ground effect is well within the state-of-the-art for production purposes; however, the wing spread and flying-boat type of performance would be a considerable disadvantage in the larger sizes. Special facilities would be mandatory, and because of its "modus operandi" this concept would only provide a doubtful marine craft.

Accordingly there appears to be some merit in singling out the CAB for more extensive analysis.

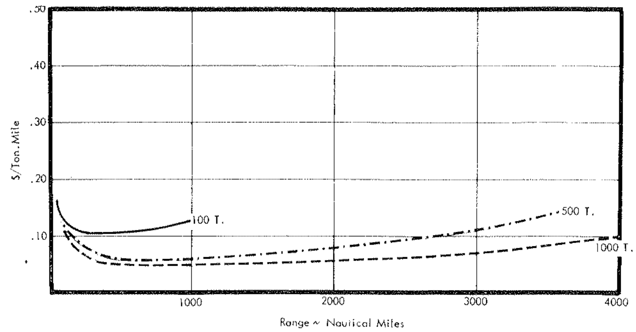

Figure 17. Growth potential aircraft in ground effect

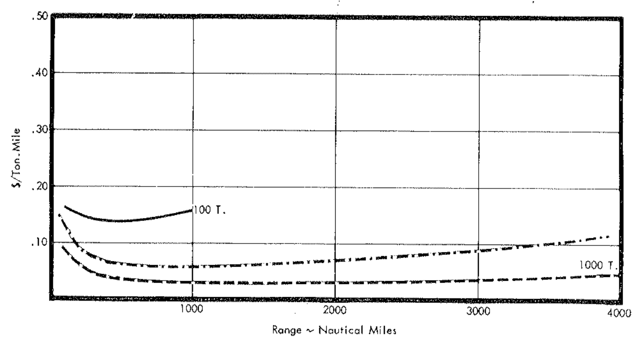

Figure 18. Growth potential ram-wing

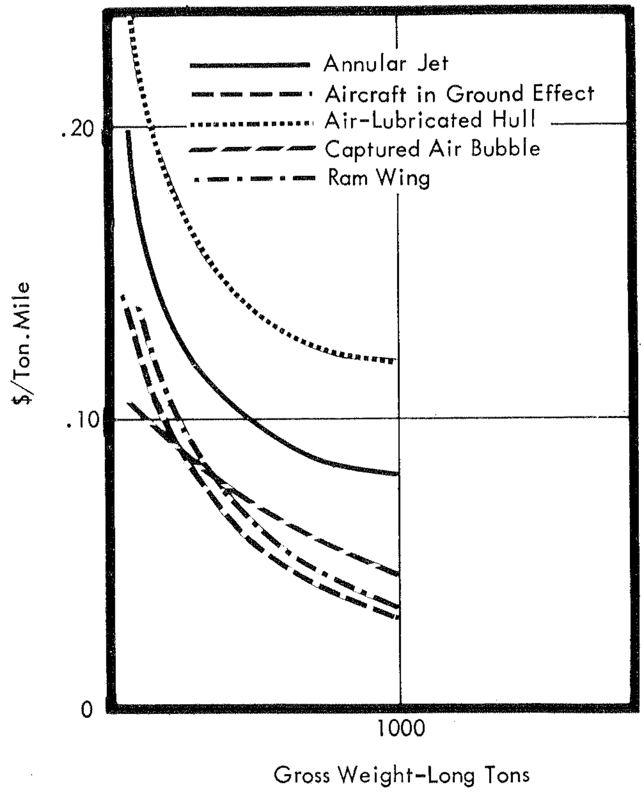

Figure 19. Operating cost comparison of the five concepts at their optimum range

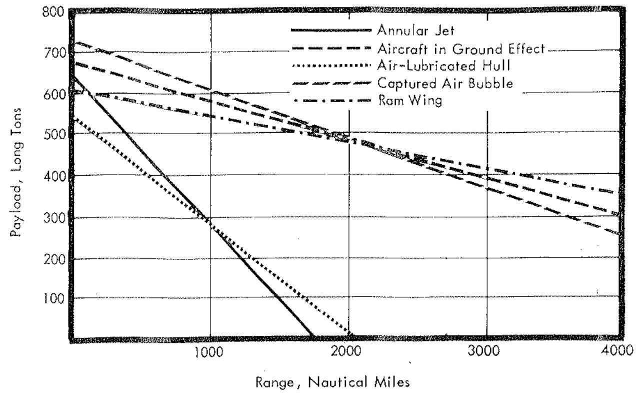

Figure 20. Estimated payload — range characteristics of the five concepts (all craft 1,000 long tons gross weight)

Table 6
VARIABLE INPUT DATA
(Data for the 100 ton Captured Air Bubble)

Run number		501
Route length		100 n.m.
Dock time per port		0.4
Percent useful load		61.5
Power requirements at 58 knots		
Operating height	1 foot	3350 horsepower
	2 feet	4800 horsepower
	3 feet	5750 horsepower
	4 feet	6840 horsepower
Power requirement at one foot		
Velocity	10 knots	3375 horsepower
	20 knots	6250 horsepower
	40 knots	3750 horsepower
	58 knots	3350 horsepower
Crew costs		$34.33 per hour
Nominal empty weight		86,240 pounds
Equipment weight		16.9 percent of empty weight
Propulsion system weight		18.2 percent of empty weight
Structure system weight		65 percent of empty weight
Number of engines		3
Horsepower per engine		2850
Engine cost		$35.00 per horsepower

Table 7

Route	Distance (n.m.)	Percent of Time (Waves >5 feet)	Average Temperature (degree)	Percent of Time Speed Limited by Visibility
Hypothetical	Variable	10	60	5
New York to London	3365	4	54	14
Los Angeles to Honolulu	2281	24	65	5
Honolulu to Tokyo	3397	18	70	6

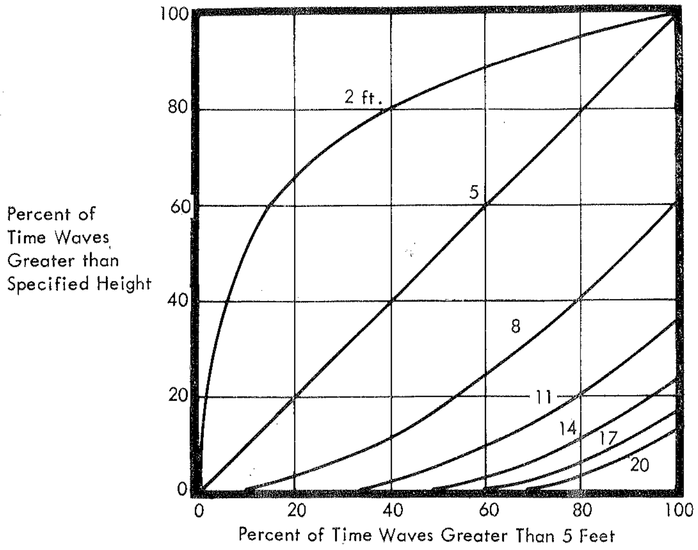

Figure 21. Wave height distribution for computer programme

Table 8
DATA INPUT

Item	Vehicle		
	1,000 T. CAB	5,000 T. CAB	10,000 T. CAB
Route Mileage Percent of time (waves > 5 feet) Average temperature Visibility factor		As defined for a specific route	
Time in open harbor		1.00	
Time in confined harbor		0.25	
Horsepower Number of engines		As defined by Analysis	
Performance reduction salt water		0.06	
SFC		0.55	
Fuel reserve ~ percent		10	
Percent useful load	71	72.5	72.5
Utilization per year ~ hours (including dock time)		7,000	
Vehicle load factor percent		100	
RDT&E cost ($/lb.)		0	
Number of vehicles purchased		10	
Equipment weight (percent gr.wt.)	4.0	3.0	3.0
Equipment cost ($/lb.)		10	
Propulsion system weight (percent gr.wt.)		4.46	
Engine ($/horsepower)		20	
Ancilliary hardware ($/horsepower)		19	
Structure weight (percent gr.wt.)		20	
Structure cost ($/lb.)		7.66	
Ship depreciation period (years)		10	
Ship depreciation factor		0.85	
Engine depreciation period (years)		7	
Engine depreciation factor		0.85	
Spare parts depreciation factor		0.85	
Eng. spare parts price factor		1.5	
Ship depreciation spare parts factor		0.10	
Eng. spare parts factor		0.50	
Non-revenue factor		1.03	
Labor rate ($/horsepower)		3.00	
Time between engine overhauls		2,000	
Attained period between overhaul factor		1.22	
Insurance costs (percent)		4.0	
Fuel costs ($/gal.)		0.12	
Fuel specific weight (lb./gal.)		6.4	
Cargo service cost		6.2	
Traffic service cost		12.3	
Promotion and sales cost		17.0	
General and administration		18.5	

Economic Analysis of the CAB Concept

To evaluate the true worth of the CAB, it is necessary to simulate the operation of a wide range of sizes over routes with considerable cargo traffic. Four routes and their characteristics were selected and are detailed in Table 7. The wave height distribution used in the model programme is as shown in Figure 21.

Input data covering 1,000 ton, 5,000 ton and 10,000 ton sizes were assumed to be as shown in Table 8.

Fifty-five cases were examined to cover a wide variety of operations. Minimum operating costs as a function of size, shown in Figure 22, indicate little or no change with sizes above 2,500 long tons. The total transport costs on actual routes (7,000 hours/annum) are shown in Figure 23. As expected, the North Atlantic route resulted in a considerably higher cost than the Pacific routes because of environmental conditions. Again, sizes above 2,500 long tons do not show appreciable savings.

Sensitivity Analysis of the Major Variables

Utilization

In the original programme, with minimal route distances less than 1,000 nautical miles, an annual utilization of 2,500 hours were assumed. Because of the restricted waters for these shorter routes, night-time operation was not considered. In the modified programme, where trans-oceanic distances were of primary concern, night-time travel was considered essential and an annual utilization of 7,000 hours was assumed to be typical. Figure 24 shows that decreasing utilization from 7,000 to 2,500 hours would mean an increase in ton-mile costs of 36%.

It should be noted that this high degree of utilization includes dock time covering loading and unloading, refuelling, and performing normal preventive maintenance. A total of 1,760 hours would, therefore, be available for periodic overhauls and general maintenance.

Research, Development, Testing and Evaluation (RDT & E)

Figure 25 shows the effect on operating costs if RDT & E are assumed as part of the investment. Using a typical value of $85 per pound of empty weight, and assuming that the initial buy is ten vehicles, RDT & E costs would increase transportation costs by 18.5%. The slope of the curve indicates a change in transportation costs of 0.219% of each dollar change in RDT & E costs.

Specific Fuel Consumption (Pound/Horsepower/Hour)

In the route analysis the engine SFC was assumed to be 0.55. For ease of calculation, the effect of temperature variations which occur on the various routes was assumed to change SFC rather than horsepower by a factor of ±0.005 per degree of temperature from an assumed mean average temperature of 60° F. Likewise, the SFC was increased by a factor of 0.06 to account for operations in salt water. For example, over a route with an average temperature of 80°, the corrected SFC was computed as follows:

$$(SFC)_e = 0.55 + 0.55\,[0.005\,(80\text{-}60) + 0.06] = 0.5885$$

Figure 26 shows the effect of varying SFC on transportation costs. For SFC of 0.5885, the transportation cost is increased by 12.6%.

Purchase Price of Fuel

Current domestic airline fuel costs of $12 per gallon are assumed. Data in Figure 27 show the effect of different fuel costs on the transportation cost (a value of 3.3% change in transportation cost per cent change in fuel cost). If the international airline fuel cost of $0.114 per gallon were used, transportation cost would increase by 7.9%.

