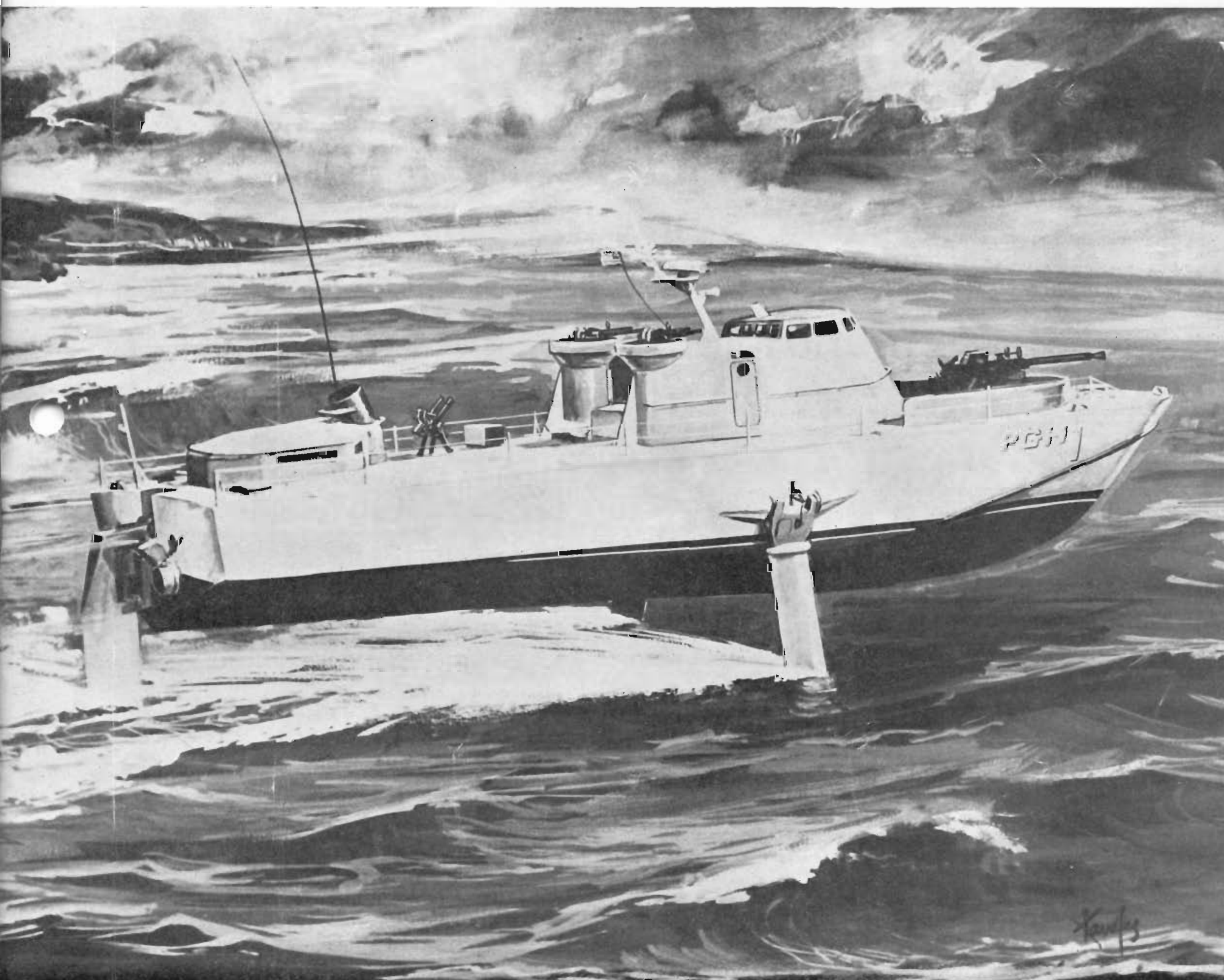
HOVERING CRAFT & HYDROFOIL

THE INTERNATIONAL REVIEW OF AIR CUSHION VEHICLES AND HYDROFOILS



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AUGUST 1966

KALERGHI PUBLICATIONS

40 knots through shallow rock-strewn waters... reefs, sandbanks, and small obstacles no problem

The SR.N5, the world's first military hovercraft, is revolutionising logistics, carrying 15 fully-equipped troops or 2 tons of stores at cruising speeds up to 62 knots. In use with the U.S. Navy, and during operational trials with the British Forces in Borneo, it has proved to be unaffected by tide state, underwater defences, shallows and the many obstacles which previously meant inaccessibility. Its work rate is many times that of conventional landing craft of comparable size and its amphibious capability gives maximum freedom of choice of operating routes and landing points. Patrols, trooping, supply, casualty evacuation, amphibious assault, search and rescue, anti-submarine warfare, will all be transformed by British hovercraft. In addition to their operations with the British Forces in Borneo, SR.N5 hovercraft are in service with the U.S. Navy. Both the 7-ton SR.N5 and the 9-ton SR.N6 with its much larger capacity are now available from the world's first hovercraft production line. Modern fighting forces have a completely new weapon.

1966
THE QUEEN'S AWARD
TO INDUSTRY 1966
WESTLAND AIRCRAFT LIMITED
SAUNDERS-ROE DIVISION

BHC

british hovercraft corporation limited

YEOVIL ENGLAND

HOVERING CRAFT & HYDROFOIL

FOUNDED OCTOBER 1961

First Hovering Craft & Hydrofoil Monthly in the World

Julian Rice, (left), Fairbanks attorney, and Larry Landry, Anchorage business man, display a model of the 18 passenger hovercraft their new organisation Skimmers Inc. will bring to Anchorage this month. *See below for further details*

If any further evidence was needed of the value of the June Hovershow, it is provided by a news report from far-off Alaska. There, an 18-passenger hovercraft has just started an operation unique in American transport history. The two men behind the experiment found their inspiration in Britain and particularly at the Hovershow.

Their names are Julian Rice and Larry Landry. They had for some time been considering how best a transport business could function in the difficult conditions to be found at the port of Anchorage, Alaska. Oil Installations in Cook Inlet needed a reliable transport service of passengers and freight which could operate on winter ice as well as choppy summer waters.

Rice and Landry knew of the hovercraft service between Oakland and San Francisco, the only such service in the United States. But in California there are no ice hazards and the craft in use there are for passengers only. To find if there was a suitable hovercraft for Alaskan conditions they decided to come to Britain to consult the hovercraft pioneers. They visited Westland Aircraft Ltd., and other firms. They were impressed. But no final decision was taken. They returned to Anchorage, looked at their problem again, and then returned to Britain for the Hovershow. There, the superb demonstrations they saw helped to make up their minds.

The result is a 30-day experiment at Cook Inlet jointly carried out by Skimmers, Inc., a firm established by Rice and Landry for the purpose, and Bell Aerosystems, the American licensees of Westland.

Two hovercraft have been taking part in the experiment. Each can carry 18 passengers or 5 tons of freight. This is the first hovercraft commercial charter operation in the Western Hemisphere.

"We believe the introduction of hovercraft in Alaska will revolutionize the transportation industry particularly in those areas previously inaccessible by conventional modes of transportation," says Mr. Landry.

"The two craft are equipped to operate under 'zero-zero' conditions. Weather, for all practical purposes, will be no obstacle in our operation," he said.

The port commission at Anchorage has welcomed the project. It promises to improve transport in the area and to assist in the exploration and exploitation of natural resources and the development of isolated territories across the inlet.

Such is the hope. It is too early yet to speak of fulfilment. But this is a pioneering enterprise that can at once be commended and should hearten all those who made the first Hovershow possible.

IN THIS ISSUE

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JUANITA KALERGHI

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COVER PICTURE: *An artist's impression of the prototype hydrofoil gunboat designed and constructed by Grumman Aircraft for the US Navy. The craft is 22 m 86 long, with a 6 m 70 beam and a 57 ton displacement. The foilborne propulsion system will be maintained by a 3,600 hp marine version of the Rolls-Royce "Tyne," gas turbine engine. A drawing of the engine appears on page 5.*

Mr Harold Wilson, the British Prime Minister, presented Mr Kosygin, Russian Premier, with a model of a Westland hovercraft when he visited the British Industrial Exhibition in Moscow on the 17th July, 1966

People and Projects

The **Boeing Company,** Seattle, Washington, are constructing a hydrofoil gunboat for the US Navy. Designated PGH2, the craft has a length of 71 ft (21.64 m), a beam of 25 ft (7.62 m) and a displacement of about 60 tons. The propulsion system takes the form of water jets. Water is drawn through rear struts into a centrifugal pump and is ejected through nozzles near the stern. One of the major advantages claimed for this system is its simplicity in operation and maintenance. A water jet does not require a complicated power transmission system and therefore eliminates any associated lubrication problems. The engine is directly connected to the pumps and forms an easily accessible, compact unit.

The water jet will be used for propulsion when the craft is using its conventional hull and when using the foils. In the former condition a Buehler centrifugal pump will be driven by a 150 hp diesel engine, and in the latter case a Byron Jackson pump will be powered by a gas turbine.

Three fully submerged foils will support the craft at high speeds and are fully retractable for slow-speed operation. Their stability will be controlled by an automatic electronic system. With the exception of the foils and struts, which are stainless steel, the hydrofoil is of aluminium construction. Armament will comprise a 40 mm gun forward, an 81 mm mortar aft, and twin 50 calibre machine-guns on each side of the bridge.

★ ★ ★

During its first year of operations, **Hovertravel,** which operates services across the Solent, has carried 302,640 passengers on 15,000 trips involving 61,000 miles between Ryde, Southsea, Sandown and Gosport, using two Westland SR.N6 craft.

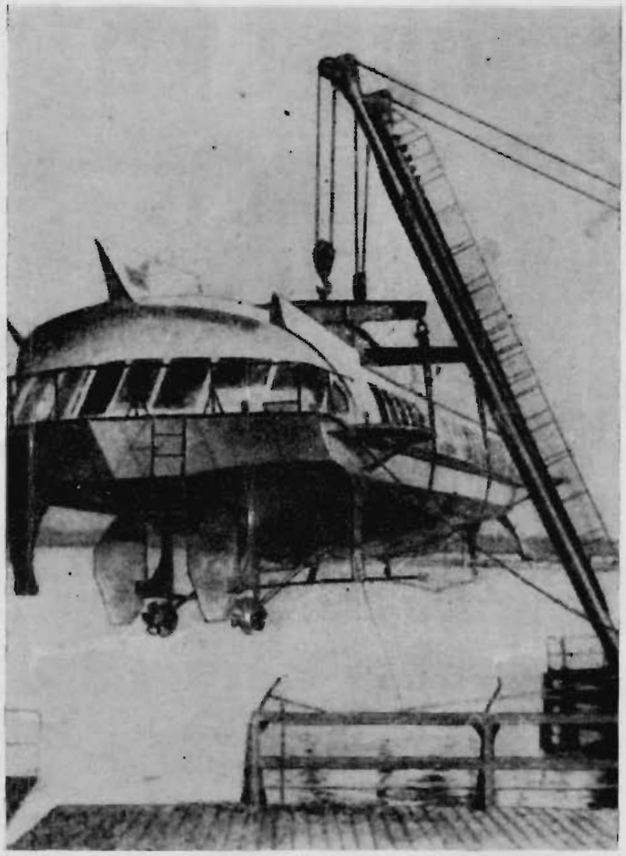
★ ★ ★

The following is based on a short article by two Soviet engineers, N. Zalslavskiy and S. Mal'chik, in the June number of Ryechnoy Transport, *monthly organ of the Ministry of the River Fleet of the Russian Federation of Socialist Republics:*

One of the problems facing the operators of hydrofoil passenger services on the Volga and other great rivers of the USSR (especially during the summer season, when they work to capacity) is that of keeping the entire fleet in serviceable condition without withdrawing units from service. This involves frequent docking of units during the night, when the services are, for the most part at any rate, suspended, and in the normal way there have been occasions where damage has been done to the vessels' hulls, more particularly in the bluff of the bow.