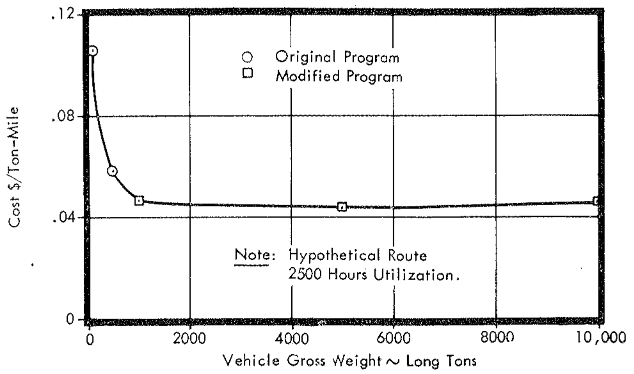

Figure 22. Comparison of minimum cost for various ship sizes

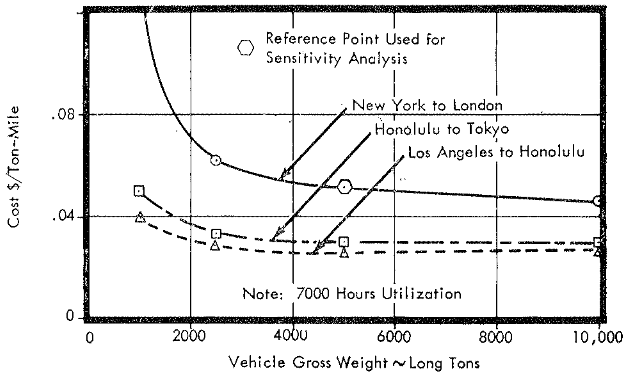

Figure 23. Comparison of costs for different routes

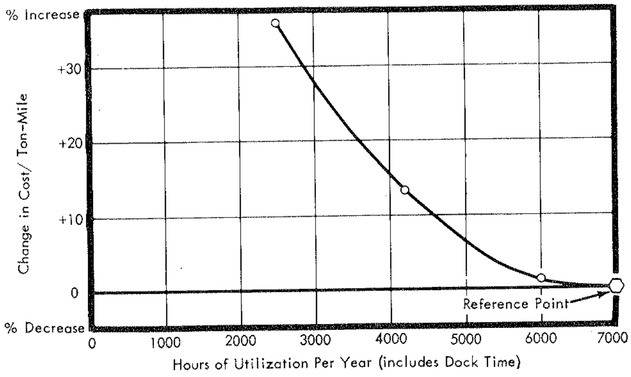

Figure 24. Effect of varying utilization

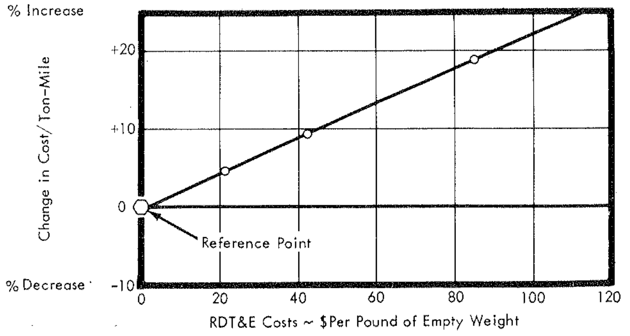

Figure 25. Effect of including research, development, test and evaluation (RDT & E) costs

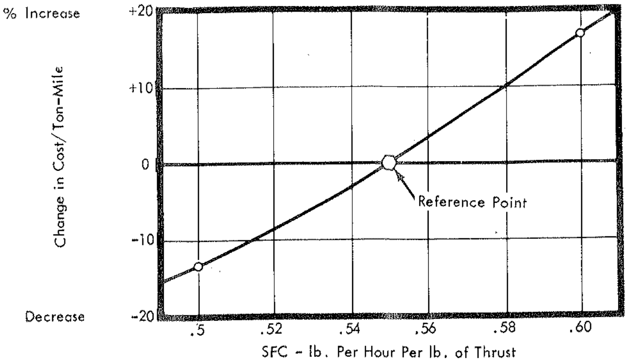

Figure 26. Effect of varying specific fuel consumption (SFC)

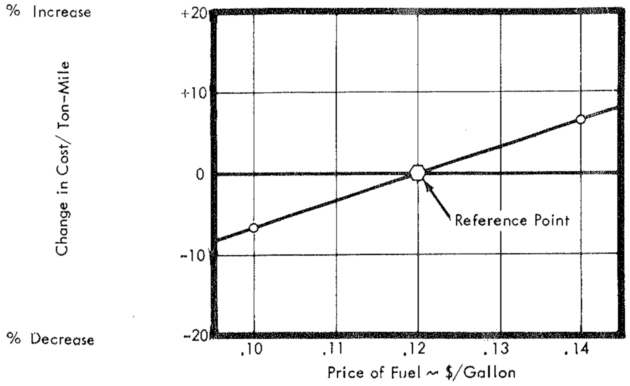

Figure 27. Effect of varying purchase price of fuel

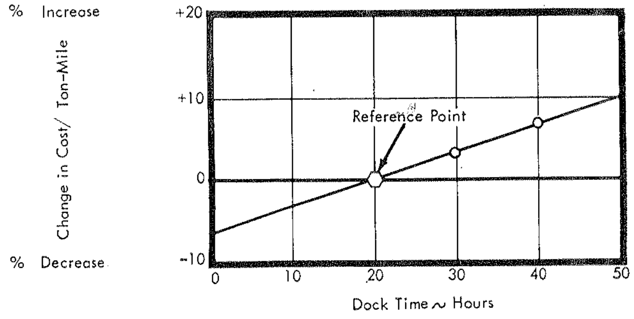

Figure 28. Effect of varying dock time

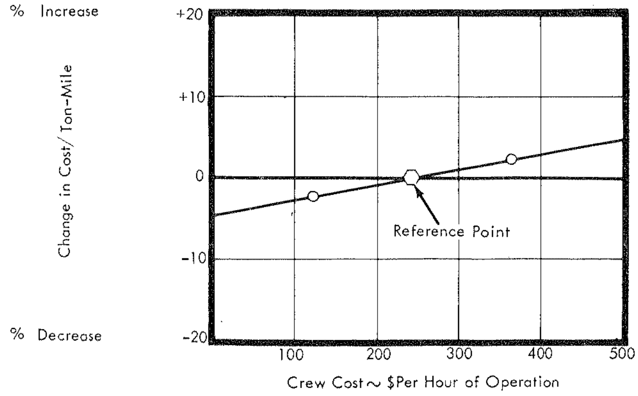

Figure 29. Effect of varying crew cost

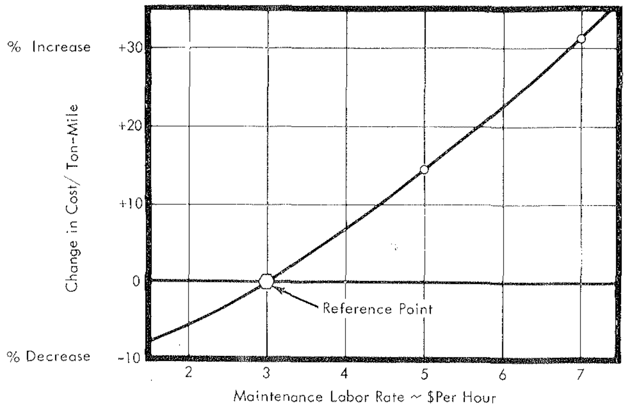

Figure 30. Effect of varying maintenance labour rate

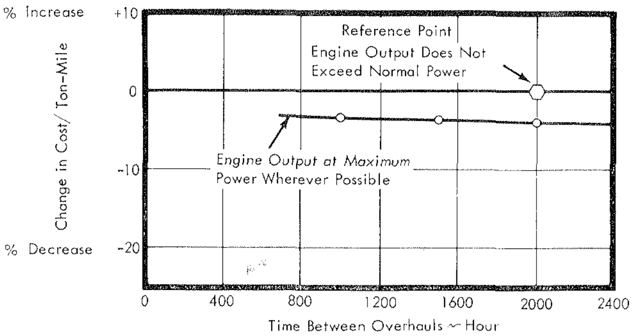

Figure 31. Effect of varying time between engine overhauls

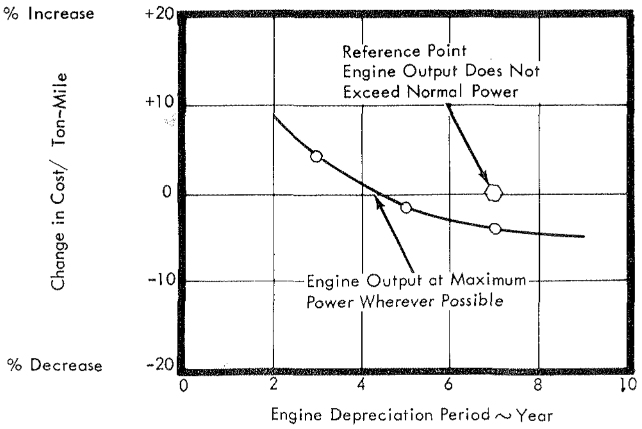

Figure 32. Effect of varying engine depreciation period

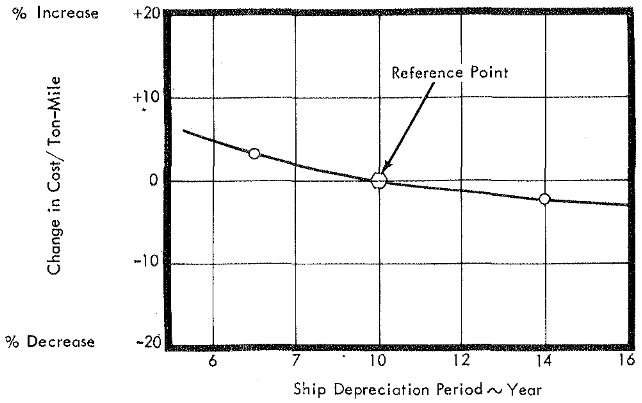

Figure 33. Effect of varying ship depreciation period

Dock Time

Figure 28 shows that if dock time is doubled for the 5,000 ton CAB ship from 20 to 40 hours per trip, the transportation cost would increase by 6.8% with the same basic utilization of 7,000 hours per year. (Note that utilization includes dock time.)

Crew Cost

A previous figure indicated the variation of crew costs with CAB ship size used in the computer programme. Data in *Figure* 29 show that increasing or decreasing crew costs by 50% changes transportation cost by only 2.4% for the 5,000 ton CAB ship.

Maintenance Labour Rate

In the route analysis the maintenance labour rate was assumed to be $3 per hour. Current shipping experience shows that the rate might be somewhat higher. Figure 30 shows that if the rate was as high as $3.50 per hour, transportation costs would increase 3.2%.

Time Between Engine Overhauls

Throughout the route analysis it was assumed that the ships had the number of engines required to operate at maximum speed with normal power (80% maximum power). There is a possibility of operating the engines at maximum power, thereby reducing the number of engines required for operations by 20%. However, if the engines are operated at maximum power, the time between engine overhauls will probably decrease and the useful life of the engines (depreciation period) would probably decrease. Figures 31 and 32 show that operating the engines at maximum power with no change in overhaul and depreciation periods would result in a decrease in transportation costs of 4%. Figure 31 also shows that decreasing the time between overhauls would have little effect on the transportation cost.