In order to eliminate the risk of such damage, the Volgograd (formerly Stalingrad) Section of the Gor'ki Central Design Bureau has introduced the use of a **floating crane** with a lift of 42 tons for lifting the hydrofoil vessel out of the water and placing it on keel-blocks in a lighter alongside, and replacing it in the water after examination and, if necessary, repair.

The floating crane used for this purpose is one of an existing type known as the "Staryy Burlak", reinforced with longitudinal beams and with supporting pillars under the winches. Such a crane can lift vessels of the *Raketa* and *Meteor* types, carrying 66 and 150 passengers respectively, which are at present in use on the rivers of the USSR. Hard ballast weighing 30 tons is provided as counterbalance for the vessel lifted, and by this means the change of trim when lifting a vessel of the larger *Meteor* type is kept to 0.12 m (4¾ in). The original crane used for this service, at the port of Volgograd (Stalingrad) in 1964, was hand-operated, but in 1965 it was fitted with electric power, provided by a Type DG-25 diesel generator



The floating crane designed by the Gor'ki Central Design Bureau, Volgograd, lifting a hydrofoil out of the water

controlled from a console on the deck of the crane pontoon. This lifts at a speed of 0.18 m/min (7 in/min), and transfers the hydrofoil vessel from the water to the keel-blocks in a lighter alongside, or vice versa, in about fifty minutes.

Since the introduction of this crane, no difficulty is experienced in completing the examination and requisite repair of hydrofoil vessels overnight, i.e. without taking them out of service. In between whiles, however, the crane is being used for minor services, with displacement vessels as well as those with hydrofoils, such as lifting the bow or the stern for examination and adjustment or repair of the underwater fittings — propellers, propeller shafts, bearings and foil systems — operations which can often be carried out in a matter of a few minutes.

★ ★ ★

A 1s 3d stamp bearing a picture of an **SR.N6 hovercraft** is to be issued on September 19th, 1966. The Post Office will provide a first day cover service on special envelopes, as well as accept addressed envelopes sent to them. The postmark will be Edinburgh.

★ ★ ★

Acceptance trials of the hydrofoil vessel *HS Victoria*, built by Maryland Shipbuilding and Drydock Company for Northwest Hydrofoil Lines, Inc. Seattle, Washington, have been scheduled for August 16th and 17th, 1966 on the Kent Island Measured Mile Course on Chesapeake Bay.

★ ★ ★

A couple of enthusiastic young constructors, I. Galkin and Yu. Chaban, at the Krasnoye Sormovo shipyard at Gor'ki, on the River Volga, main hydrofoil development centre in the USSR, have spent the last year building a catamaran yacht on hydrofoils, the *Andromeda*, which is now in use and has shown itself considerably faster than a similar yacht without hydrofoils. No details of the size, etc, of this novel yacht have been published yet, but the short report about it published in *Izvyestiya* of July 15th states that the designers are so encouraged by their success that they are now building "a younger brother" — twice the size.

★ ★ ★

A tyre-shaped rubber tube which has been successfully tested on a 5 ft flying model at Wright Patterson Air Force Base, Ohio, promises to allow heavy aircraft to land on ice, swamp, desert or ploughland, without requiring prepared runways.

Designed by **Bell Aerosystems**, the rubber tube is inflated before landing, and the perforations create an air cushion which enables the aircraft to float several inches above the ground. Braking is by reverse thrust of the jets, and for final braking some of the airjets are cut off, and special friction shoes skid along the ground to bring the aircraft to a halt. During flight the deflated tube is sucked close against the fuselage.

Engineers claim that the flexible cushion will allow landings even over obstacles 18 in high.

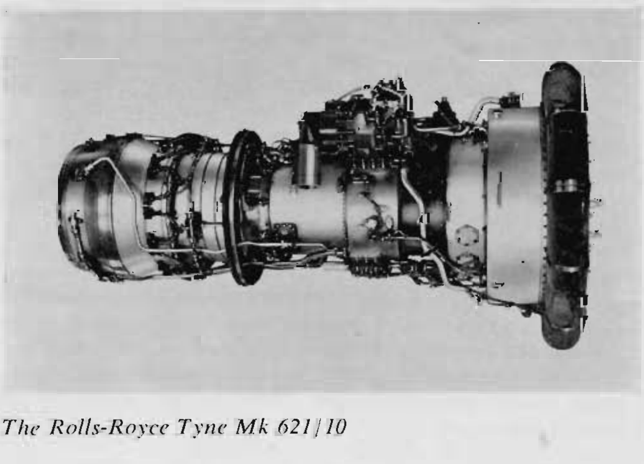
★ ★ ★

One man using an air cushion system developed by the **Clark Equipment Company** of Buchanan, Michigan, can move around pallets, loaded with goods weighing 3 or more tons.

Pallets operated by the system must be connected to an 80-100 lbs. per sq. inch compressed air line and operation can only take place on smooth, level floors.

It is understood that the company is developing a hand truck which will compress its own air and thus be free of air hose length limitations.

★ ★ ★



The Rolls-Royce Tyne Mk 621/10

The Wave Resistance of a Compartmented Cushion

T. K. S. Murthy, MSc, MA, DIC, CEng, AFRAeS, AMRINA
Vickers Ltd

1. SUMMARY

This article contains one possible explanation of the reason why hovercraft sometimes have difficulty in accelerating through the hump. It is shown from theoretical considerations that when a pressure differential exists between the two compartments of a conventional hovercraft cushion with a transverse stability skirt, the wave resistance is increased at all speeds, the increase being high enough at some low speeds prior to the hump to make the thrust power based on the hump resistance of the uniform cushion possibly inadequate to accelerate through that speed. The requirements of pitch stiffness and of low wave resistance appear to be contradictory, but as very low pressure ratios do not appear to be desirable from considerations of the latter, it may be possible to effect a compromise by installing pressure relief valves between the two compartments.

This study is based on two-dimensional theory but the usual wave slope limitations on wave resistance at low speeds have not been included. The general trend is however likely to be as presented.

2. INTRODUCTION

The wave resistance of the general type of tandem cushion $(\alpha, \beta; \sigma)$ can be derived from first principles using two-dimensional theory. The notation $(\alpha, \beta; \sigma)$ is used to denote a composite cushion consisting of two pressure bands moving in tandem and extending from 0 to αL and from βL to L where L is the *total* length of the tandem cushion, the origin being taken at the leading edge of the front cushion. The two bands are assumed to be moving together at a speed V along the negative direction of the x-axis. The ratio of the pressure in the rear cushion to that in the front is σ, but in the case of a twin tandem cushion, i.e. when the bands are of equal length, $(\alpha + \beta)$ equals unity, and σ can then be simply the pressure ratio between the two cushions for all the results are valid when σ is replaced by $1/\sigma$ and when the motion is along the *positive* direction of the x-axis.

A conventional hovercraft cushion with a transverse stability skirt achieves its pitch stiffness from the efficiency of this skirt in creating a pressure differential between the compartments on either side particularly when the trim of the craft alters, for the pressure in the down-going compartment is expected to rise and produce a restoring moment.

3. STEPPED CUSHION

When there is a pressure differential on either side of the transverse stability skirt the cushion originally containing uniform pressure becomes a stepped cushion $(\alpha, \alpha; \sigma)$. The induced wave formation is now altered and it may therefore be expected that the wave resistance and the moment due to wave resistance will be different.

4. WAVE RESISTANCE

The formula for the wave resistance, R_w, of a stepped cushion with equal compartments $(\frac{1}{2}, \frac{1}{2}; \sigma)$ can be derived as:

$$R_w = \frac{8W^2}{gpL^2B} \frac{(1 - \cos F/2)(1 + \sigma^2 + 2\sigma \cos F/2)}{(1 + \sigma)^2} . \qquad (1)$$

where W is the weight supported by the cushion,
L the length of the cushion,
B the width
and $F = gL/v^2$.

This is based on two-dimensional theory. It is known that three-dimensional theory yields lower values for the wave resistance in the case of a simple cushion (uniform continuous cushion) depending on the B/L ratio and a similar effect may be expected in the case of a stepped cushion.

The result corresponding to Equation (1) for a simple cushion of the same dimensions (i.e. when the craft is at a level trim or when the stability skirt is ineffective) is

$$R_{w_0} = \frac{2W^2}{gpL^2B}(1 - \cos F) . \qquad (2)$$

The propulsive power is usually based on R_{w_0} and we will have to examine the increase in resistance, if any, given by Equation (1) due to the possible adverse interference between the separate wave trains induced by the two compartments at different pressures.

Since

$$1 + \sigma^2 + 2\sigma \cos F/2 \leqslant (1 + \sigma)^2 .$$

it is clear from Equation (1) that

$$R_w \leqslant \frac{8W^2}{gpL^2B}(1 - \cos F/2) .$$

The maximum value of $1 - \cos F/2$ is 2 and therefore

$$R_w \leqslant \frac{16W^2}{gpL^2B} \qquad (3)$$

giving an upper bound for the resistance.

5. VARIATION OF RESISTANCE WITH SPEED

The maximum and minimum values of resistance are obtained by differentiating the RHS of Equation (1) with respect to V or, what is virtually the same thing, by differentiating with respect to F, and setting the result equal to zero.

Now

$$\frac{\partial R_w}{\partial F} = \frac{8W^2}{gpL^2B(1+\sigma)^2}\left[\frac{1}{2}\sin\frac{F}{2}\left\{(1-\sigma)^2 + 4\sigma\cos\frac{F}{2}\right\}\right] .$$

The turning points of R_w are therefore given by

(A) $\sin\frac{F}{2} = 0$

and (B) $\cos\frac{F}{2} = -\frac{(1-\sigma)^2}{4\sigma}$, provided $(1-\sigma)^2 \leqslant 4\sigma$.

To see whether these represent maxima or minima we must evaluate $\frac{\partial^2 R_w}{\partial F^2}$.

Now

$$\frac{\partial^2 R_w}{\partial F^2} = \frac{4W^2}{gpL^2B(1+\sigma)^2}\left[\frac{1}{2}(1-\sigma)^2\cos\frac{F}{2} + 2\sigma\cos F\right] .$$

Case (A)

$\sin\frac{F}{2} = 0$ when $\frac{F}{2} = n\pi$ where n takes the values 0, 1, 2, --

and $\cos F/2 = \mp 1$ according as n is odd or even.

Case A(i)

$$F = 2n\pi\ , \quad n \text{ even } (= 2p)$$

$$\text{i.e. } F = 4p\pi\ , \quad p = 0, 1, 2, -----$$

$\sin F/2 = 0$, $\cos F/2 = +1$, $\sin F = 0$, $\cos F = +1$.

$$\frac{\partial^2 R_w}{\partial F^2} = \frac{2W^2}{gpL^2B}\ , \quad \text{a +ive quantity .}$$

The resistance is therefore a minimum and, in fact, equal to zero.

Thus

$$R_{w(min)} = 0 \quad \text{when} \quad F = 4p\pi\ , \quad p = 0, 1, 2, ---- \qquad (4)$$

Case A(ii)

$$F = (4p+2)\pi\ , \quad p = 0, 1, 2, ---$$

$\sin F/2 = 0$, $\cos F/2 = -1$, $\sin F = 0$, $\cos F = +1$.

$$\frac{\partial^2 R_w}{\partial F^2} = -\frac{2W^2}{gpL^2B}\left[\frac{(1-\sigma)^2 - 4\sigma}{(1+\sigma)^2}\right]$$

which is positive or negative according as $(1-\sigma)^2 \lessgtr 4\sigma$, i.e. $\sigma + 1/\sigma \lessgtr 6$. Thus, when σ lies between 0.172 and 5.828, $\sigma + 1/\sigma < 6$ and R_w is a minimum. If, on the other hand, $\sigma < 0.172$ or > 5.828, $\sigma + 1/\sigma > 6$ and R_w is a maximum. In either case,

$$R_{w\,(max./min.)} = \frac{16W^2}{gpL^2B}\left[\frac{1-\sigma}{1+\sigma}\right]^2 . \qquad (5)$$

When $(1-\sigma)^2 = 4\sigma$, i.e. when $\sigma = 0.172$ or 5.828, $\frac{\partial^2 R_w}{\partial F^2} = 0$, and it is necessary to examine the higher differential coefficients.