Engine Depreciation Period

Figure 32 shows that decreasing the engine depreciation period would have a significant effect on transportation costs. For instance, if the depreciation period decreased by two to six years due to operation at maximum power rather than normal power, the reduction in transportation cost obtained by using fewer engines would equal the additional cost incurred by reducing the engine life.

Ship Depreciation Period

In the route analysis the ship depreciation period was assumed to be ten years. Figure 33 shows that if this depreciation period is increased by fifteen years, transportation costs would be reduced by 2.5%.

Power Requirements

Data in Figure 34 show relationships between required horsepower and speed for the 5,000 ton CAB ship. The results of the route analysis described previously assumed that the ship was travelling at the speed for normal rated power at all times, as shown by the base reference line in Figure 34. Three additional power schedules were examined to see if it might be less expensive to operate at a slower speed and lower horsepower. Schedule (1) assumes a maximum speed of 118 knots; Schedule (2) assumes a maximum speed of 100 knots; and Schedule (3) assumes a speed of 82 knots (with the maximum speed for ship operation at a height of 8 ft).

Data in Figure 35 show that there is an optimum place to operate at somewhat less than maximum speed, but that the reduction in transportation cost is quite small — about 2% at 130 knots. However, operation at the maximum speed for the maximum operating height (82 knots at 8 ft) would mean an increase in transportation cost of over 22%. *The value of operating surface effect ships at high speed is clearly emphasized.*

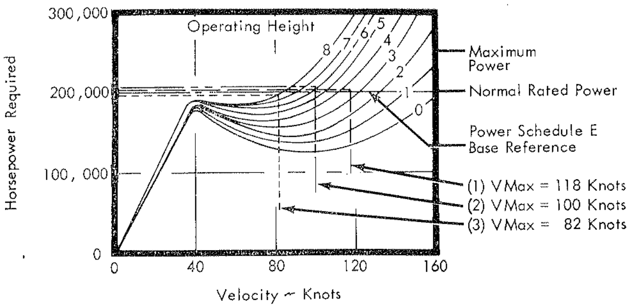

Figure 34. Power requirements — 5,000 ton CAB

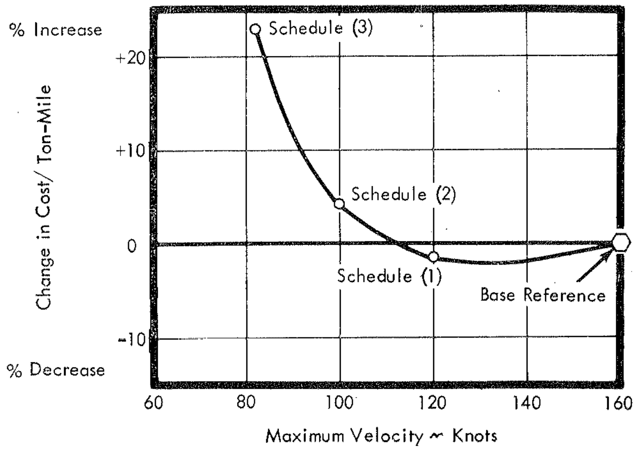

Figure 35. Effect of varying power schedules

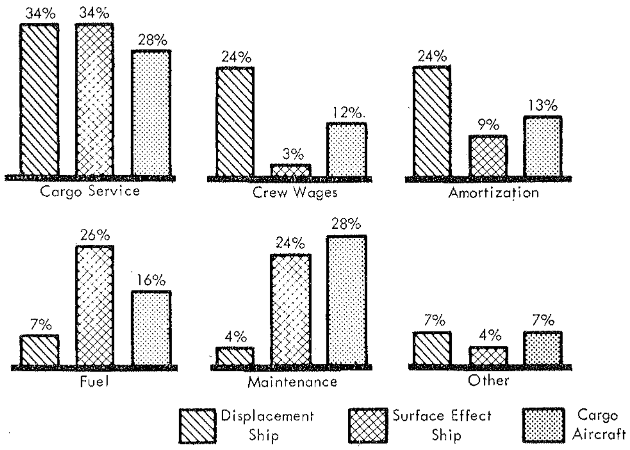

Figure 36. Comparative operating cost of ships, surface effect ships, and aircraft

Table 9
LONG RUN AVERAGE TRANSPORTATION COSTS

Transport Mode		Freight Cost (¢ per ton-mile)
Railroad		1.75
Highway		5.30
Waterway		1.00
Ocean		0.95
Air		21.00
CAB SES (5000-ton)	New York to Southampton	5.100
	Los Angeles to Honolulu	3.000
	Honolulu to Tokyo	2.600

Table 10
ANNUAL CAPACITY (NEW YORK TO SOUTHAMPTON)

Type of Vessel	Dead Weight (Long tons)	Payload (Long tons)	Cruise Speed (knots)	Annual Capacity (Long tons)
2,500-ton CAB		732	81.0	103,212
5,000-ton CAB		1,620	88.5	202,500
10,000-ton CAB		3,540	98.4	343,800
C 2 cargo ship	9,072		15.5	108,864
C 3 cargo ship	11,648		16.5	139,776
C 4 cargo ship	12,544		20.0	150,528

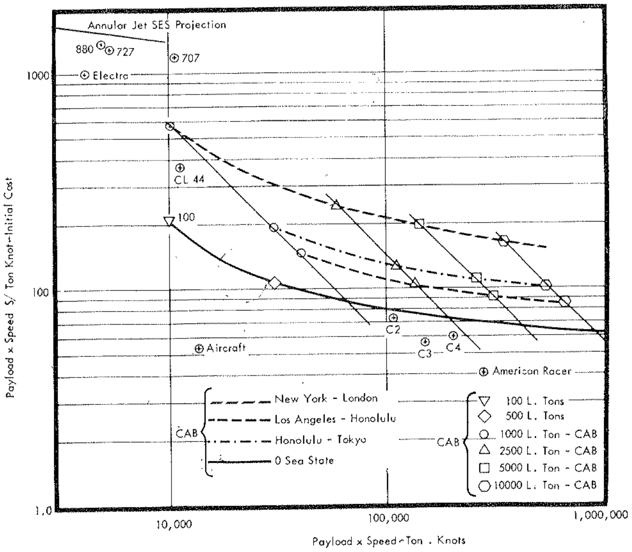

Figure 37. Initial cost as a function of the work capability

The CAB and its Competition

The final analysis of a particular transport as a prime carrier requires consideration of its cost structure in relation to its competitors. Figure 36 is helpful in visualizing the differences in cost structure. The figure shows the per cent distribution with respect to operating cost of displacement ships, cargo aircraft and the CAB ship. The five indices are believed to form a valid basis for comparing transportation systems, marine or otherwise.

- **Cargo Delivery Costs**

  The cost methodology employed provides accurate initial ship investment costs.

  The CAB ship costs, when compared with average costs of other transportation means, provides a basis for evaluation of the ship as a prime carrier. In making such a comparison, the CAB ship is being presented in a rather unfavourable light because the other cost data have not been developed on the same basis. It is perhaps appropriate to remind the reader that these other costs and rates result from many years of operating experience and adaptive changes in designs of the equipment, and in operating procedures to improve their effectiveness, while the CAB ship is the first of its kind and its cost characteristics are derived on the basis of operating a single unit. Long-run average costs of various transportation means are presented in Table 9.

- **Passenger Transportation Cost**

  No passenger service has been considered in this analysis of large Captured Air Bubble SES's in transoceanic routes.

- **Annual Capacity**

  The annual capacity measures the total production of the ship and gives an absolute measure of the work capacity.

  The annual capacity of the CAB ships of different sizes, and that of the current cargo vessels in service operating on the same routes, are shown in Table 10.

  The ultimate use of annual cargo capacity data would be to determine the number of operational units required to perform the mission in a selected market and, in that way, to determine the initial system investments. Neither a large nor a small annual cargo capacity signifies the merit of the carrier. However, it should bear a consistent relationship to the traffic volume and characteristics to make possible high load factors and utilization.

- **Capital Investments**

  Capital costs of CAB ships are expected to be high. These ships are relatively expensive and are close to aircraft costs in production quantities; however, the cost of terminals is expected to be less than those for conventional ships or aircraft. The CAB is expected to use existing docks and terminal facilities up until the time there are enough in operation to warrant facilities tailored to suit their specific needs.

- **Return on Investment**

  The provision of transportation service is generally a low profit enterprise. Beyond this fact, the surplus of shipping as well as air transportation capacity has created a highly competitive market in which these ships will have to operate. Furthermore, it is practically certain that rates will be subject to some regulation. In view of these considerations, it is most likely that capital will be attracted to CAB ship operation on the basis that a high return on investment would be realized. *In many instances, the acquisition of the CAB ship by the Merchant Marine will resemble the state of the market in the early 1950's when jet transports were being introduced on the airlines.*

  However, like so many of the other unknowns which may be encountered in the implementation of a new service, there is too little information available to be specific on this matter. Only experience can provide the answer as to what can be anticipated in the way of return on investment in the CAB ship. Return on investment must be considered in the analysis of specific routes which should be undertaken with care, based on considerations prevailing at the time when the CAB ship has demonstrated its apparent potential.

- **Potential Work Cost**

  As a final index of the transport means, the potential work capacity, expressed in terms of ton-knots as a function of the cost per ton-knot, may be an important factor.

  Based on the work by Trillo (Reference 2), different sizes of the CAB ship aircraft, and conventional cargo ships have been plotted.

  Figure 37 shows that the CAB ship follows a general trend of decreasing cost with increase in work capacity. The figure also shows that these ships can provide the same work capacity of conventional merchant vessels at slightly higher cost per ton-knot. *This interesting relationship places in the proper perspective the value of the CAB ship's higher speed and capability, in relatively small sizes, to compete on important trade routes with conventional shipping.*

  In this respect, it is estimated that the CAB ship's higher cost will be offset by the much higher relative speed (five to one) which will provide an express cargo transoceanic service with its inherent effect of lower warehousing and insurance costs.

Summary Remarks

The CAB ship in its present state of development appears to offer the greatest potential to the American Merchant Marine on several counts:

1. The development of sidewall craft such as the Denny D1 and D2 craft, the hydrokeel and the NADC man-carrying model, provide a firm basis for future development.
2. The ship-like form of the CAB ship, with its intimate contact with the water, will require no advanced handling techniques in congested seaways or open water.
3. Technology in supercavitating water propulsion systems and water pump propulsion systems is well advanced.
4. Total transport costs of five to ten cents per ton-mile over ranges suited to the North Atlantic offer a service competitive with conventional shipping.
5. Cruise speeds in the range of 60 to 80 knots will offer unprecedented gains in transporting cargo between heavily industrialized countries.
6. Return on investment is likely to be slow due to high initial outlays, but may be phenomenal as operations eliminate the competition by time and ton-mile cost advantages.
7. With annual utilization similar to high-speed displacement ships, together with a speed differential of almost five, the CAB ship offers the same productivity as cargo ships plus the benefit of 48 hour delivery schedules over North Atlantic routes.
8. Initial costs on a ton-knot basis are comparable to displacement ships.
9. Current developments in sealing the bow and stern openings between the longitudinal skegs offer a variety of solutions. These developments include a water wall which also acts as the main propulsion system, a flexible skirt with water skis, and variations of the two.
10. The high degree of automation in cargo handling containerization, currently under consideration for displacement ships, will be further enhanced by the internal stowage configuration of the CAB ship.