Now,

$$\frac{\partial^3 R_w}{\partial F^3} = -\frac{4W^2}{gpL^3B}\left[\frac{1/4(1-\sigma)^2\sin F/2 + 2\sigma\sin F}{(1+\sigma)^2}\right] = 0$$

But

$$\frac{\partial^4 R_w}{\partial F^4} = -\frac{4W^2}{gpL^2B}\left[\frac{1/8(1-\sigma)^2\cos F/2 + 2\sigma\cos F}{(1+\sigma)^2}\right] =$$

$$= -\frac{4W^2}{gpL^2B} \times \frac{3\sigma}{2} ,$$

a negative quantity. The resistance is therefore a maximum and has the value

$$R_{w\,(max)} = \frac{8W^2}{gpL^2B} . \qquad (6)$$

Case B

$$\cos F/2 = -\frac{(1-\sigma)^2}{4\sigma}\ , \quad \text{defined for} \quad \frac{(1-\sigma)^2}{4\sigma} \leqslant 1\ ,$$

$$\text{i.e. } 0.172 \leqslant \sigma \leqslant 5.828$$

$$\frac{\partial^2 R_w}{\partial F^2} = \frac{4W^2}{gpL^2B}\left[\frac{(1-\sigma)^4}{8\sigma} - 2\sigma\right]$$

which is negative if $\frac{(1-\sigma)^2}{4\sigma} < 1$. R_w is therefore a maximum and has the value

$$R_{w\,(max)} = \frac{W^2}{gpL^2B}\,\frac{(1+\sigma)^2}{\sigma} \qquad (7)$$

when F takes the values

$$2\cos^{-1}\left[-\frac{(1-\sigma)^2}{4\sigma}\right] + 4n\pi\ , \quad n = 0, 1, 2, ----$$

i.e.

$$F = \pm 2\cos^{-1}\left[\frac{(1-\sigma)^2}{4\sigma}\right] + 2(2p+1)\pi\ , \quad p = 0, 1, 2, --- .$$

If, however, $\frac{(1-\sigma)^2}{4\sigma} = 1$, $\cos F/2 = -1$, and this case reduces to case A(ii).

It will be seen that by setting $\sigma = 0$ or ∞ in Equation (5), we derive

$$R_{w\,(max)} = \frac{16W^2}{gpL^2B}$$

the same as the result obtained from the basic Equation (1) or from Equation (3).
This is the maximum resistance of either the front or the rear compartment when the adjacent compartment is empty.
Also, setting $\sigma = 1$ in Equation (7) gives $4w^2/gpL^2B$ as the maximum resistance of a uniform cushion without compartments, which is a well-known result, as can also be seen from Equation (2).

6. SUMMARY OF RESULTS

(1) For all σ, $R_{w(min)} = 0$, when $F = 4p\pi$,

i.e. at Froude Nos. 0.282, 0.199, 0.163, 0.141, 0.125, ---

(2) $0.172 < \sigma < 5.828$ $\quad R_{w(min)} = \dfrac{16W^2}{gpL^2B}\left[\dfrac{1-\sigma}{1+\sigma}\right]^2$,

when $F = 2(2p + 1)\pi$

i.e. at Froude Nos. 0.399, 0.230, 0.178, 0.151, 0.133, ---

$$R_{w(max)} = \frac{W^2}{gpL^2B}\,\frac{(1+\sigma)^2}{\sigma}, \text{ when}$$

$$F = \pm 2\cos^{-1}\left[\frac{(1-\sigma)^2}{4\sigma}\right] + 2(2p + 1)\pi$$

(3) $\sigma < 0.172$ or > 5.828 $\quad R_{w(max)} = \dfrac{16W^2}{gpL^2B}\left[\dfrac{1-\sigma}{1+\sigma}\right]^2$,

when $F = 2(2p + 1)\pi$

i.e. at Froude Nos. 0.399, 0.230, 0.178, 0.151, 0.133, ---

(4) $\sigma = 0.172$ or 5.828 $\quad R_{w(max)} = \dfrac{8W^2}{gpL^2B}$ $\quad$ -do-

(5) $\sigma = 0$ (Front cushion only) $\quad R_{w(max)} = \dfrac{16W^2}{gpL^2B}$ $\quad$ -do-

(6) $\sigma = \infty$ (Rear cushion only) $\quad$ -do- $\quad$ -do-

(7) $\sigma = 1$ Uniform cushion $\quad R_{w(max)} = \dfrac{4W^2}{gpL^2B}$ at $F = (2p + 1)\pi$

i.e. at Froude Nos. 0.564, 0.326, 0.252, 0.213, 0.188, ---

7. DISCUSSION

The Froude Numbers indicated in paragraph 5 are based on the length of the complete cushion even when one of the compartments is empty ($\sigma = 0$ or ∞). The regimes for σ can be simplified by defining σ as the ratio (less than unity) of the pressures in the two compartments for, as stated in paragraph 2, all the results are true when $1/\sigma$ is substituted for σ. Figure 1 has been plotted showing the variation of maximum and minimum resistance for all values of σ ranging from 0 to 1.0.

A study of Figure 1 reveals some interesting features. The wave resistance of a uniform cushion (in terms of

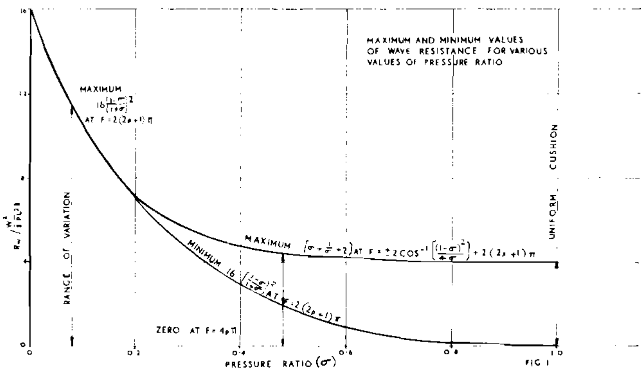


Figure 1

W^2/gpL^2B) fluctuates from 4.0 to zero, but when the pressure ratio between the two compartments is, say, 0.5, the maximum resistance is slightly increased to 4.4; the minimum is not always zero but about 1.7 at some speeds. When the pressure ratio is 0.172 the maximum resistance is doubled and the value increases sharply to four times the normal value when σ approaches zero. This is easy to understand for when the craft is borne on the front (or rear) cushion only the cushion pressure is doubled while the length is halved.

If the transverse stability skirt is fully effective a pressure ratio will certainly be developed when the craft pitches nose-up or nose down. Figure 2 shows that although the hollows of the resistance curve for a uniform cushion at $F = 4\pi$ and 8π are still hollows for all values of σ, the hollows which existed previously at $F = 2\pi$ and 6π are now humps of very high magnitude when $\sigma \leqslant 0.172$. For higher values of σ approaching unity there are still secondary hollows at these values of F with humps on either side, but the resistance at these hollows is not zero as in the case of a uniform cushion but can assume very high values approaching twice the hump value of the resistance of the basic cushion.

It is clear therefore when the cushion is non-uniform with the two compartments at different pressures, the average value of the resistance is very much higher than in the case of a uniform cushion. When the craft starts from rest with a uniform cushion the changing pattern of the induced waves sets up a pitch oscillation (as is amply shown in trials) and this in turn produces a pressure ratio causing a large increase in resistance. This is probably one reason why some hovercraft do not pass through the hump easily even when adequate thrust power is provided on the basis of R_{w0}.

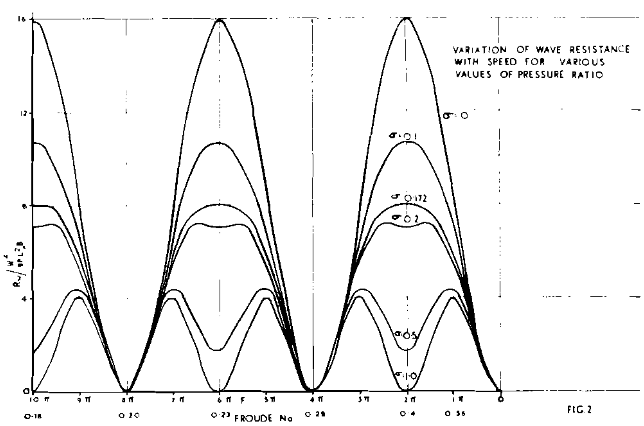


Figure 2

8. CONCLUSIONS

The above study is based on two-dimensional theory and is applicable to a hovercraft with two equal length compartments divided by a transverse stability skirt amidships operating over calm, deep water. A comparison with a uniform cushion shows that the wave resistance is likely to be higher at practically all speeds below the hump when the compartments are at different pressures. The requirements of pitch stiffness and low wave resistance appear therefore to be contradictory, but it may be possible to install pressure relief valves between the two compartments so that the pressure ratio drops no lower than that required for adequate pitch stiffness.

It is known that certain limitations on the theoretical results for a uniform cushion (two-dimensional theory) can be imposed from considerations of maximum wave slope and similar limitations can possibly be imposed in the case of a stepped cushion. The trend will very likely be the same as that presented herein.

SEASON TICKET NO.1

Seaspeed

British Rail Hovercraft Ltd

invites
MR. R.H. HUDSON

to travel On the 7.30 Cowes to Southampton
xxxxx

xxx
xxx Returning 16.00 Southampton to Cowes

date Monday to Friday 1.8.66. - 5.8.66.inc.
Monday to Friday 8.8.66. - 12.8.66.inc.

xxxx

Conditions: Issued subject to the conditions and regulations of British Rail Hovercraft Limited appearing in their publications and notices

The first season ticket for the British Rail Hovercraft service between Southampton and Cowes has been issued to Mr R. H. Hudson, Export Sales Director of Dimplex Ltd, the Southampton manufacturers of heating appliances

Seaspeed Spearheads British Rail Potential

A Cadman Clinton CEng, FRAeS, FBIS, MSEE

SOUTHAMPTON, the premier passenger port and gateway to the world, has a long and lively history of pioneering maritime projects and adventures. Notably, in education and training there is the School of Navigation with courses for naval architects and marine engineers, and at the University advanced research includes sail design for yachts, propulsion, and the hydrodynamics of hovercraft.

Probably there has been nothing quite so exceptional as the rapid evolution of the hovercraft in this area. Here Mr Christopher Cockerell, the inventor and developer, had the ideas (covering the fields of science, engineering and practical operations), formed Hovercraft Ltd, and then became Technical Director of the Government-sponsored Hovercraft Development Ltd at Hythe. Here he continued with a staff for several patient years through consecutive stages of successful design, leading to the present generation of craft of which the N.6 is probably the best known. The craft was built at Cowes by British Hovercraft Corporation, who are now on the way with the 160 ton N.4 planned for the cross-Channel service in 1968.

Not least in contributing to the success has been the many hours of testing in the local sea states in the Solent, where short steep waves, sudden squalls and the wash of big ships have imposed the most severe conditions.

One of the most promising transport developments started on July 5th when British Rail linked their system by *Seaspeed* hovercraft to the Isle of Wight. While this is in the nature of an exploratory service for obtaining experience with passengers and freight, analysing loads, speeds, power, maintenance and efficiency, it will be a guide to the projected operation to France of the N.4 in 1968. In fact the conditions in the Solent, with N.6, when scaled up are directly comparable with those on the French route.