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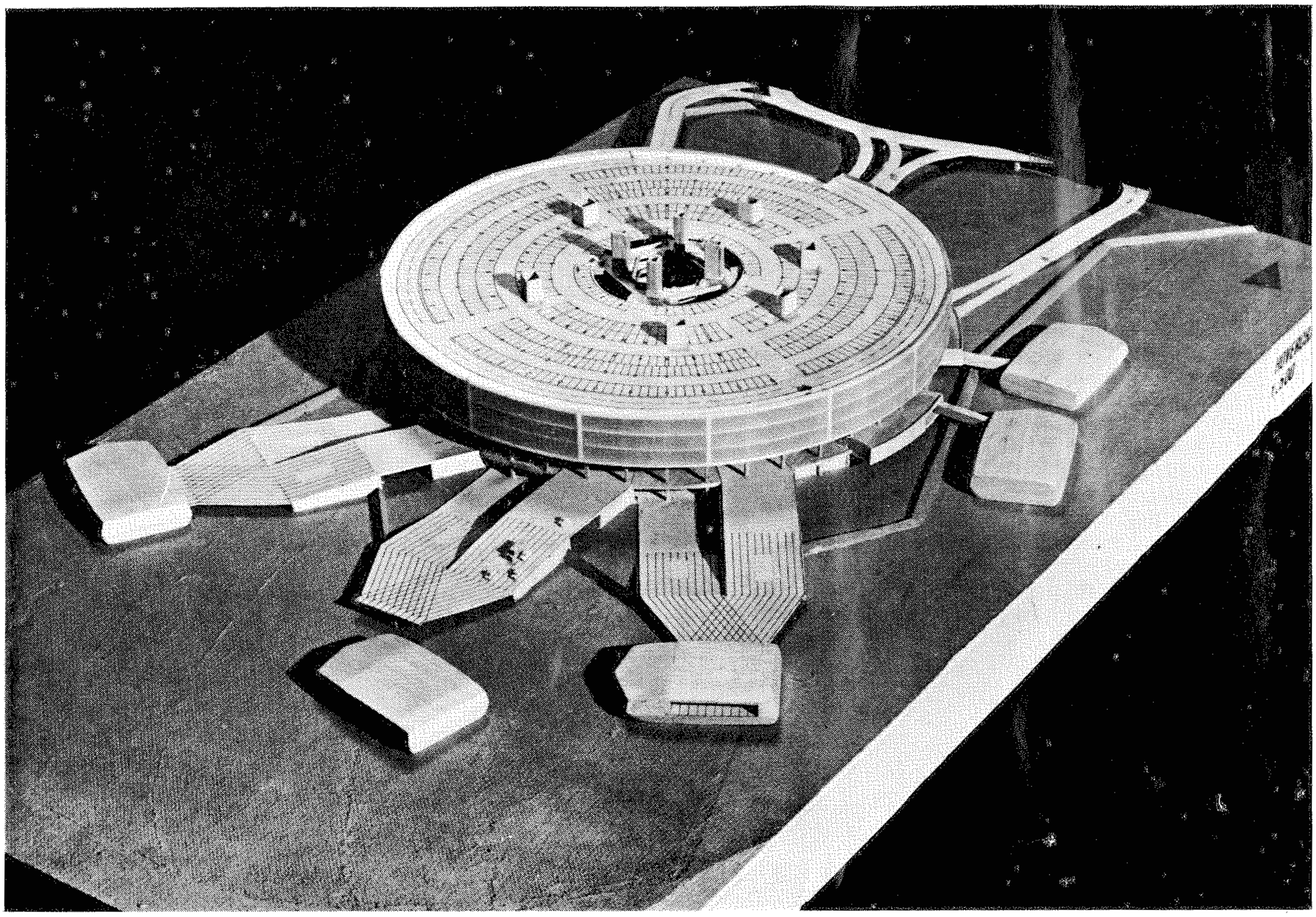
2. R. L. Trillo, "What Price Hovercraft" *Air Cushion Vehicles,* Flight International Supplement, August-September 1963.



A model of the proposed hoverport with the car parking section removed to show the public concourse with feed-on to passenger craft and vehicle craft

HOVERPORT

By a final year School of Architecture student

General interest is growing — the bubble is about to burst.

This thesis for a diploma in architecture is an attempt to show the potentiality of a hovercraft service from Felixstowe on the South-east English coast, and to indicate the design requirements of a hovercraft port in such a location.

Cross-Channel traffic has increased at a spectacular rate.

The figures for this year, already 10% above 1964, have brought many extra car ferries into service.

Small coastal ports, using drive-on/drive-off freight facilities, are challenging the strikes and time delays of the London docks.

Scandinavian firms with an eye to the future cross-Channel market are becoming increasingly interested in hovercraft.

The advantages are great: speeds of 70-100 knots, fast turnround times, and no deep-water requirements.

Cross-Channel hovercraft will be produced and operating within the next two years.

1. POTENTIAL OF THE HOVERCRAFT

Amphibious hovercraft

THE main emphasis in the field of hovercraft at the present time is on the *amphibious* type because of its advantage of being able to rise out of the water on to dry land with little difficulty. These craft can be used as conventional displacement ships (in the water) for slow-speed manoeuvring, but after a certain speed (hump speed) the depression in the water underneath the body caused by the air pressure disappears, and the craft becomes airborne. This is because the craft has moved on before the depression has time to form and in this "windborne" state the hovercraft is oblivious to currents, tides and depths of water.

Coupled with the fact that they can travel over small rock protrusions, ice-floes, rapids, mudflats and sandbanks and over flat land and sea at 70-80 knots, they become an attractive proposition for many uses.

Dover-Calais 20 mins?

The main use being developed at the moment is for car and passenger ferrying to replace or support existing conventional ships. Their vastly superior speed of travel gives them a great advantage over conventional ships, particularly over the longer sea routes, and even the twenty-two-mile Dover to Calais journey could be cut from 1½ hrs to 20 mins.

Experimental ferries

The Scandinavian countries, particularly, are keenly interested in the development of the hovercraft as a ferrying craft, and already experimental services have been tried in various parts of the world, notably on the Thames and Solent in England, across the Oresund between Denmark and Sweden, between Long Island and New York, and in the St Lawrence river.

Regular services

The first regular *all-the-year-round* services commenced on the Clyde in Scotland in summer 1965, and in 1967 a Westland SR.N4 will operate on the Solent with a capacity of 230 passengers and thirty-two cars approximately.

This 150 ton craft is also capable of crossing the Channel and will be used for other regular services to the Continent in 1967 and 1968.

In the not too distant future it will be possible to build large hovercraft able to ride the ocean waves with greater comfort than the conventional *Queen* ships at speeds of 100 knots or more!

Ocean hovercraft

It is difficult, though, to forecast the role of transatlantic hovercraft since they would be in direct competition with the much faster jet airliners, but on the short-haul routes such as across the Channel they will certainly prove to be very competitive with the airline companies and will probably handle a large percentage of the total traffic very soon.

Lifeboats and landing craft

Swamps and ice-floes

The hovercraft's ability to ride over objects several feet high (6-8 ft at the present time) makes it eminently suitable for crossing surfaces impossible by normal wheeled vehicles or boats. Demonstrations have shown its ability to cross swamp and marshland where Land Rovers become bogged down, and it has been used successfully on the St Lawrence river when completely covered with ice-floes. The hovercraft can travel over rapids and fast-flowing rivers without being influenced by the shallow water or by currents.

It will be particularly useful as a lifeboat, being able to operate at any state of tide and capable of safe operation along rocky coastlines where rocks and protruding corals prove fatal to the vulnerable hulls of conventional craft. There would be no necessity for steep launching slipways into deep water since the craft could be stationed on dry land, and the speed factor would prove invaluable in saving lives.

Military use

The same capabilities of shallow-water operation and resistance to minor obstacles are also useful in military operations. Hovercraft are already used as troop-carriers and gunboats (Vietnam 1965) and will obviously be used as tank landing craft, fast supply boats and missile launching boats.

Nuclear powered

Anti-submarine hovercraft should prove a formidable weapon against nuclear submarines. They will be able to get to the target area very quickly, the submarine will not "hear" the characteristic ship noise, and for pinpointing purposes the hovercraft will remain stationary.

Looking some years ahead, it is quite conceivable that immense nuclear-powered hovercraft will be used, crossing the world's oceans at 150-200 mph with a strike force of Polaris missiles or flight deck of jet aircraft!

Freight

Returning to more peaceful purposes, the hovercraft will be immensely useful for freight carrying. At the present stage of development it is only suitable for low-density freight, that is, bulky but light goods. This is because the craft are essentially low density themselves. Their speed potential makes them commercially suitable for the swift delivery of foodstuffs, bulbs and flowers, for example, between England and Denmark or Holland, and they could be extensively used for the exports and imports of the car industry.

Dry land loading

The ease with which unloading and loading can take place on dry land will be particularly attractive since the unpredictable elements of the weather will be less disturbing. The writer envisages the growth of the drive-on/drive-off facilities for freight lorries will accelerate even more with the advent of hovercraft.

The air cushion can improve manpower capability by overcoming frictional losses between a heavy load and the ground, enabling man to concentrate on pushing the load in a particular direction. This "quality" can be used on the building site for carrying ready-mixed concrete and bricks, or on the factory floor for components and in the domestic field for such appliances as lawn-mowers. There is, in fact, one example on the market now which can be used on 45° slopes quite easily.

Apart from hovering Land Rovers for crossing waterlogged fields, hovercraft will be used for transporting bruisable fruit such as bananas and apples over rough terrain where up until now lorries have had to slowly bump their way.

Hovertrains

Australian outback

Similarly they will be used in the Australian outback for transporting cattle where there is a serious loss of cattle if they are driven over distances of up to 400 miles, and they should be very suitable for desert operation where traffic density is low and obstacles few.

Inter-city

One of the most attractive propositions is for an inter-city monorail hovertrain system, with the prospect of 150-seat hovercars travelling 400 miles from London to Edinburgh at 300 mph or more. The cost of erecting a double track for the system would be anything up to £200,000 a mile.

Another system has been proposed using drained canal beds with a precision-made concrete track with hovertrains travelling on a ½ in cushion of air, using linear electric motors.

2. PROPOSED SERVICE — CHOICE OF ROUTE AND SITE

Felixstowe service

Purpose

The hovercraft service at Felixstowe is an attempt to spread the load of cross-Channel vehicle traffic and relieve the congestion which occurs on the classic ferry routes, notably emanating from Dover.

As can be seen from the diagram below, the Felixstowe service is intended to commence operation in 1970 or 1971 and therefore will not necessarily be the *first* cross-Channel hovercraft service to operate. Townsend Ferries, Svenska Lloyd, and British and French Railways have all announced within the last few months plans to commence cross-Channel services in 1967 and 1968.

These services will probably supplement existing routes and will no doubt utilise existing port facilities. The Westland SR.N4 hovercraft to be used belongs to the "first generation" of larger craft with cross-Channel capabilities and will be leaving the production line in 1966-67.

Craft to be used at Felixstowe in 1970-71 would be of the "second generation", as it were, with more advanced capabilities and larger cargo capacity.

The Felixstowe service, as well as helping out with the increase in peak holiday traffic forecast by the Ministry of Transport, will prove to be the most attractive outlet of traffic from England to Scandinavia, Holland and Germany, and vice versa.