It was an enthusiastic party that met at the BR *Seaspeed* Terminal, Southampton, where the blue-and-white *Seaspeed* was waiting, and it was here that Mr Stanley Raymond, Chairman of the British Rail Board, accompanied by Dr Sydney Jones, Chairman of British Rail Hovercraft Ltd, opened the new service. The Mayor of Southampton, Alderman S. M. G. Mitchell, with other civic guests, warmly supported the enterprise. Later the party embarked in the *Seaspeed* for Cowes, escorted by a party of journalists in another N.6, the two craft keeping station at 50 knots across the Solent, sailing a dog-leg course to the Cowes Terminal.

The welcoming party on the Island was headed by Mr L. G. Daish, Chairman of the Urban District Council, and Mr L. H. Baines, Clerk of the County Council, and there were also some members of the British hovercraft industry. The warmth of the welcome was increased by the shrill shouts of children behind the wire fences.

While both terminals have waiting rooms with the usual offices, Cowes also has accommodation for crews and maintenance staff. Self-contained car parks adjoin each place.

The staff at the terminals, in nautical blue uniform, includes hostesses issuing tickets and assisting passengers, and a beachmaster with his assistants to deal with traffic control and general servicing.

Displayed in the waiting rooms are the Conditions of Carriage and pictorial instructions for fitting a life-saving jacket, but in the fairing above the *Seaspeed* cabin there is the large inflatable raft in case of emergency.

Refuelling may take place at either terminal, but maintenance and inspection are undertaken at Cowes, where lifting tackle at the end of the apron is available when required. As the British Hovercraft Corporation works are just across the river, any special facilities or spares are quickly available.

Maintenance costs at present are high, but it was hoped that these would reduce and fit in the economic plan.

At the present time the N.6 was hired and the manufacturers keep in close touch with the operations.

After the lunch at Cowes, Mr Raymond emphasised that the *Seaspeed* service was a small start, a small addition to their national services, and he hoped that it would introduce successfully the new transport era. It was just over 100 years ago that the railway started in the Island, and about twenty years later that ships were introduced.

Ships had been used to link up many of our off-shore islands, and there was every prospect, first of all to introduce more hovercraft links with the Island, and then with the more distant ones like the Channel Islands, the Scillies, Ireland and so on round the coast.

British Rail were the largest concern in the world operating short sea routes, and it was necessary to try out the new form of transportation to see what it could do, as BR were the largest potential users of hovercraft.

It was important that transport should be modernised to meet the demand for rapid travel, and so this small start with the *Seaspeed* link will help. It is also necessary to find out if the new service could be used efficiently all the year round, and what developments there might be for freight. The planning proposes to deal with night operations as the shorter days approach, and also the question of improved steering at slow speeds in congested areas.

In referring to the Island's rail system, Mr Raymond said that the route between Ryde and Shanklin would be electrified and some of the London Transport District Railway stock would be used. During the preparations for the *Seaspeed* service BR had operated from the beach at the Hovershow and on one day carried more than 2,000 people; this was a slight indication of the interest.

In order to investigate the whole problem the Board had hived off this separate small operating company, now consisting of about thirty people, young men and women keen on the job. Mr C. A. Brindle was the manager, and in the course of some four months all the planning, training, technical and commercial negotiations had been undertaken and achieved, not least being the certification of the route. The manager had qualified as a driver and had taken the engine course.

While the Board would support the new company, it was vital that it felt free to develop in every way and to find out what it was worth commercially.

It was important to have a terminal adjoining the rail station at Portsmouth to provide a second link with Cowes this year, and it was hoped to find a suitable piece of adjacent beach, since it was not at all satisfactory to have a bus journey from the station. With this kind of development in view, the company would discover the snags in public service conditions; these could then be reviewed with the designers and development engineers so that improvements could be made. All this would be valuable for the N.4, which has been ordered, and it is hoped that the first off the production line will have the BR livery.

There was every hope that the twenty-minute service opening to the public on July 6th would encourage the people from the Island to visit Southampton in greater numbers, for shopping and entertainment and possibly to explore the beauty of Hampshire. There seemed to be little doubt that there would be many visitors to the attractive Island.

While Mr Raymond was speaking a hovercraft passed close inshore: the noise was slightly noticeable, although a bus starting away in low gear really was disturbing.

The noise question was considered by Mr Raymond to be a tractable problem, bearing in mind that the N.6 was the prototype of more sophisticated designs. The N.6 was a new noise to many, and it was hoped that there would not be too much discussion about it as, according to the sound recordings made and compared with some buses and lorries, the hovercraft was less noisy The work being done by the development teams to meet the operators' demands should much reduce the noisiness of the next generation of craft, as well as that of the later models of the N.6. In any case travel noise was tedious and fatiguing, and the Board also had made great efforts to reduce noise in trains and had succeeded quite well on the electric rail services to Manchester.

Passenger comfort studies would include air-conditioning, seating, ease of entry and exit, and lighting.

While the terminals are suitable for the present conditions, more sophisticated layouts are planned where the hovercraft will be guided to the ramp and up to the covered arrival bay, so that passengers will be close to the facilities and amenities of a first-class terminal. There will be a modern freight-handling system dovetailed into the national trunk network. The application of the air cushion principle to the handling of freight is a "must" for the future.

Seaspeed establishes the first rail-hovercraft link to the Isle of Wight, and BR claim that the journey from London to Cowes is completed in just under two hours.

LETTERS TO THE EDITOR

Dear Editor,

With the first hovercraft show behind us, this is as good a time as any to consider what may be done in the future in the way of shows and exhibitions. For the time being it is a hard job putting over the argument for such a novel form of vehicle, and it will be so for some time to come—particularly so far as civil operators are concerned.

What then may be done to propagate interest and involvement in the future? Obviously the maximum use must be made of the usual press, radio and television outlets, with news, features and discussions being widely disseminated at home and abroad. As useful as these are, there is no substitute for a live show with which to generate interest. There are two reasons for this. First, the show itself, as well as the participants and personalities, becomes a local feature. Secondly, live activities draw a great deal of public interest, and particularly so if speed can be effectively demonstrated.

If the case for a show at regular intervals is accepted in general, then the question of location inevitably follows. Much can depend on the choice of venue, and for this such things as local population density, availability and adequacy of accommodation as well as the sufficiency of the show area and facilities have to be considered. Thus, as much for domestic and human reasons as for any other, cities and shows become synonymous with each other: the Auto Show — London; Aero Show — Paris; Trade Fair — Hanover; Industrial Fair — Leipzig; Film Festival — Cannes, etc — all international events. So far as hovercraft are concerned I would like to suggest Venice for earnest consideration and propose a combined Hovercraft and Hydrofoil Show.

Of course there are sure to be protagonists for holding the show in the UK and others who will insist on an all-British event after the style of the past SBAC shows. These insular minds should be silenced from the start, for nothing is more damaging to an industry and its image as seen from abroad than a purely national show. We have nothing to lose but everything to gain by backing an international event. What is more, we have no really suitable display site within the British Isles.

The unique city of Venice provides a natural arena with adequate facilities for demonstrations, fuelling and engineering installations, and a good communications system connecting with the rest of Europe. Many ships use the port and they would be able to off-load their charges straight into the lagoon. As a city, Venice has a large number of alternative attractions for the leisure hours and for entertaining. Timing would have to be chosen to avoid clashing with the high summer tourist traffic. Late August or early September would probably be the best time, and the city authorities would undoubtedly welcome the event as an aid towards extending their useful business season. A bi-annual air show is there during September and it may be possible to arrange a joint effort.

Apart from the internal aspects of this city, its geographical location makes it an excellent base for prospective hovercraft operators. A nominal 100 mile (160 km) range goes beyond Ravenna to Rimini on the Italian coast — a popular holiday area. Trieste is only about two-thirds of this distance away, and the Yugoslav mainland a little less. Additionally, a service working in this area would come to the notice of interested parties in Greece, Turkey and the Aegean area in general.

A glance at the map and only a slight knowledge of the area show that the Adriatic and Mediterranean regions hold more prospects for hovercraft and hydrofoil operation than many other parts of the world. The tremendous holiday traffic now being generated as millions of Europeans migrate towards the sun and the sea offers an untapped potential. Some of the probable routes are perhaps a little too long for the present generation of hovercraft, but those capable of 200 miles (320 km) will be able to cope with them.

Even if the major hovercraft manufacturers feel that a Venetian venture is not worth their while, the smaller ones may think otherwise. Many vessels of a variety of type and size provide day-to-day transportation there either as public utilities or as personal transports. The city is rich and exists as three main entities — the Lido, which emphasises beach and water sports; the main city as a tourist attraction; and a port and industrial area on the mainland. The international airport is also on the mainland. For commercial reasons, the fastest transportation system is required, and hovercraft can provide this. It is significant that there is a regular hydrofoil service between Venice and Trieste which is operated by a Rodriquez vessel.

Yours faithfully,

R. A. Cole

* * *

Dear Editor,

Your magazine continues to give excellent coverage to hovercraft affairs, and its photographic presentation is second to none. I particularly liked the display of Hovershow 66 exhibition stands, which after all were the basis of the Show. As a civil engineer concerned with the rather primitive existing terminal designs and also with more sophisticated future layouts, may I add certain remarks to the article on "Hoverports — A Planner's Notes for Guidance" by Peter Sarony.

First, the list given of SR.N6 operators does not, I think, give due eminence to the performance of Hovertravel Ltd, who have operated a continuous service since July 1965, and have to date carried over 3,000,000 passengers, and are at present running at up to 3,000 fare-paying passengers per day and have completed over 3,400 operational hours. Figures for all other operators can only be a small fraction of these, and would make interesting reading! Notable omissions from Sarony's list are ScanHover and San Francisco Oakland Helicopters Inc, although they are not UK operators. The benefit to the industry of the valuable developments carried out on the Solent run is now being, I believe, recognised by the British Hovercraft Corporation and surely cannot be overstated.

Secondly, the article, while purporting to be a "Planner's Guide", misses surely the fundamental point of hoverport design, which is the ability of the craft to operate without ports at all! In other words, terminals must be of minimum cost and so sited that they take full advantage of all the hovercraft's natural advantages. The siting of the apron to take advantage of natural gradients is of first importance. This would reduce the cost on the figures quoted to £140,000, which I think is nearer the mark.

Mr Sarony's other criteria for planning I completely concur with; they are in fact exactly similar to those for modern airports, although as yet on a much smaller scale. The areas involved for hoverports are in fact insignificant when compared to even a small domestic airport.

Thirdly, in the discourse on ramps, I cannot see why a dished ramp should not have a flat bottom, and in the remarks on noise, following my own experience with noise recordings of both N.2 and early N.5s in 1964, taken in conjunction with Hovercraft Development Ltd, the problem is not only in the close proximity of the terminal but over the surrounding area of, say, half a mile radius, when baffles such as are proposed in the article would have little or no effect until the craft is "in" the ramp. This has been fully discussed in articles published in this very journal by Wheeler, Donno and Trillo in 1965, Vol 5 Nos 1 and 3.

The solution to the problem of large aprons put forward in the article is certainly ingenious and worthy of further studies. It is perhaps relevant that no actual costs are mentioned and, as an engineer, such a system to cater for an approach speed of even 10 knots with an acceptable deceleration would seem quite an undertaking for the 160 ton SR.N4. It should not be forgotten that every force has an equal and opposite reaction, and the engineering problems do not stop with a jet of water.

Finally, may I refer to the summary. All publications of large-scale hoverports have in fact been "artistic"; no further comment is necessary. However, if one studies the photograph on page 24 of your July issue, of the Association of Consulting Engineers' stand, all the models on display show the sea level at dead low water, as also did the model on the BHC stand. Mr Sarony asks the question: "What proposals have been put forward to date?" If he was inside the industry he would perhaps be a little more informed, and would quote other newspapers than the *Evening Standard* and *Illustrated London News*. It is a pity that the author has confused selling his patented scheme with criticising other schemes and with writing an article titled "A Planner's Notes for Guidance".

Yours faithfully,

A. W. Grinyer, BSc(Eng), AMICE

* * *

Dear Editor,

I am saddened that Mr. Grinyer, who is "in the industry", should so readily have misinterpreted both my text and my motives, and I welcome the opportunity of answering his criticisms for the benefit of those who may be misled by them.

Firstly, the terminal schemes I described have been evolved concurrently with Craft developments over a six-year period and stem from original research and analysis into hovercraft and their operation. Assistance from Hovercraft Development Ltd., and operators such as British United Airways have enabled us to prepare detailed Design Studies and Reports on international (e.g. Cross Channel) hovercraft services from that time to date.

Secondly, my paper was in no way intended to belittle the worthy and well-praised performance of Mr. Grinyer's company, Hovertravel. The point I was making is that British Rail Hovercraft and Townsend Hover Ferries would almost certainly not have come into existence anything like so early had the Swedish shipping interests not entered their Cross Channel service so decisively to U.K. waters, rightly or wrongly notwithstanding the earlier commencement in service of Clyde Hover Ferries and Hovertravel.

In further clarification, the list was a synopsis of the "state of the market" at that time and refers specifically to those running or intending to run within or to-and-from U.K. waters.

Incidentally, the passenger figures Mr. Grinyer gives for Hovertravel are impressive, but it is perhaps unfair baldly to compare these to those of other Operators, for on a Cross-Channel service of, say, 27 n. miles far fewer loads can be carried per day than on a sheltered water service such as a Solent crossing of perhaps only 4.3 n. miles. This is especially so if one compares different factors within "Turnaround", involving such important differences as passports, customs, immigration, etc. None of which apply to a domestic ferry turnaround.

I nonetheless agree that other Operators' figures might well be of interest to some, and in this respect I would welcome Mr. Grinyer's clarification of his own statistics: namely, 3,000 passengers per day x 400 days = 3,000,000 carried! It would appear that even if two SR.N6 Craft each transported a fresh load every 10 minutes at a 100% load factor every time, 6,579 operating hours would be required to carry 3,000,000 passengers. Alternatively, if 3,000 passengers are carried every day, it would take 1,000 days to move 3,000,000 people. I believe Mr. Grinyer has misread the figures: to my knowledge, Hovertravel carried a total of 337,818 passengers up to 9th August, 1966.

Mr. Grinyer is also apparently confused about various companies' policies. He must surely either advocate that international services should be run from bare beach terminal sites or recognise with me the need for the most careful planning of a terminal complex. He seems already to be doing the latter by assisting in the design of "more sophisticated terminal layouts", which he later describes as "artistic". This may aptly describe other schemes with which he has been involved and which do not appear to recognise that a Hoverport design involves intricate planning of the main buildings and not simply ramps and block plans. Our own designs are in fine details and in some cases have been advanced to working drawing stage.

Generally, I contend that the hovercraft image is no more impaired by advocating the provision of sophisticated hoverports than the aircraft image was damaged by the construction of sophisticated airports.

Cost is, of course, of great importance, especially when considering SR.N4 facilities, but I would certainly not advise an Operator to choose a site by virtue of a convenient existing gradient alone. If the cost of improving road and rail connections to such a site is included, the cost would soar above any saving by using such a gradient. In any case, a reduction on one system by virtue of an existing gradient effects a proportionate reduction on the system I propose by the same means. I have therefore illustrated a hypothetical case in the article, embracing the most adverse and typical conditions which are likely to prevail: namely, a restricted site area, with the whole complex built out over unstable mud or ground, necessitating piled foundations, as could be the case if a Hoverport were to be built over the mud banks in Ramsgate Outer Harbour.

As I believe I explained to Mr. Grinyer's associates at the Hovershow, and as is no secret to anyone who attended Browndown or read the numerous accounts of my system in a variety of technical journals and newspapers (e.g. *Daily Telegraph, Evening Standard, Southern Echo,* etc.) the comparative costs on this piled basis, for the Hoverways and ramps complete, are approximately £1,250,000 for the large concrete platforms, and continuous ramp designs, as against £120,000 for the containment system which I support, and I do agree that this IS highly relevant.

The suggestion for a flat bottomed ramp is not new, and is generally accepted by the Industry as being unworkable, not only for the reasons I mentioned, but also because of the width required for the Tidal section. This has to be sufficient for the Craft to be manoeuvred onto it at any state of the tide, and thus, apart from the expense, could allow the Craft to work up a dangerous lateral speed.

The comment on noise is not in conflict with my statements. It may well be objectionable to the ear within a half-mile of the source, but excessive noise is at a peak when climbing a ramp, due to the use of maximum power during this manoeuvre. It is therefore at this time that the reduction at source can be effected by the acoustic baffles.

Since designers of existing SR.N6 facilities did not anticipate the lateral instability factor, the three incidents of Craft being smashed against obstructions were not obviated by the introduction of such a guidance system as the one I propose, (a fact which I had declined to reinforce). It is perhaps, therefore, not surprising that Mr. Grinyer does not believe that these incidents dictate a basic planning requirement when considering docking systems for the 160-ton SR.N4 Craft, with the vastly increased moment which will be involved. If he considers the desired action to be one of a deflective nature, I think he will grasp more of the fundamentals of the system. He need not be too concerned that the forces involved are impossible to absorb within a swing of 10 feet, if he compares the moment taken up by a short action on the shock absorbers, via the point loaded tyres on a Boeing 707 jet, weighing many tons and landing at a speed of over 100 knots.

As Architects our Code precludes us from being as deeply involved with certain companies as Mr. Grinyer appears to be with Hovertravel, and I had not considered any disadvantage that this may represent.

Although labelled by him as "ingenuous", I am pleased to note that this Gentleman considers the ideas worthy of the further studies being carried out by the team of Engineers and Scientists who continue to be engaged upon this, and I would add that should Mr. Grinyer see any room for improvement that has not been already implemented, we should naturally be most interested to discuss these ideas with him. Perhaps, to this end, he could well benefit from studying the article in criticism more carefully.

Yours faithfully,

PETER P. B. SARONY, Dip.Arch., A.R.I.B.A.

The History of Hydrofoils

(Part X)

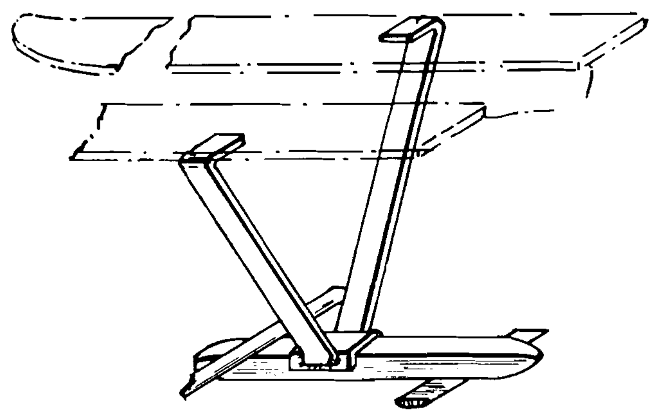


Figure 81. Cosmos Dynamics Inc

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

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

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

by

Leslie Hayward

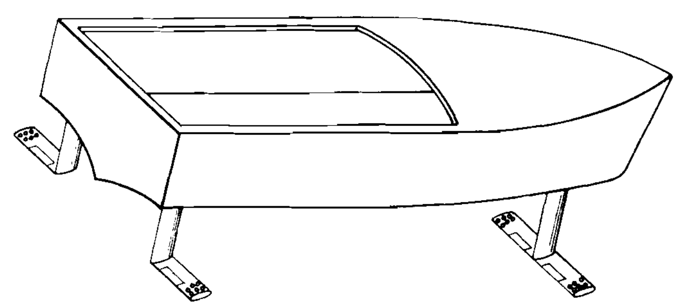


Figure 82. James Turner

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

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

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

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

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

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

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

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

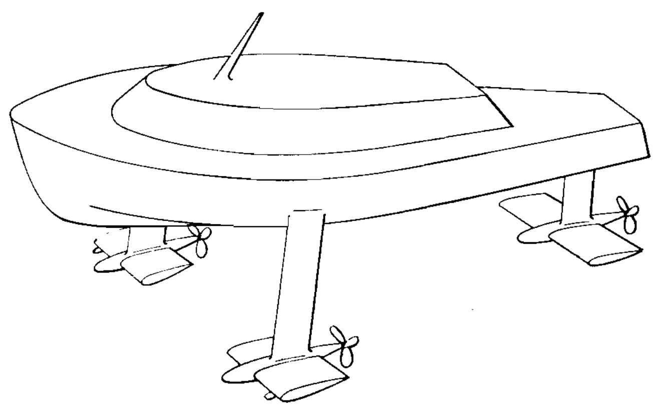


Figure 83. R. E. Bowles

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

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

Considerable hydrofoil development has been carried out by the Russians. In 1957 work was completed on their first multi-seat passenger hydrofoil, the 90 ft long *Raketa*. This single-screw craft, capable of carrying sixty-six passengers at a speed of 45 mph, has a displacement draught of 6 ft and a foilborne draught of $3\frac{1}{2}$ ft. The *Raketa* was initially powered by an 800 hp diesel, but this has been changed to a more economical 1,000 hp diesel.

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

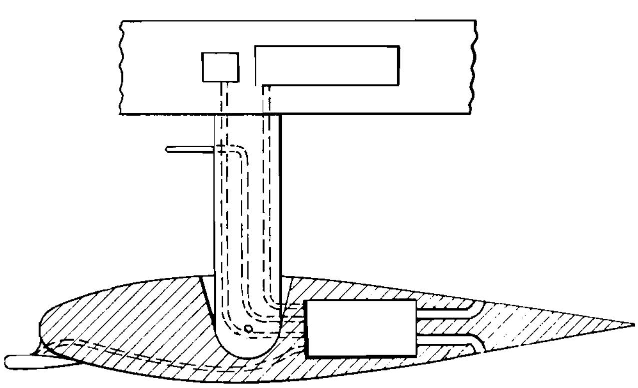


Figure 84. R. E. Bowles

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The Small Hydrofoil Prototype to the Stryela

by E. A. Aframeyev

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

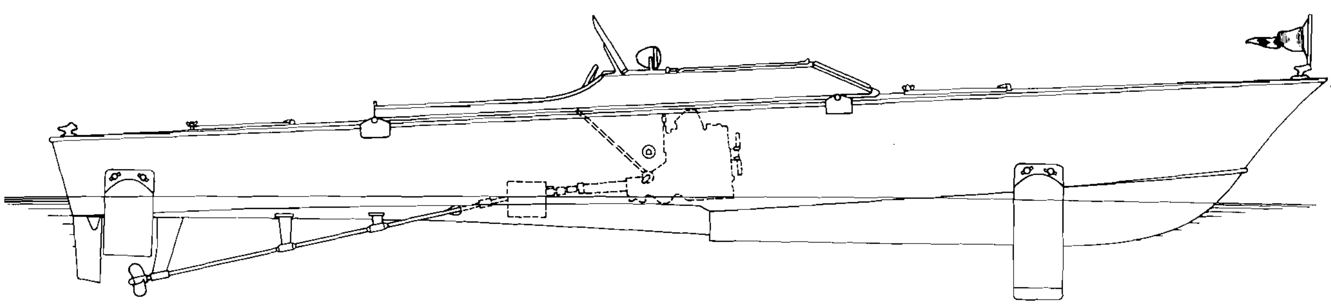


Figure 1. General view of the motorboat from the side

PRINCIPAL PARTICULARS, ETC

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

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

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

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

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

The foil system is made of an alloy AMr5B.