Phase-in

EXPANSION OF TRANSPORT SYSTEMS ACROSS THE CHANNEL AND NORTH SEA

1965 — Conventional shipping expanded.
6 — Ditto.
7 — Hovercraft begin to help out existing ports.
8 — Continued expansion in use of hovercraft.
9 — Ditto.
1970 — Hovercraft ports and second generation craft commence.
1 — Ditto (including Felixstowe).
2 — Channel tunnel in operation (six years to build).
3 — FROM HERE ONWARDS:
4 Tunnel takes large proportion of traffic and
1975 sophisticated hovercraft facilities gradually
6 replace conventional shipping to a large
7 degree.
8
9
1980
1
2
3
4
1985

Assumptions

It is assumed that the existing forms of cross-Channel transport (ships and aircraft) will continue to operate at roughly the present level of frequency, and that the increase in traffic from now onwards will be taken up, *first*, by introducing additional services using hovercraft (also eventually replacing a good many conventional ships with hovercraft) and *second*, if negotiations are ever settled in time, by building a Channel tunnel. Preliminary sea-bed testing has been done now, but the author wonders whether a tunnel will ever be built, particularly since British and French Railways have shown great interest in cross-Channel hovercraft services.

Essential outlet for Britain

Diversify routes

The tunnel alone would be capable of absorbing a very large proportion of the forecast traffic from 1965 onwards but it would seem somewhat undesirable to concentrate it all on to one route, particularly since some types of traffic wish to spread and diversify more than others. For example, rail traffic is by its very nature limited to a few trunk lines, whereas car traffic is not limited to any such degree.

It is suggested, therefore, that by the 1970s, even if the Channel tunnel is in operation, Felixstowe will be in a position to provide an essential service to:

(i) holiday traffic emanating from East Anglia and the Midlands wishing to cross to the Continent, and
(ii) freight to and from Holland, Germany and Scandinavia, and the industrial Midlands of England.

Mixed cargoes

The SR.N4 hovercraft designed by Westland is intended to be an "adaptable" craft and is able to undergo internal changes so that different configurations of payload can be carried, i.e. all passengers (566), or a mixture of cars and passengers (35 cars, 116 passengers), or coaches in addition (15-18 cars, 3 coaches, 228 passengers), or freight (60-65 tons). This entails moving passenger seats around, strengthening the floor in places and even increasing the headroom over part of the deck for larger lorries. This may look very desirable and efficient on paper, but when other aspects of efficiency are studied, such as unloading times at destinations, the picture is less rosy. It is quite possible to unload a cargo of cars alone from a craft in a matter of minutes, but to unload 800 passengers takes a great deal longer. Thus, if cargoes are mixed, time is lost in turnround for some types, such as cars. This does not matter so much over longer routes of several hours' duration, but for the car ferries on short cross-Channel hops it is ludicrous to sacrifice the hovercraft's inherent advantages of speed by mixing cargoes.

Separate "Felixstowe" craft

It has been decided, therefore, contrary to present manufacturers' trends, to use two distinct types of hovercraft for the Felixstowe service:

Type (i) — to carry passengers only (800 passengers);
Type (ii) — to carry vehicles and their occupants only (e.g. sixty-five cars).

Felixstowe to Ostend 80 mph

It is proposed to relieve the summer congestion of the Dover route by running a crack car ferry service from Felixstowe to Ostend, departing every thirty minutes. This journey will take less than one hour and should prove immediately attractive, being half an hour less than the present Dover to Calais run by conventional ship. This route will serve holiday traffic from a large hinterland which includes East Anglia, North-east London and the whole of the Midlands.

Passenger service

This main car, coach and lorry service will be supplemented by a less frequent passenger-only service to Ostend, and there will also be passenger and vehicle services to the Hook of Holland.

Freight service

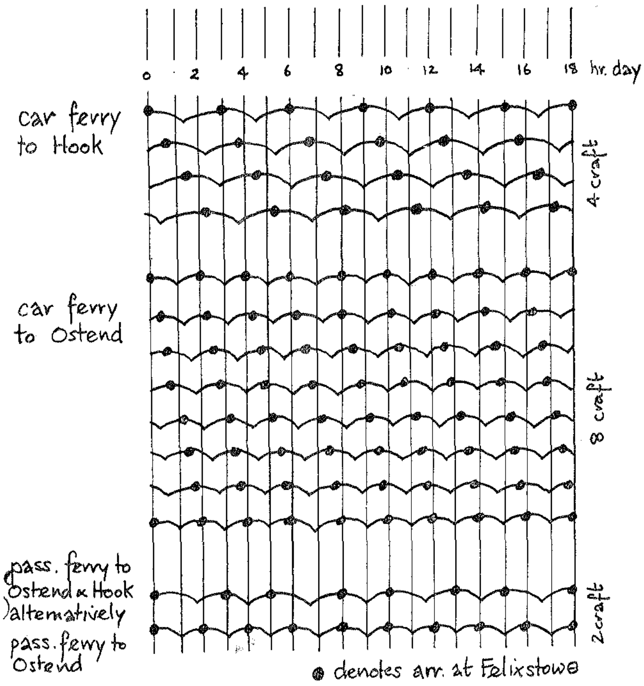
During the remainder of the summer months when holiday traffic is a little less demanding the frequency of the crack Ostend service will be reduced and the craft utilised on other routes for regular freight and charter services.

During winter months the slackness of the holiday service will be taken up to a great extent by freight services using lorries on a drive-on/drive-off basis. It is envisaged that this service will be increasingly used by Dutch, German and Danish firms wishing to export foodstuffs, flowers and other perishable goods to England by the quickest possible means and by British manufacturers exporting similar goods and industrial goods, particularly cars.

Existing Felixstowe port

The small port which already exists at Felixstowe is at the present time being expanded and revitalised for a drive-on/drive-off freight service using conventional ships, so how much more attractive it would be to use hovercraft which would cut the journey time to the Hook from seven hours to two hours.

1985 TIMETABLE
Peak Day 1985



Computer link

Nerve centre

The author visualises the future of Felixstowe as a focal point of routes to several continental ports linked together by computer which would determine the traffic inflow at the various ports and compile the most efficient timetable for the craft operation. This would be especially practicable with hovercraft operation, since the overall fleet would be made up of a large number of *small* but *fast* units, which are always easier to deploy than a *few, very large* units. By feeling the pulse of each port the computer can continually report back the overall picture of traffic densities entering the Channel and North Sea ports, and any sudden build-up can be dealt with efficiently and quickly.

On normal days the movement of craft at Felixstowe would not be very intense (probably one arrival every three-quarters of an hour), but the port has been designed for the worst possible conditions and below is a timetable for a peak day in 1985 based on the predicted traffic figures.

When proposing the location of a new ferry route a great many variables influenced the decisions made.

Diversification of road traffic

The main decisive factor in this case was the author's belief in the necessity to spread and diversify cross-Channel traffic. It would seem patently obvious that the roads and ferry facilities in the Dover area of Kent are becoming far too overloaded and that an attractive outlet on the East Coast would reduce the traffic flowing south through London and encourage a cross-flow to areas of Germany and Scandinavia.

Cost

Up until now it has been impossible to develop large ports on this coast because of the cost of dredging to provide deep water for the larger ships But now with the advent of hovercraft no deep water is required at all, and outlets on the East Coast are a commercial proposition

Choice of site

Siting

This particular peninsula of land at Felixstowe was chosen for the site because, first, on a national scale the road connections with the main towns of East Anglia, London and the A1 are very good (minor improvements would have to be made in some places between Ipswich and Felixstowe), and second, on a local scale the site provides ideal landing beaches on a piece of unused land clear of the more intensely used sailing and bathing beaches, and a fair distance away from residential development. The only disadvantage appears to be that the land is low-lying with a possibility of flooding, and it is fairly exposed to the elements. Both these factors can be "designed out" by the architect in the final form of his building.

Hydraulics

The hydraulics of this site are very satisfactory for hovercraft operation. The shingle beaches run into the water at a shallow angle and the outflow from the combined estuaries of the rivers Stour and Orwell tends to build up the land rather than eat it away. It is proposed to "bind in" the runway area and landing beaches by a suitable method (either timber matting or sprayed tarmacadam) to prevent furrows developing, and that minor shifts in the beach be adjusted by bulldozer. The presence of breaking waves on the beach is not important since the large hovercraft can operate through this type of surf.

Traffic forecast

Traffic estimates

The amount and nature of traffic which will use the hovercraft port at Felixstowe is rather difficult to estimate in advance, since it employs a completely new mode of transport as well as fresh routes and destinations. However, estimates have to be made, and in the absence of any "artificial" controlling factors, such as Government subsidy of fares, the main influential factors controlling traffic growth seem to be such things as: speed of journey, comfort of travel, convenience of route, ease of access to port, connections with other types of transport, lack of congestion and swiftness of passing through port formalities.

Felixstowe would be one of several hovercraft ports around the country and would also be in competition with conventional shipping and aircraft as well as possibly a Channel tunnel.

Method of calculation

The method of forecasting traffic has therefore been to

- — find out the total amount of traffic crossing the Channel (sea and air) in 1964 and how it was distributed over the various routes,
- — suggest the likely changes of distribution which would occur when a tunnel and hovercraft commence operations,
- — then increase the figure by a percentage consistent with the general traffic increase forecast by the Buchanan Report.

For these approximate calculations the ferry routes have been lumped together into four categories:

(i) all air routes,
(ii) the proposed routes from Felixstowe,
(iii) all routes emanating from Dover including a tunnel,
(iv) Newhaven to Dieppe route plus others.

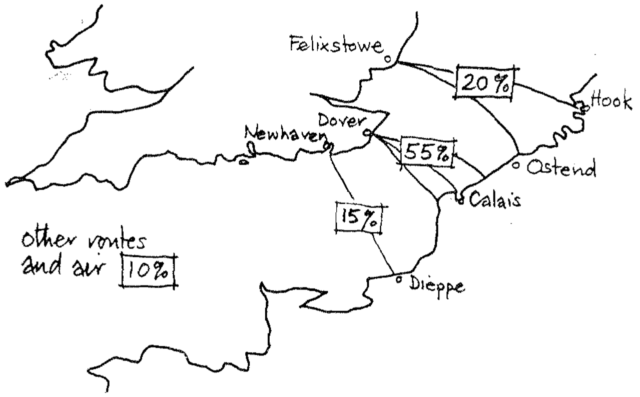
Cars and occupants

Assumed 1964 distribution

In 1964 Dover handled 550,000 cars (both directions combined), which was, say, 55% of the total cross-Channel traffic (all routes combined). This was in a year when the total cars in use in this country were 7,000,000.

In 1974 there will be 14,000,000 cars in this country (Buchanan); in 1980, 19,000,000; in 2010, 30,000,000; i.e. in twenty years' time (1984) the number of cars will treble.

By 1970-71 and onwards, distribution over various routes including Felixstowe and the tunnel will probably be as shown on the map that follows at the head of the next page,



Cars and occupants

then the proportion which Felixstowe will handle from 1971 onwards will be 20/55 × 550,000 + forecast increase in cross-Channel traffic.

In 1984 the cars in use will treble but the cross-Channel traffic will probably quadruple (because more common use of the car will generate extra traffic), i.e. in 1984 *Felixstowe will handle* 800,000 *cars per year.* Average per day = 2,200 (both directions combined). Therefore peak days = 2,200 × 4 (similar to Dover 1964) = 8,800, of which say *6,000* approximately travel in one direction

Peak day service 1985

Therefore, 18-hour day service would be:
say 4,600 to Ostend, i.e. eight craft, one leaving every fifteen minutes;
1,400 to Hook, i.e. four craft, one leaving every forty-five minutes.

Average per day = 2,200 (both directions combined).