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

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

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

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

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

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

The propellers are three-bladed, with a diameter of 0 24 m

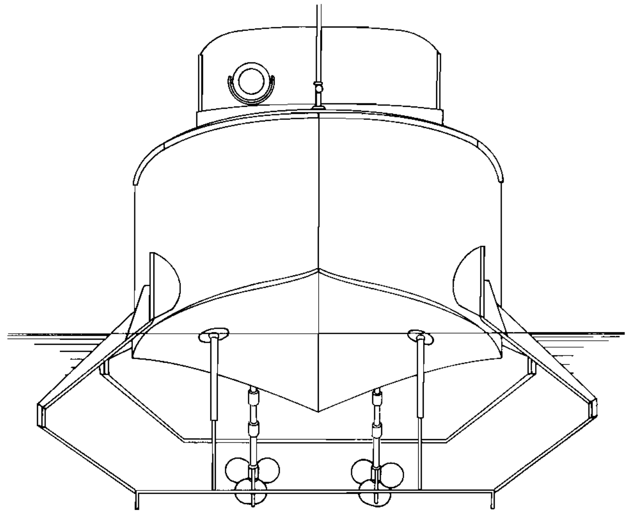


Figure 2. View of the motorboat from ahead

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

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

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

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

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

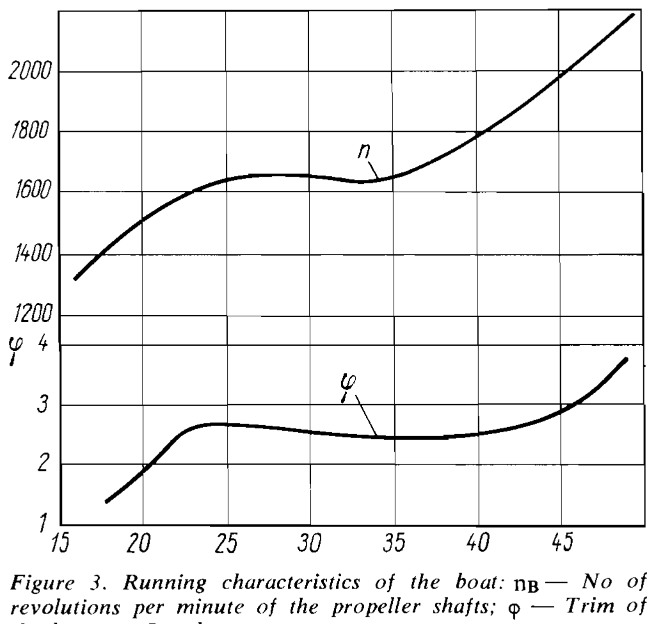
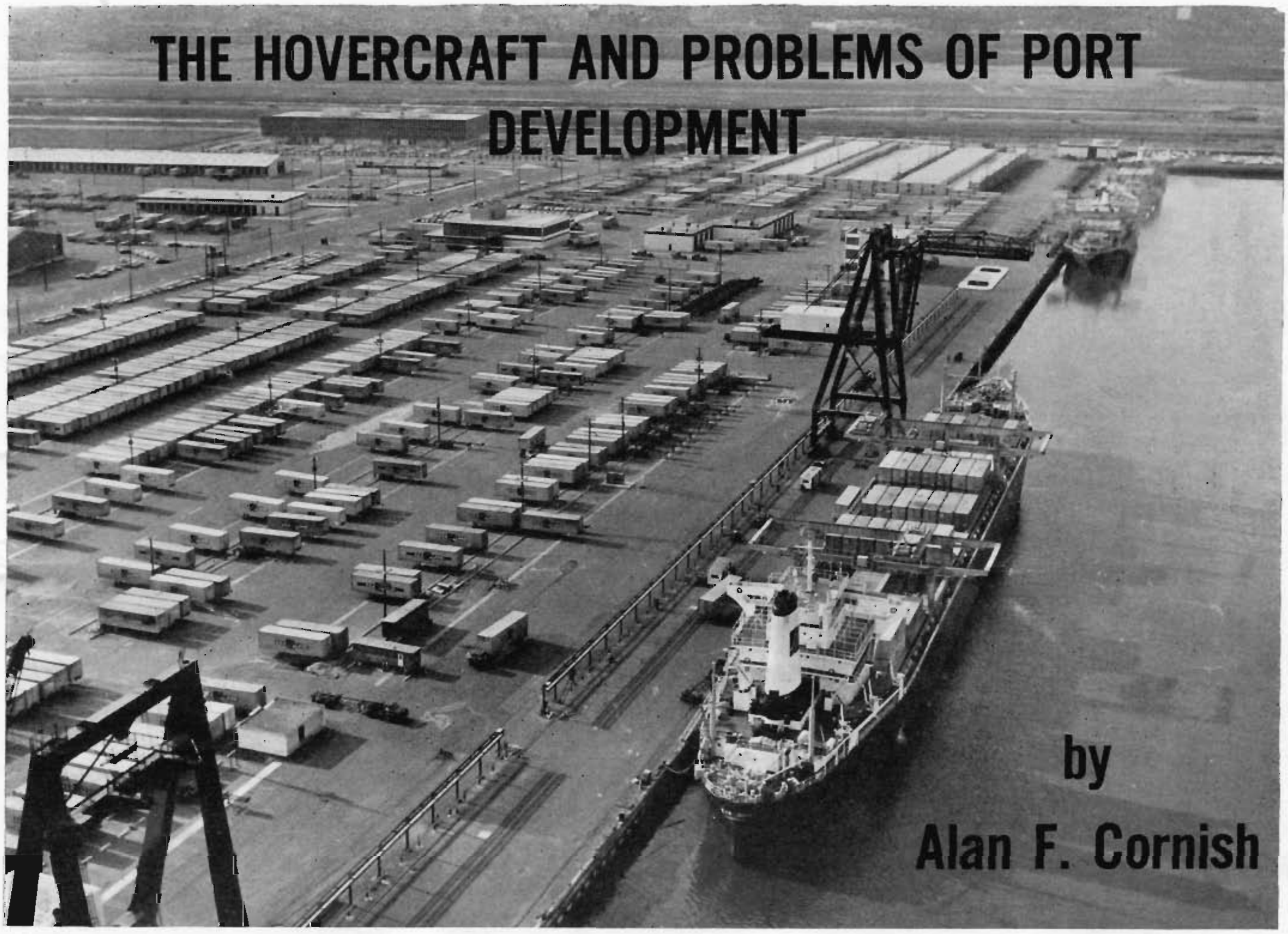


Figure 3. Running characteristics of the boat: n_B *— No of revolutions per minute of the propeller shafts;* φ *— Trim of the boat; v—Speed*

THE HOVERCRAFT AND PROBLEMS OF PORT DEVELOPMENT

by Alan F. Cornish



Sea-Land Headquarters, Elizabeth Terminal, Port of New York (Photograph by courtesy of Sea-Land Service Inc and Port of New York Authority)

Dockside Trends

THE trend in dockside "furniture" — transit sheds, warehouses, etc — has in recent years been towards a certain lightness of design, utilising materials such as alloy sheeting in single-storied structures, quite distinct from the massive multi-storied reinforced concrete buildings of a few years ago. One of the main reasons for this is the recognition that changes in the practices of cargo handling and movement can, in a relatively short number of years, render a building totally obsolete. One is then presented with the choice either of modifying the most efficient and up-to-date methods to suit the outdated building, or of tearing down the building and replacing it with something more suitable. Thus many dockside buildings now take on an almost temporary air, as the pace of the development philosophy behind their construction is so great following the many studies to which the industry has recently been subjected.

Progress in Dock Design

However, the design of the actual dock itself, whilst progressing in terms of layout and space utilisation, remains on a very massive and permanent scale in most cases. For example, plans for the development of the Western Dock at Southampton, mostly on an area now covered by the waters of the Redbridge Channel, envisage an expenditure of about £65 millions, spread over a number of years, to produce only thirty or so berths. The project will enjoy no subsidies — charges will be tied directly to the cost of facilities used — so that to ensure a realistic return on capital whilst still remaining competitive, it will be necessary to use the berths for anything between fifty and a hundred years before the full cost of their construction is recovered — presupposing, of course, that every calculated assumption of the economists and financial experts has been correct and that the traffic develops in precisely the way anticipated. The Southampton scheme, incidentally, is representative in both scale and cost of four or five similar projects now under consideration.

Taking another example, the original Tilbury Docks — part of the responsibility of the Port of London Authority — were built in the 1880s, and yet it is very doubtful whether they made any profit at all until after the second World War. Thus the construction of a port effectively locks up a very large capital sum for a great many years. Since it is virtually impossible to make any radical alteration to a system of docks, especially impounded docks, once their layout and pattern is established, the only guarantee of security for the invested capital lies in the continuation, with only minor modification, of existing methods and types of shipping. Any basic change in the development of the vessels which are to use the facilities must place the invested capital at hazard. This fact is particularly relevant when it is remembered that the economic life of the normal oceangoing ship is barely one-third of the accounting life of the port facilities it uses. In an age of exploding technological innovation such long-term investments become more vulnerable almost day by day.

Vessel Changes

At a time when this country is embarking on a port construction programme of unprecedented proportion, it is clear that any hint of a change in the basic characteristics of deep-sea ships must be closely investigated and an evaluation made of any potential threat to the capital about to be invested. Upon identification of such a change the gains likely to accrue to the shipowners and shippers must be assessed. These will determine the likelihood of implementation of the change. The construction programme must then be re-examined and amended in the light of the direction and scale of change expected to occur to the vessels which in twenty or thirty years will be using the ports. In the past year at least one such idea has been publicised which clearly represents an identifiable and radical change in the existing and developing conventional method of ocean carriage of general cargo. This is the atomic-powered ocean-going high-capacity hovercraft. Whilst it is obvious that the introduction on a large scale of such craft would not drive from the seas overnight all conventional vessels, it has been predicted in some quarters that a very considerable impact could be made in about twenty years. They are therefore at least a possibility worthy of examination in the time scale of the life of any new port.

The Hovercraft

It is now practically certain that in 1968 at least one cross-Channel vehicle ferry service will be in operation using hovercraft instead of ships. The SR.N4 hovercraft now under construction for this purpose will weigh about 160 tons, have a payload of 30 cars and about 250 passengers, and will offer a comfortable ride in all but the roughest Channel conditions. It will thus be in direct competition with present vehicle ferry operators. The pattern of commercial hovercraft operations in the future will be greatly influenced by the experience gained in 1968. Mr Christopher Cockerell, inventor of the hovercraft, has suggested that only the selection and proving of economic routes now delays development of ever larger hovercraft. All technical details appear to be surmountable. One shipping company is convinced to the extent of putting £2 million into the testing of the Ramsgate–Calais route, and further orders for hovercraft of a similar size have been quick to follow.

If the service is a commercial success — and it is to be emphasised that operations on this scale will be the first that most hovercraft enthusiasts consider capable of going beyond the experimental stage — then many more cross-Channel hovercraft services will soon be introduced. The economic range and size of the vehicles available will govern choice of route, and these are likely to increase steadily as manufacturers gain experience from the research likely to be required to develop military hovercraft, in which there now appears to be very considerable interest. In fact it seems probable that the real spur to development will come from that quarter henceforth. Already several types of military vehicle are being contemplated. A logistic support or fast patrol capacity would call for a hovercraft in the order of about 400 tons, which might be available within five years, whilst a frigate-sized vessel of between 1,000 and 1,500 tons is under consideration as a later possibility. It was recently indicated by Mr Lewis Boddington, Assistant Managing Director (Technical) of the British Hovercraft Corporation, that projections of up to 4,000 tons, with a payload of 1,600 tons and a range of 1,000 nautical miles at a cruising speed of 40 to 50 knots do not seem impracticable. Such vehicles appear capable of offering serious competition to conventional shipping on all British–Continental routes.