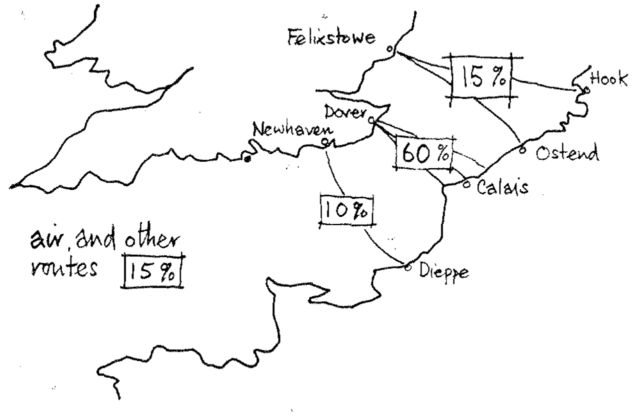
Therefore average off-peak day (during nine months of the year) = 1,100 (if similar to Dover 1964 figures), of which say *550* approximately travel in one direction.

Off peak day 1985

Therefore, 12-hour day service would be:
say 350 to Ostend, i.e. one craft leaving every two hours;
200 to Hook, i.e. one craft leaving every three hours.

Unaccompanied passengers

By 1970-71 and onwards, distribution over various routes including Felixstowe and the tunnel will probably be as shown on the map below.



Unaccompanied passengers

Dover in 1964 handled 3,500,000 unaccompanied passengers (both directions).

In 1984 the figure will be 6,500,000, of which Felixstowe will handle 6,500,000 × 15/60 = 1,625,000. Average per day = 4,452 (both directions combined). Therefore peak days = 4,452 × 4 (similar to Dover 1964) = 17,808, of which say *12,000* approximately travel in "worst" direction.

Peak day service 1985

Therefore, 18-hour service would be:
say 9,000 to Ostend, i.e. one craft leaving every two hours plus one craft leaving every five hours;
3,000 to Hook, i.e. one craft leaving every five hours.

Average per day = 4,452 (both directions combined).

Therefore average off-peak day = 2,226, of which say *1,113* travel in one direction.

Off-peak day service 1985

Therefore, 12-hour service would be:
say 600 to Ostend, i.e. one craft leaving daily;
513 to Hook, i.e same craft leaving daily.

With thoughts on a regular cross-Channel service in a few years' time using the large SR.N4, Townsend Ferries and a Swedish firm wish to experiment meanwhile with the SR.N6 which were used to start the first all-year-round services in June and July 1965 on the Clyde and at Gosport. Both these craft were chartered from Westland.

The most significant step will be the production of the large £1,500,000 SR.N4 able to carry 230 passengers and 32 cars at 70 knots over Channel conditions.

Both Townsend Ferries and Svenska Lloyd hope to operate with these in 1968, and British Railways and French Railways would like to pip them at the post, but with some financial support from the Governments.

"Felixstowe" car ferry

The design of this craft, suggested by the author, is based on the capabilities of existing craft. It is slightly larger than the SR.N4, and incorporates performance and manoeuvrability improvements which the next few years of development should bring.

Capacity

Length 160 ft 0 in; width 100 ft 0 in; height 35 ft 0in.

AU weight 200 tons; payload 70 tons, i.e. 60 cars and occupants, or 48 cars and 6 coaches and occupants, or 30 coaches or lorries and occupants, or 800 passengers.

Steering system

The method of berthing this craft at the Felixstowe port will depend upon future developments in the accuracy of control of hovercraft. At the present time control is fairly inaccurate, but the author believes that by the time the Felixstowe port is in operation in 1970-71, one or other of the suggested methods would be operating satisfactorily. Given a more precise control over the air thrusts from the engines, it should be possible to guide the hovercraft electronically by means of underground cables. These guides would be "picked up" a short distance from the loading ramp and would take over from the normal ship-to-shore radar system. Minor inaccuracies of placing due to extreme wind conditions are taken care of by adjustable ramps, and in the case of passenger craft the telescopic loading arms are able to swivel through 90° horizontally as well as a small amount of vertical adjustment for different-sized craft.

Any system of guidance using wheels in contact with the ground would only be suitable for small craft and would seem to the author to detract from the advantages of the air cushion principle.

3. DESIGN CRITERIA

This building deals with the movement of people from one mode of transport to another. It is essentially a giant mixing machine for transport, and should only need the minimum of "instructions for use" on the outside.

It must be efficient but at the same time "human". It should be easy and pleasant for people to move about it, and simple to use.

Circular

The author has chosen to use a circular building for several reasons; one being that it is easy for the newcomer to grasp its basic layout. The shape is already familiar to him and he knows that a circle radiates around a central point. He has less fear of getting lost, with this central "refuge" already established in his mind, and any confusion from past experiences of transport buildings should be lessened by this feeling of familiarity.

The author has taken the idea of a ceneral refuge further by forming the core of the building into a pedestrian concourse. The concourse facilities are buildings within a building.

Exposed site

Because it is on a very exposed site on the coast, it has been necessary to provide stages in the "transition" of people from the outside to the inside. When people are in cars they don't mind if it is raining, but when they get out they must at least be sheltered from the wet, and when they eat, drink or rest they must be in the dry and warm. Thus the hardy elements such as cars move around the outside of the building, the car park areas act as a "doormat" and the essential facilities of life are in the "dry" centre porition. It has not been thought necessary to provide gallons of sea air and sunshine for the people using the concourse, because most of them will only be there for a short time. Nevertheless sun will penetrate the glass roof and light up the concourse, escalators and lifts

Future expansion

There are two different types of expansion to deal with when increasing the total amount of traffic passing through the hovercraft port.

Two types

A larger throughput of traffic can be dealt with by increasing the frequency of the ferries, but when the limit is reached, however, the only course left is to physically expand the building with more facilities.

This building has been designed with *both* in mind. Everything has been designed to deal with the forecast traffic figures up to twenty years ahead, not only in terms of total per year but also the highest likely density of use which occurs on summer peak days. Even if these generous forecasts are ever exceeded, all the facilities, customs, parking, number of hovercraft, restaurants and other items can be expanded in one or other of the above ways. When the limit is reached, another hovercraft port would be built in addition, either near by if land was available, or somewhere else on the coastline.

Loading ramps

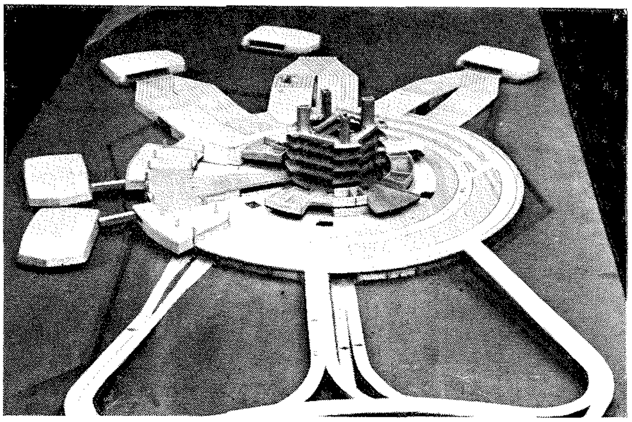
There is room for a 25% increase in the width of the vehicle loading ramps to allow for even larger hovercraft, and vertical adjustment (by hydraulic jacks) of the ramps is possible to cater for the higher or lower loading platforms of craft.

Ferrying capacity

The capacity for ferrying vehicles and passengers can be vastly expanded over and above the 1985 figures merely by increasing the number of arrivals and departures. Even if it was ever thought necessary, a fourth vehicle loading ramp could be added on reclaimed land on the west side of the port, thus increasing the capacity further.

Vehicle customs

The inward-coming customs procedure for vehicles is likely to become in the future if anything less formal, but the speed of passing vehicles through is governed both by the spacing of craft arrivals and the number of officers employed on the bays. If all the bays provided were fully manned, then three hovercraft could unload simultaneously and each vehicle could go to its own bay with absolutely no waiting whatsoever. The likelihood of three craft arriving simultaneously is very small, but it can be seen that enough customs bays have been provided for any eventuality in the future.



Aerial view of hoverport showing vehicle ramps (foreground)

The outgoing customs and immigration check is very much simpler and is done by officers on foot just before departure on to the craft. Since no special bays are needed, an increase in the number of officers will provide for adequate expansion.

Passenger customs

The speed of clearance of passengers through customs and immigration in both directions can also be governed by the number of officers on duty. There is adequate bench length for a full craft of 800 passengers to be dealt with without delays. It is also possible to install additional bench length in the future.

Car parking

The car parking provided on three floors at 640 car spaces per floor totals 1,920 spaces, and there are also an extra 640 spaces in the open air on the roof car park, which would only have to be used on a summer peak day in 1985. Even during an average day in 1985 only one or one and a half floors will be filled. The structure of the building is adequate to take two more parking floors on top.

Restaurant and cafeteria

The capacity of the restaurants and cafeterias has been calculated in conjunction with the 1985 traffic figures, but, as with all the facilities provided in the central core, there is provision for expansion or infill within the present structural system.

Concourse

There is a band of "free" space vertically below the concourse facilities to allow for the addition of new lifts and ducts, or for the alteration of existing ones. These service lifts are fed from lorry unloading bays situated within the staff car park below ground.

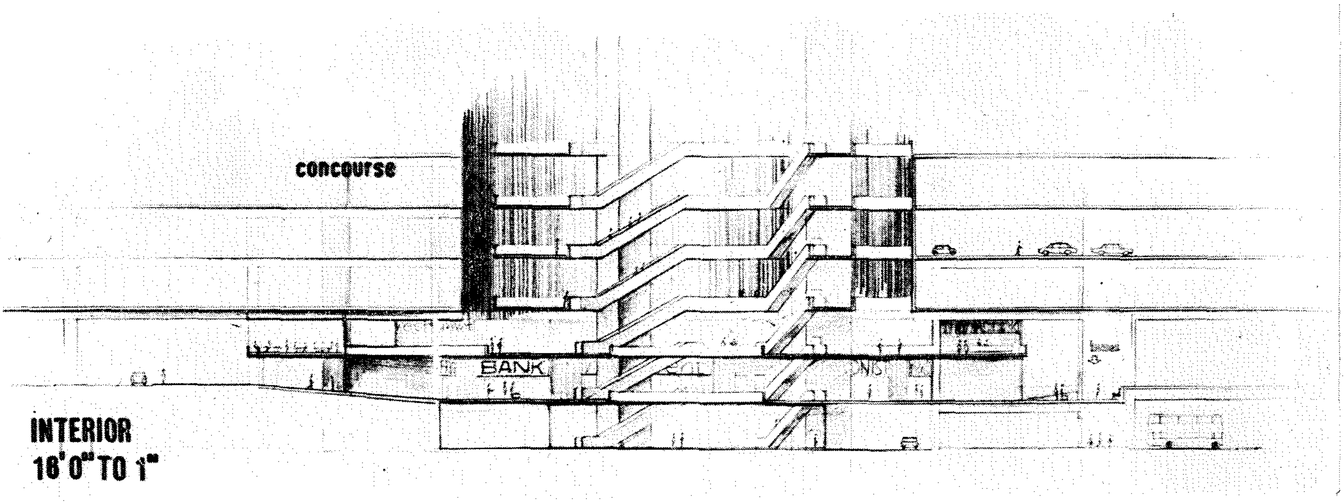
SPACE REQUIREMENTS

Peak day 1985

	No per day	*Worst No per hour*	*No per sitting*	*Seating area sq ft*	*Kitchen area sq ft*
			@ 15 mins	@ 16 sq ft	
Snacks	19,780	1,300	325	5,200	1,800
			@ 30 mins	@ 12 sq ft	
Meals	12,500	1,000	500	6,000	2,700

Off-peak 1985

	No per day	*Worst No per hour*	*No per sitting*	*Seating area sq ft*	*Kitchen area sq ft*
			@ 15 mins	@ 16 sq ft	
Snacks	3,400	280	70	1,200	700
			@ 30 mins	@ 12 sq ft	
Meals	2,510	500	250	3,000	1,500