Preliminary American studies have shown that hovercraft for transocean use appear to be economically and theoretically sound, technically feasible, insensitive to the labour rate differential between American labour and foreign competition, and have vehicle characteristics capable of restoring the US Merchant Marine to its original vigorous state without requiring Government subsidy to survive. Recently a special committee of technical advisers recommended that the US Department of Commerce, through the Maritime Administration, should sponsor a $70 million research programme on the important technological problems at present likely to impede a commercially competitive operation. The Naval Ship Systems Command (formerly the Bureau of Ships) has also proposed extensive research and development of air cushion vehicles, and a joint naval/commercial programme seems likely to emerge. The main aim of this will be to determine the technological feasibility of building multi-thousand ton air cushion ships for military purposes and surface effect ships for commercial operation. The initial recommendation envisaged a 5,000 ton ship capable of crossing the Atlantic in the mid-1970s at speeds of up to 100 knots at a hoverheight of 20 ft with a payload of 2,000 tons. A nuclear power unit might be one of the possibilities studied.

Using the above figures as a basis for calculation, and at the same time making a number of fairly sweeping assumptions, it is possible even at such an early stage to form some picture of any gains likely to accrue to shipowners and shippers, at least indirectly. As their costs are largely incurred in the use of various capital assets, a computation of the likely capital costs involved may provide a sufficient yardstick for the purpose required. Direct operating costs must remain unassessable, since the hovercraft postulated is merely a recommendation for development in years ahead. However, for the purposes of this exercise, they are assumed to be the same as for the sort of container ship with which such hovercraft might compete. The exercise is based on a requirement to transport 6,650,000 tons of dry cargo per annum each way across the Atlantic, and examines three possibilities — moderately improved conventional ships, container ships, and hovercraft equipped with specialised containers, together with major ancillary requirements, giving the benefit of any doubts which arise to the hovercraft. This is particularly so at stage 19 of the study, where it is necessary to assume a capital cost per craft. The figure of £5,000,000 used in the calculation is probably very low, and depends largely on research and development costs being spread over a far greater number of craft than would be required for this route and trade. Various estimates for small numbers of such vehicles range up to totals of £20,000,000 per craft — a figure anticipated by Christopher Cockerell in his historic paper to the Royal Society of Arts in 1960 and current still in the thinking of naval experts both in this country and America. However, any figure higher than that used in the exercise would only further substantiate the ultimate conclusion of this paper.

Although the crew of each hovercraft may only be fifteen in number (assumed) in comparison with the crew of each container ship of, say, thirty men, it is probable that a number of additional complete relief crews would be required to maintain such an intensive schedule of operations, and since also at least some members of the hovercraft crew might also have to be qualified nuclear engineers on a substantially higher pay scale, it is probably favouring the hovercraft to assume identical crew costs. Similarly, although any nuclear fuel consumption of the hovercraft is likely to be purely nominal, other maintenance costs, to skirts for instance, are likely to redress the balance. All of these factors are apparently appreciated by the US Maritime Administrator, Mr Nicholas Johnson, who acknowledges that large savings are not expected directly. The benefits which he identifies are of an indirect nature, i.e.:

(a) Higher utilisation of crews and equipment;
(b) No locks required for docking;
(c) No canals required to serve inland cities;
(d) Projects such as a second cutting to supplement the Panama Canal or widening of the Suez Canal and St Lawrence Seaway would be unnecessary;
(e) Greatly increased transit speeds would allow:
  (i) reduced stockpiles;
  (ii) reduced interest on capital goods (cargo);
  (iii) reduced insurance on volume of goods both in transit and stockpiled;
  (iv) increased number of departures and hence better and more flexible service;
  (v) increased chance of higher load factor per container each trip.

The last point is of great practical significance, since it is unlikely that the container ship would sail regularly with all containers fully loaded. The assembly of 10,640 tons of cargo to be available precisely as required during the very tight turn-round schedule of the container ship would in itself require an extremely efficient and expensivly equipped back-up organisation. Additionally there is great attraction in the type of development to be anticipated in other fields which a move in this direction would appear likely to precipitate. It would only require a latter-day Henry Ford to produce a "Model T" hovercraft, for instance, and the entire transportation network of the world could be revolutionised. Bridges on the scale of the Forth and Severn Road Bridges would be unnecessary, as would the Channel Tunnel. Underdeveloped countries would no longer be obliged to lay down precious millions on an infrastructure of enormously expensive concrete roads and steel permanent way when grass tracks would serve as well. Of course hovercraft as we now know them are noisy, and research aimed at greatly reducing this nuisance is already showing signs of success, but compared with the sonic boom of the Concorde now under construction, even present noise levels are comparatively insignificant. With such virtually unlimited possibilities of revising old notions on the whole field of transportation, it would not be long before the skill of man began to put hovercraft to uses such as the few here touched upon. Indeed, British firms such as Britten-Norman and Manx Hovercat are making moves in such directions more likely day by day.

However, in the context of deep-sea general cargo movement, a saving on capital costs of such a marginal nature as that indicated by the theoretical exercise seems unlikely to provide adequate incentive to justify the change, which would have to be in the face of the current momentum towards container ships as postulated, and across the barrier of an enormous and indeterminate research programme on an invention of only ten years' standing. The introduction of a factor for depreciation definitely substantiates this view. The decision of the US Department of Commerce will doubtless settle the question, and it will be interesting to see what weight is attached to the military aspect of such vehicles, where a different order of priorities may prevail. Nevertheless, for short sea cargo and ferry services the hovercraft certainly appears much more likely to supersede all other types of shipping, and for this reason it should be studied and anticipated now. Convenient sites, even several miles inland, with clear access routes to the sea should not be wasted or pre-empted for other purposes, and future coastal development and protection works on these routes should reflect the need for shallow sloping embankments with no sudden drops or other awkward barriers. Berths constructed for conventional short sea ferries will be totally unsuitable for handling hovercraft, but fortunately these are usually of a much less massive and permanent construction in themselves, and this fact in conjunction with their ability, normally, to produce a much higher throughput and rate of return anyway, has resulted in their accounting life being much shorter than that of the deep-sea berths. Obviously when the economic life of berth and ship are practically the same, the risk to capital invested in the berth is minimal, and the only danger lies in over-provision of such berths *vis-à-vis* ferry ship buildings, which is not too difficult to avoid.

INITIAL CAPITAL COST OF SYSTEMS TO MOVE 6,650,000 TONS GENERAL CARGO US/EUROPE AND RETURN PER ANNUM

Detail	*Conventional Ship*	*Container Ship*	*Hovercraft*
1. Assumed nominal disposable load per craft	6,650 tons	15,200 tons	2,000 tons
2. Unladen weight per container (if used)	—	2.5 tons	0.5 ton
3. Container type, dimensions and nominal loaded weight	—	ISO stackable 20 × 8 × 8 ft — 20 tons	Aircraft type non-stackable 10 × 8 × 8 ft — 10 tons
4. No of containers per craft — aboard ...	—	760	246
5. No of containers per craft — ashore ...	—	3,040	2,460
6. Cost per container	—	£700	£250
7. Capital cost of containers per craft employed	—	£2,660,000	£676,500
8. Actual cargo carried per round trip (assuming containers 80% full by weight)	13,300 tons	21,280 tons	3,739.2 tons
9. No of round trips required per annum	1,000	625	3,557
10. Rate of cargo handling per 12 hr day ...	1,000 tons/day	1,045 tons/hour	664.2 tons/hour
11. Craft's turn-round time	13½ days	2 days	6 hours
12. Craft's average speed	17 knots	22 knots	100 knots
13. Transatlantic voyage — 3,000 nm ...	7½ days	5¾ days	30 hours
14. Round trip of craft	42 days	15½ days	3 days
15. Rotation period per set of containers at each terminal	—	31 days	15 days — assumed packed and returned quicker (size)
16. No of days required per annum ...	42,000	9,688	10,671
17. No of craft required per annum (365 days)	116	27	30
18. Add 10% (maintenance, etc)	128	30	33
19. Cost per craft	£1,000,000	£2,500,000	£5,000,000
20. Capital cost of total craft	£128,000,000	£75,000,000	£165,000,000
21. Total containers required	—	102,600	81,180
22. Capital cost of total containers ...	—	£71,820,000	£20,295,000
23. Days at berth per round trip (12 hr day)	27	4	1
24. Days at berth per annum	27,000	2,600	3.557
25. Maximum workdays per berth per annum	280	280	280
26. Assumed berth occupancy	60%	30% — higher density containers	60%
27. Actual days working to craft per berth per annum	168	84	168
28. Total berths required (US and Europe)	162	32	22
29. Required throughput per berth per annum	168,000 tons	1,053,360 tons	1,339,028 tons
30. Cost per berth	£1,750,000	£2,500,000	£1,000,000
31. Capital cost of total berths	£283,500,000	£80,000,000	£22,000,000
32. Capital cost, berths + containers + craft	£411,500,000	£226,820,000	£207,295,000

ACROSS THE CHANNEL BY HOVERCRAFT

Leslie Colquhoun GM, DFC, DFM

Chief of Operations Hoverlloyd

THE English Channel captures the imagination probably more than any other stretch of water in the world. For centuries it has presented a challenge that has proved irresistible, and the stories of human bravery and endeavour are legendary. People have crossed it on beds, in barrels, ships, canoes, aircraft, balloons and gliders, and of course it has been swum; perhaps there remains only one thing left, to walk across it or of course to go by hovercraft. The walking will have to wait for the tunnel but the hovercraft like other forms of transport has in 1966 become old hat, although occasionally spiced with adventure.

It was in 1959 that the first hovercraft, the SR.N1, crossed between Calais and Dover and so celebrated the fiftieth anniversary of Bleriot's adventurous crossing. This was an epic "first" and a pioneering effort in the true vein. It was fitting that Mr Cockerell who invented the hovercraft as we know it should have been a member of the crew, albeit a wet one, since for most of the voyage he was outside the cabin attending to the trim of the craft. Now, seven years after this adventurous crossing, Hoverlloyd are running a scheduled passenger service between Ramsgate and Calais using the thirty-six-seat SR.N6. With such a small craft the service is run subject to weather conditions; pleasure-boat accidents have featured too prominently this summer to take any risks with passenger safety.

When in 1965 the news was released that Hoverlloyd — then referred to under the names of its parent companies, Swedish Lloyd and Swedish America Line — had signed contracts for the chartering of two SR.N4s and two SR.N6s to carry out cross-Channel hovercraft services, there was jubilation that at last a breakthrough had occurred, and the future outlook of the hovercraft industry brightened considerably. However, there were many whose enthusiasm for the project was dulled by the news that the service was to be initially operated with the SR.N6. They rightly considered that this craft was too small to cope with the sea states that would be experienced in the Channel even on relatively calm days.

At Hoverlloyd we were, and are, well aware of the limitations of the SR.N6 and with three months' operating experience behind us we know some of the vagaries of the Channel. As a craft we have found that the SR.N6 will cope with waves up to 8 ft high and winds of up to Force 6-7, but as a passenger-carrying vehicle these limits must be more severe simply because above all else the safety of the passengers must be considered, and secondly some thought must be given to their comfort. There is a tremendous difference between putting up with difficult conditions for a few minutes on a run across the Solent and in enduring the same for fifty minutes to an hour on the Channel.

Experience on the route has shown us that winds of above 15 knots will generate sea states in the English Channel that are unacceptable on these counts. This of course puts a very severe limitation on operations. Statistically it can be proved that using a 15 knot wind and 4 ft wave height as passenger-carrying limits it should be possible to operate Channel crossings for 60% of the days of May to September inclusive, and this was the basis on which the service was planned. Our experience in May and June was in line with this forecast, but July 1966 — as any luckless holidaymaker will confirm — has been a month well below the statistical average; as a result, in July, Channel operations were possible on only fifteen out of the possible thirty-one days.

If one briefly considers the statistics for July, our figures taken from visual observations on weather forecasts show that wind forces of less than Beaufort Force 3 were experienced for only 23.5% of the time. The statistical average based on observations for the past thirty years gives a figure of 67%. If one looks at wave predictions the same pattern emerges. Statistically the wave heights were expected to be 4 ft or less for 81% of the time at the East Goodwin Light Vessel. Our actual experience based on figures given us twice a day from the East Goodwin Light Vessel were that for only 48.6% of the time were waves of 4 ft or less. Waves of over 6 ft were reported for 20.4% of the month, whereas the equivalent statistical figure is only 7.3%. Naturally in any statistical information there are bound to be good averages and bad averages; it is unfortunate that July proved a bad average.