A view of the interior of the hoverport showing the "floating" floors of the concourse connected by escalators and lifts

CAR PARKING

PEAK DAY 1985

	No parked at any one time
Cars travelling by hovercraft 8,800 in 18-hr day = 490 per hr × 60% stop (for 1 hr)	300
Coaches travelling by hovercraft 560 in 18-hr day = 30 per hr × 70% stop	21
Lorries travelling by hovercraft 8 craft load per day = 8 × 30 = 240 × 45% stop	100
Cars collecting and seeing off passengers 17,000 per 18-hr day = 944 per hr × 25% stop = 250 per hr	160
Passenger travellers leaving cars behind 12,000 × 15% ÷ 1.5 ppc	1,200
Staff cars	1,000

OFF-PEAK DAY 1985

Cars travelling by hovercraft 1,100 in 12-hr day = 100 per hr × 70% stop (for 1 hr)	70
Coaches travelling by hovercraft 70 in 12-hr day = 6 per hr × 70% stop	4
Lorries travelling by hovercraft 40 arrs and deps per 12-hr day @ 30 per craft = 100 per hr × 50% stop	50
Cars collecting and seeing off passengers 2,250 passengers per day × 25% stop @ 1½ per car = 420 per 12 hr	35
Passenger travellers leaving cars behind 2,250 × 25% ÷ 1.5 ppc	420
Staff cars	800

CATERING

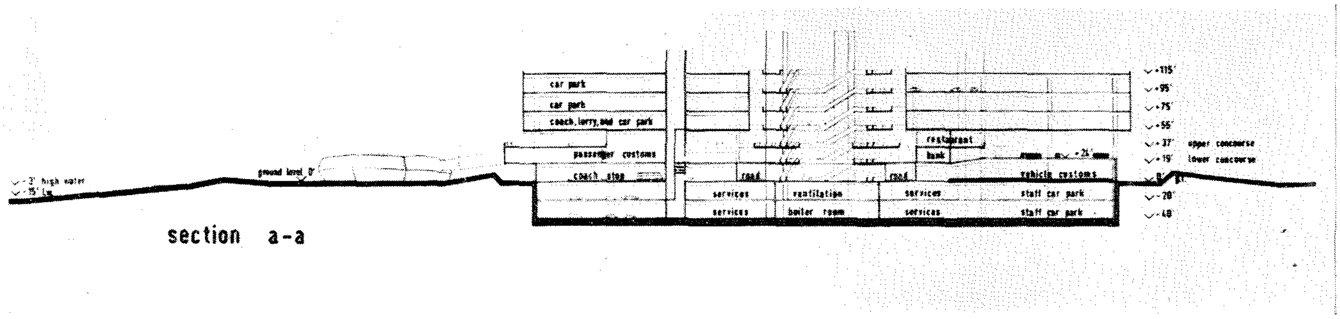
NUMBER OF PERSONS USING CATERING FACILITIES

Peak day 1985

		Persons per day	*Wanting snacks*	*Wanting meals*
Cars (both directions	8,800	26,400 + (30% coach persons) = 34,400	30% i.e. 10,000	22½% i.e. 7,500
Pedestrian passengers	17,808	17,808	50% i.e. 9,000	25% i.e. 4,500
Extra people (visitors)	300	300	80	100
Freight vehicles	250	500	200	50
Port staff	1,000	1,000	500	350
Total			19,780	12,500

Off-peak days 1985

Cars (both directions)	1,100	3,300 + (22% coach persons) = 3,550	40% i.e. 1,400	30% i.e. 1,000
Pedestrian passengers	2,226	2,226	50% i.e. 1,200	25% i.e. 560
Extra people (visitors)	500	500	100	200
Freight vehicles	750	1,500	500	250
Port staff	800	800	200	500
Total			3,400	2,510



A section through the hoverport building showing public car parking above, with lifts and escalators feeding down to central concourse facilities

The History of Hydrofoils

(Part VI)

by

Leslie Hayward

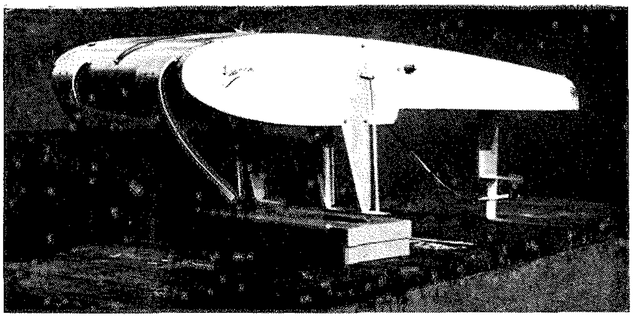


Figure 56

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

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

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

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

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

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

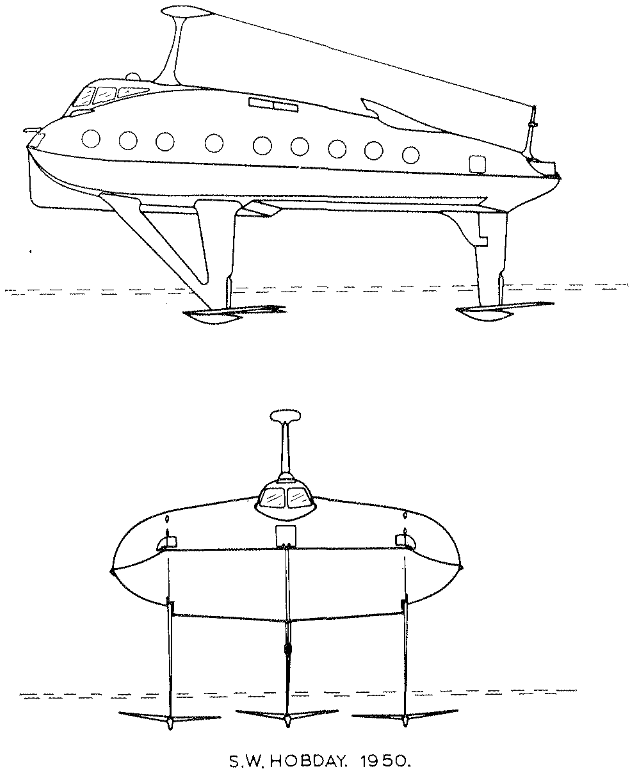


Figure 57

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

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

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

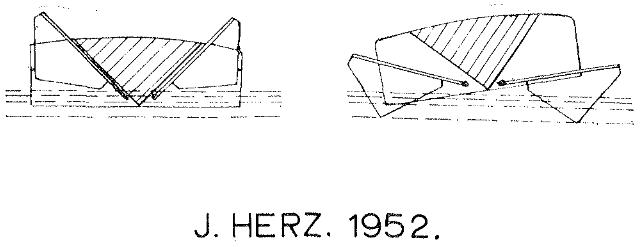


Figure 58

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

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

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

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

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

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

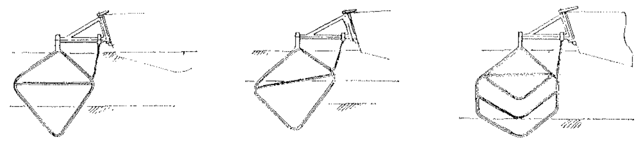
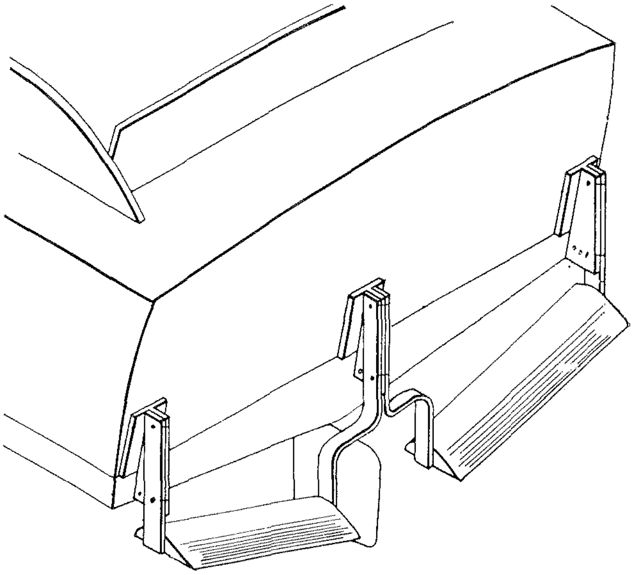


Figure 59

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

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

During the early part of 1957 Boericke proposed that his various foil and strut sections should be so shaped and chosen relative to each other and to the speed of the craft that they should be free of destructive cavitation at speeds when they would normally be submerged. For instance, at speeds up to 45 knots all sections could be submerged, no cavitation taking place, at speeds up to 55 knots the top section would be out of the water no cavitation taking place on the remaining submerged sections, up to speeds of 65 knots when only the lower non-cavitating section of the foil assembly would remain under the water. US Patent 2,890,672 gives details of these proposals.



D.A. P.V. ELYOSIUS. 1955.

Figure 60

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

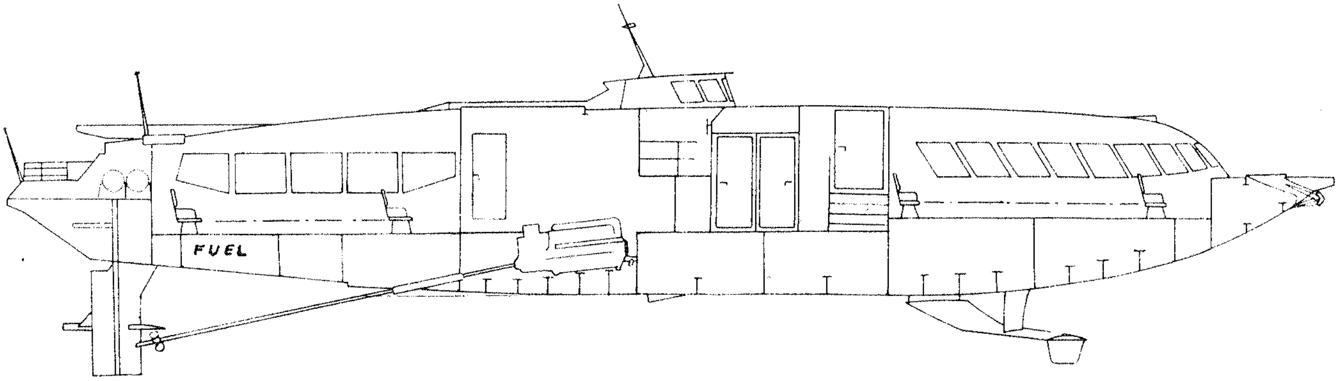
Further developments concerned the retraction of foils extending transversely across the underside of the keel, the foils carrying propulsion propellers, and, designs for a craft wherein the propeller struts act as after foils. These proposals are described in detail in US Patents 2,991,747, 2,984,197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

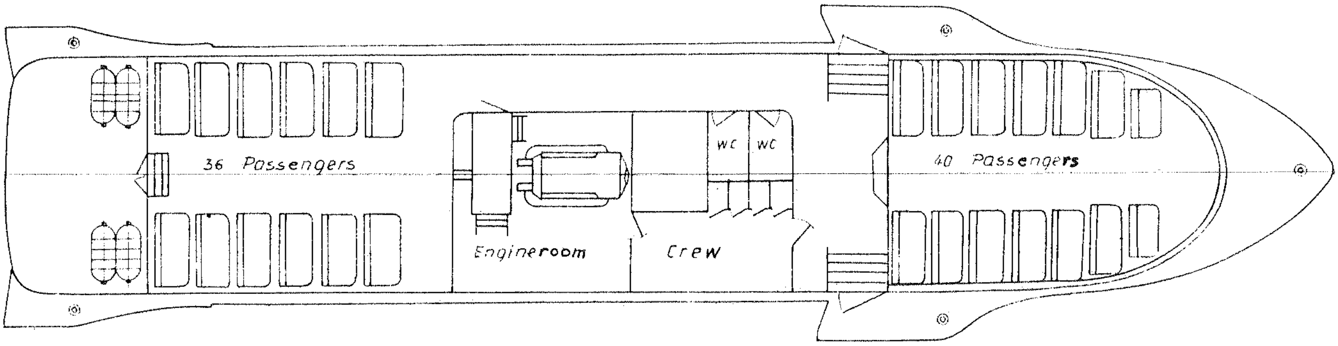
Aeronautical Boat Shop Inc and Joseph Lyman of Halesite, New York, USA, proposed a design of sailing craft having a vertical keel with horizontally extending fixed submerged hydrofoil surfaces in the early part of 1955. The hull of the craft is said to have been "rocket shaped" and a deep keel incorporating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

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

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

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





underwater part of the hull has been coated with anti-corrosive paints, cathodic protection also being applied.

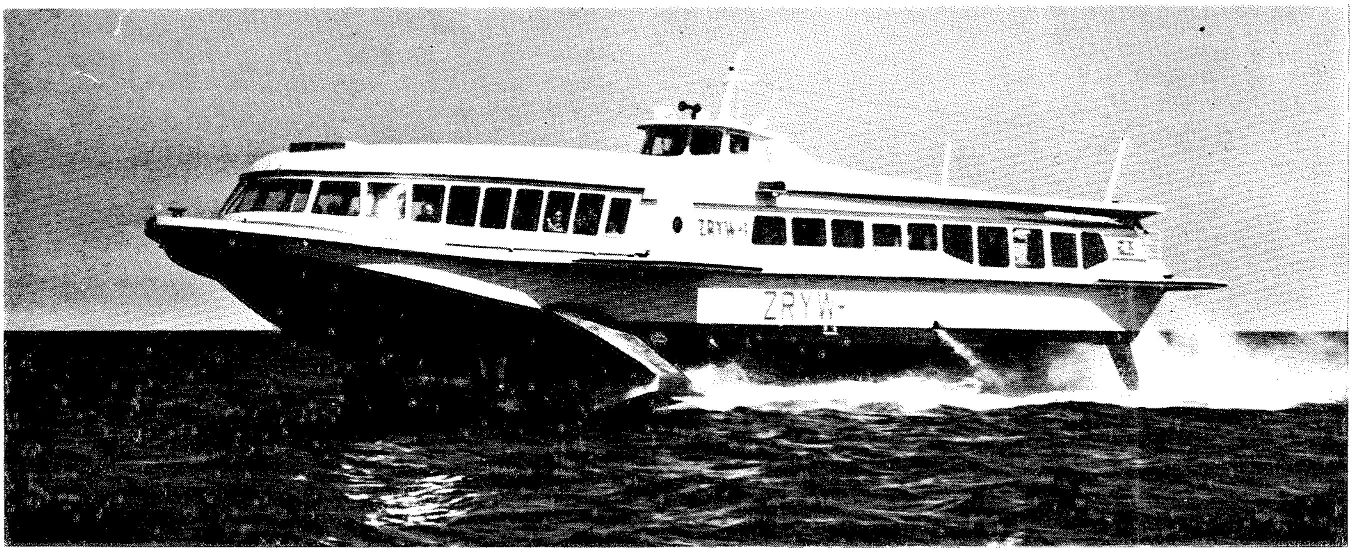
The hull has a longitudinal construction based on strong framings and bulkheads. The spacing of frames, up to No 13 frame, amounts to 1,250 mm and from No 13 frame onwards, 725 mm. The distance between the longitudinal bracings is 240 mm in the bottom and 360 mm in the roof. The frames and strong longitudinal girders are made of 100 x 60 x 5 tee-bars. The remaining longitudinal girders are made of 50 x 4 clamp flat-bars.

The bottom outer plating is of 4-5 mm-thick plates, the plating of sides, bulkheads and deck is 3 mm thick, the plates of the roof being 1.5-5 mm thick. PA3 plates and PA1 rolled profiles have been applied.

The foils and their brackets are made of stainless 1J18N9T steel. The foils are made of 5-7 mm-thick plates and are of fully welded construction.

Principal Particulars

Length overall	27.60 m (90 ft 6½ in)
Length bp	23.00 m (75 ft 5½ in)
Breadth, maximum	6.70 m (21 ft 11¾ in)
Breadth of hull	4.40 m (14 ft 5¼ in)
Depth to outer deck	2.05 m (6 ft 8¾ in)
Draught waterborne	2.05 m (6 ft 8¾ in)
Draught foilborne	1.25 m (4 ft 1 in)
Displacement, total	30.7 tons
Passengers	76 persons
Crew	4 persons
Payload	8 tons
Maximum power	1,200 hp
Cruising speed, designed	35 knots
Operating range	250 miles



Machinery

The engine room, situated amidships, houses the main engine with reversible gear, auxiliary set, tanks and pumps serving the engine room system. The main engine is a M-50F4 type diesel of Russian manufacture. Maximum power is 1,200 hp at 1,850 rpm; continuous power, 1,000 hp at 1,700 rpm; operating power, 900 hp at 1,600 rpm. The engine is provided with a reversible friction clutch with conic reverse gear. The clutch is hydraulically or hand controlled, either directly on to the engine or remote from the wheelhouse. The speed governor is hand controlled directly on to the engine or remote from the wheelhouse. The engine is started by means of compressed air. The DGPKN-8/1500-1-type auxiliary set includes a diesel engine of 12 hp at 1,500 rpm and a dc generator of 6.1 kW and 230 V. The propeller shaft, with a diameter of 98 mm, is made of 2H13 stainless steel. It is set in three water-lubricated rubber slide bearings.

The three-blade propeller of 0.65 m diameter, 0.80 m pitch and 1.1 surface coefficient, is of MM55 brass.

Equipment

Passenger compartments are provided with comfortable upholstered bus-type armchairs, and racks for light luggage. Large windows ensure good visibility. Both passenger compartments and engine room are provided with heat and acoustic insulation. The floors in the passenger accommodation are covered with vinyl, the deck being felt-covered.

Compartments are heated by means of electric heaters totalling 6 kW, operating both when stationary (shore supplied) and while in motion. The vessel is ventilated through ventilators set in the roof. Life saving appliances include four pneumatic, 20-person rafts, eighty life jackets set under the armchairs, and six lifebuoys. Fire-fighting equipment includes five foam extinguishers and three carbon dioxide extinguishers.

There is a hand steering gear controlled by mechanical gear, while hydraulic steering gear may be added at a later date. The hydrofoil is provided with a 50 kg anchor suspended in a hawser port forward, which is lifted by a hand-hoisting winch operated from the forward passenger compartment.

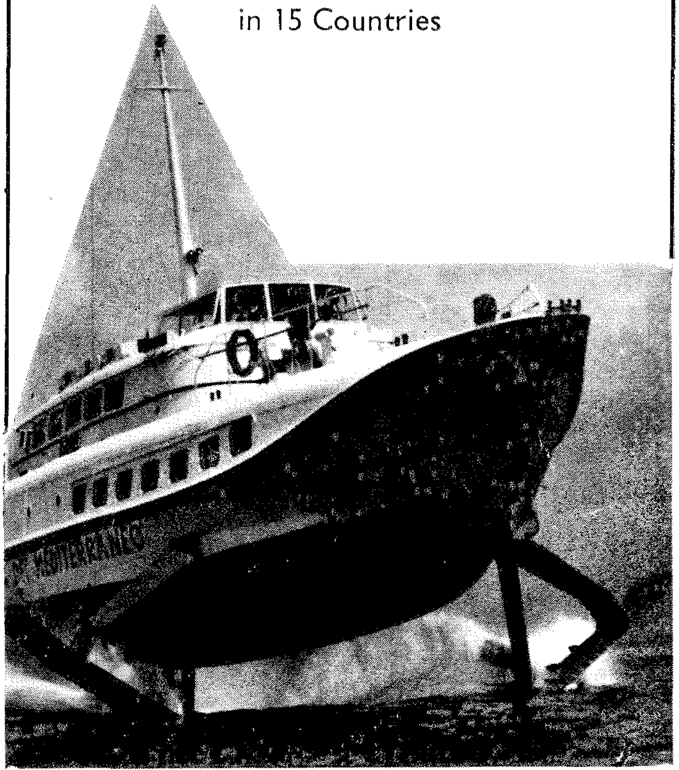
Radio-communication devices comprise an intermediate-wave radio-telephone and type FM-302 vhf radio-telephone. The intermediate radio-telephone, which has a type S112A transmitter of Elektromekare manufacture and a type OK102 receiver of the MORS make, ensures duplex communication by means of transmitting and receiving aerials.

Operation

Construction of the *Zryw-1* was completed in May, 1965. In May and June she underwent trials at the shipyard and at sea, as well as special trials under varying weather conditions. The trials were carried out in the Bay of Gdansk with the state of the sea at from 2 to 5 and up to wind force 7. The final test of efficiency was the passage from Gdansk by way of Swinoujscie to Szczecin with the state of the sea at from 2 to 4 and wave-height up to 1.5 m.

After putting the *Zryw-1* into service on the Szczecin-Swinoujscie route in good weather she covered the distance of 67 kilometres in about 55 minutes, her average operating speed being over 73 kilometres/hr (39 knots). At the end of July the hydrofoil boat was temporarily withdrawn due to damaging her stern foil.

With acknowledgments to "Shipbuilding and Shipping Record"



the sides of the rail as an alternative to the airscrew, for propulsion. Such a change would, of course, necessitate an allination of the method of braking, at present to be done by running the airscrew in reverse, eg by introducing some means of producing friction with the rail.

It is not yet clear just where this new vehicle can best be fitted into the existing transport system, but the services for which it would appear to recommend itself would appear to be for rapid transit between airports and town-centres, and as a preferable alternative to an overhead railway for commuter traffic. It may also prove handy for supplementary conventional railway services such as that between Paris and Lyons, which is expected to reach saturation point in 1970. In order to become economically viable, it must carry about 2,000 passengers a day in each direction.

The Society for Aerotrain Research has launched out simultaneously in another direction, under the management of M. Marchetti, in the development of a 30 ton "naviplane" as it is called, for use over water. This type of air-cushion vehicle is designed to carry eighty passengers at speeds of 90-100 km/hr (56-62 m/hr) and will be able to cope safely with waves of 2-3 metres (6 ft 6 in — 10 ft) in height. The prototype of this vessel is to be launched towards the end of 1966, but plans are already being made for the building of successors of 200-2,000 tons with speeds of about 150 km/hr (93 m/hr).

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Within the past few weeks **Westland Aircraft Ltd** have received five orders from Washington for the military version of the eighteen seat SR.N5, and three more are under negotiation. The cost of an SR.N5 without armaments is £76,000. The first three orders were placed by the United States Navy through Westland's American licensee, Bell Aerosystems, about two and a half months ago, and last week the US Navy ordered two further craft. Meanwhile the United States Army have opened negotiations for three similar craft.

A military version of the SR.N4 seems likely, and Westland are engaged in discussion with British naval experts on the design of a high speed frigate capable of sustained cruising at 20-25 knots and short-burst speeds of up to 90 knots. This craft would probably be twice the size of the SR.N4.