So far we have carried 6,000 people across the Channel, despite the fact that at the moment out of the possible four scheduled return trips per day we have been forced to cancel 48% due to weather conditions.

The passenger load factor varies between 40 and 50% on each Channel crossing but on a good weather week has reached 62%. With the French and British holiday periods coinciding in late July and August even this figure might be exceeded. Day excursion passengers from Ramsgate have formed 80-90% of our fare-paying passengers and it is significant that of all the tickets sold at least 80-85% of them have been sold from Ramsgate. Our experience and that of other cross-Channel conventional ferry operators indicates that the French day tripper is a rare bird that not even the novelty of hovercraft travel can bring to light. Could not our immigration and Customs habits be to some extent responsible? English day trippers are welcomed with a minimum of fuss in France, and I am sure that if these conditions were reciprocated it might be possible to effect an improvement. This comment, of course, does not refer specifically to Ramsgate.

It must be quite obvious to any reader that the cross-Channel service must be running at a financial loss. This of course is true and indeed a loss was expected, but such losses must be set against the invaluable experience we are gaining. It can be stated quite unequivocably that Hoverlloyd's operating experience is now second to none. The operation embraces all facets of hovercraft operations such as navigational problems, open-water operations, overland operations (Goodwin Sands), operating in and out of crowded harbours and, perhaps most important of all, the 150 miles that we are away from the manufacturer means that we must be capable of tackling all maintenance problems on the site. At least two days would be required to return a craft to the British Hovercraft Corporation at Cowes for the rectification of a defect. This of course does not mean that the British Hovercraft Corporation does not give us any assistance. On the technical and design side there is the closest co-operation, since what we are learning is of tremendous importance to the design of SR.N4, particularly in relation to the skirts, even at this late stage.

It can be seen, therefore, that our endeavours in 1966 and 1967 are an essential build-up to the great moment in May 1968 when we take delivery of our first SR.N4 complete with its permit for cross-Channel operations. Our hoverterminal and operating team will be ready and fully trained for such a moment. We are very conscious of the fact that as the first cross-Channel operators of the SR.N4, and indeed of the SR.N6, the success of the hovercraft industry rests upon the outcome of our efforts. Should we fail or give up in our endeavours, heavy suspicion will have been aroused amongst other potential operators at present sitting on the fence. The importance of these two critical years, 1966 and 1967, thus becomes more heavily underlined.

The experience so gained will help the major task of introducing the SR.N4 on to the Channel route in 1968. With this craft Hoverlloyd hope to reap the reward of these early pioneering efforts and give passengers the reliable, fast cross-Channel service that they are seeking.

NORWAY'S HOVERCRAFT LEGISLATION

Ministry of Trade and Shipping

ODELSTING BILL NO 26 (1965-1966)

Re Temporary Law concerning Air Cushion Craft

RECOMMENDATION from the Ministry of Trade and Shipping, March 18th, 1966,
approved by Order in Council same day.

(Presented by the Minister, Kare Willoch.)

In a letter of February 23rd the Directorate of Shipping submitted to the Ministry an Odelsting Bill draft for a temporary law concerning air cushion craft. The text in the present Bill is in all essentials based on the draft received.

I. GENERAL OBSERVATIONS

1. Definition

Air cushion craft are characterised by the fact that they rest on a cushion of air when in motion.

The craft are not intended or designed to move in water like conventional craft, or on land or ice like ordinary vehicles. They can, however, in an emergency, land in water and keep afloat on tanks while moving at slow speed. Furthermore, the craft can in certain circumstances also move on (over) land and ice. The ordinary operational field of the air cushion vehicle is, however, the air, with the craft freely raised above the surface at a limited distance (height).

2. Introduction of Air Cushion Craft in Norway

The air cushion craft known in this country have been developed in recent years in England by Westland Aircraft Ltd. In Norway air cushion craft have been introduced by the Messrs Scandinavian Hovercraft Promotion Ltd A/S, who started a trial service in Møre and Romsdal in April 1965. The trial service was in operation — with some interruptions — until into September 1965, when the craft were transferred to Danish waters.

3. Control of Air Cushion Craft

In 1964 the question of which administrative body should be given responsibility for the control of air cushion craft was the subject of discussion in the Government. It was decided that the Directorate of Shipping should be in charge of technical and safety control and also be responsible for rules of navigation at sea for air cushion craft.

4. Appointment of a Committee to Inquire into Problems in connection with Air Cushion Craft

To assist the Directorate of Shipping, a Committee was appointed by Order in Council of January 15th, 1965, with the following terms of reference:

"To evaluate the technical, operative and practical aspects of air cushion craft, and to submit a recommendation concerning the legal aspects, aspects of traffic, concession and liability related to these craft, and concerning the public control device which should be effected. The Committee shall further make proposals for detailed lines of policy and possibly for temporary regulations for the construction, arrangement, equipment, manning and operation, and for special precautions and safety measures which should be effected to ensure a safe service."

The following were appointed as members of the Committee:

For the Directorate of Shipping:
(1) Director of Shipping, Neubert Wie, the Directorate of Shipping, Oslo, Chairman.

For the Ministry of Transport:
(2) Secretary (now Traffic Chief) at the Ministry of Transport,, Olav Haukvik, Oslo.

For the Ministry of Fisheries:
(3) First Secretary in the Directorate of Harbours, Erik Reichborn Kjennerud, Oslo.

For the Norwegian Federation of Ships' Masters and the Norwegian Association of Mates:
(4) Director of the Norwegian Federation of Ships' Masters, Henry Bjønness, Oslo.

For the Council of Hovercraft in Sunnmøre:
(5) Harbourmaster Leif Thue, Alesund.

For the Technical College of Norway, Trondheim:
(6) Chief Engineer Harald Walderhaug, Trondheim.

Deputy members:

For No 1: Deputy Director in the Directorate of Shipping, Modolv Hareide, Oslo.

For No 2: Inspector of Coastal Shipping K. L. Bugge, Ministry of Transport, Oslo.

For No 4: Director of the Norwegian Association of Ships' Mates, Ole Tennfjord, Oslo.

For No 5: Head of the Alesund College of Navigation, Knut Larsgaard, Alesund.

For No 6: Professor at Norway's Technical College, J. K. Lunde, Trondheim.

To reinforce the Committee in its consideration of special problems, the following were appointed:

For the Telegraph Board (problems of telecommunication):
Inspector at the Telegraph Board, Rolf Antonsen, Oslo.

For the Roads Directorate (problems concerning operation over land):
Departmental Director (now Traffic Director) in the Roads Directorate, Rolf Normann Torgersen, Oslo.
Deputy: Chief Engineer in the Roads Directorate, Odd Schøyen, Oslo.

For the Directorate of Aviation (technical aviation problems):
Civil Engineer in the Directorate of Aviation, O. E. Kjølas, Oslo.

The First Secretary in the Directorate of Shipping, G. A. Bull, was appointed Secretary of the Committee.

5. Trial Service

The trial service referred to with an air cushion craft at Møre and Romsdal was started at Alesund on April 5th, 1965. A regular passenger service was opened on April 6th. On Thursday, April 8th, 1965, the air cushion craft capsized during a demonstration trip. The capsizing is thought to have been the result of several circumstances. It is assumed in the first place that the centre keel of the craft, during earlier manoeuvring on the landing stage, had received initial damage which then materially deteriorated when the pilot made three demonstration emergency stops immediately before the craft capsizd. During the third demonstration emergency stop, which consisted of a pirouette manoeuvre, i.e. the craft in motion turned through 180° against its direction of travel, the craft lost stability.

The latter manoeuvre appears to have been unfortunate in combination with a calm water surface on account of a special suction effect under the craft. The damage the craft suffered from the accident was so great that the craft had to be transported back to England for repair.

A new trial service with an air cushion craft of a larger and improved type was inaugurated at the end of June 1965. Later an additional craft of this type was put on to the trial service. According to the reports which have been received, the trial service mentioned with air cushion craft in Møre and Romsdal has been dogged by major and minor accidents.

Apart from the capsizing on April 8th, 1965, grounding, collisions with people, fences, pontoons, etc, have occurred as well as several engine breakdowns and damage to the "apron" (the lower part of the craft).

It appears that the pilots of the air cushion craft have found difficulty in retaining control of the craft during take-off and landing.

6. Legal Problems

The first question that arose in preparing regulations for air cushion craft was whether the craft could be regarded as ships, aircraft or vehicles, or whether this was a question of a completely new means of transport. Another question was whether existing laws and regulations could be extended, or whether entirely new legislation was needed for air cushion craft.

The question was submitted to the Ministry of Justice by the Directorate of Shipping, and the Ministry stated as follows:

"It must be considered doubtful whether air cushion craft, as described in the letter from the Directorate of Shipping, are covered by the concept of a ship as understood in the Law on Seaworthiness. It is assumed, however, that it is defensible — until the question is further clarified — to interpret the Law on Seaworthiness so that it applies also to air cushion craft, and it is assumed therefore that regulations may be prepared for such devices under this law, in respect of aspects connected with travel over open water.

"It is assumed that air cushion craft are beyond the concept of a ship as traditionally understood in maritime law. It therefore appears uncertain whether and to what extent air cushion craft come under the law of shipping, and the Ministry cannot make a definite statement on this point.

"The question can arise differently in relation to the separate rulings of the law. It must be considered necessary to take legislative measures to solve the many doubtful problems connected with air cushion craft. This applies, among other things, to eventual registration and mortgaging, and to questions of liability towards passengers, goods and outside third parties who suffer damage.

"Express provision for safety regulations — in the event, by addition to the law on seaworthiness — should be included, when the matter is being regulated by law in other respects.

"Attention is drawn to the fact that in the bill for a new law on road traffic it is stipulated in the motivation documents that the law's concept of a vehicle can include air cushion craft used on land (and on ice).

"Accordingly, it would be reasonable to let the maritime rulings include all traffic at sea.

"It would seem that a solution to the questions mentioned could best be established on an international basis (compare conventions in the fields of shipping and aviation)."

The Committee, whose mandate was *inter alia* to consider the legal problems connected with air cushion craft service, was of the opinion that it was not possible to work out proposals for laws intended to cover all aspects concerning air cushion craft before the trial service was due to start. This was due not only to the short time at their disposal, but also to lack of knowledge of the air cushion craft. On the other hand the Committee found it necessary to have further regulations for the use of air cushion craft. The Committee therefore sought to prepare temporary regulations for air cushion craft with reference to existing laws.

Temporary regulations for air cushion craft were prepared by the Directorate of Shipping on April 2nd, 1965. These regulations were in accordance with a draft prepared by the Committee.

On the basis of experience gained during the first part of the trial service, including, among other things, the breakdown in April 1965, the Committee found that certain alterations should be made to the temporary regulations. New temporary regulations were therefore prepared by the Directorate of Shipping on June 18th, 1965, on the Committee's recommendation. The regulations contain rules concerning definition, range of use, passenger certificate, standard of craft, standards for pilot and crew, rules for steering and navigation, use of lights and machinery, maintenance, logbooks and surveys.

Several aspects of general importance have not been included in the temporary regulations, such as the question of concession for regular service with air cushion craft, questions of registration, mortgaging, liability towards passengers, goods and outside third parties who suffer damage, and, further, questions in connection with landing stages and travel over land. The reason for this is that the Committee could find no basis in existing laws for laying down rulings on these matters.

II. DRAFT FOR TEMPORARY LAW ON AIR CUSHION CRAFT

1. General

In a preliminary recommendation the Committee has stated that it does not consider its work completed with the preparation of the temporary regulations, and that it considers its further task should be to follow the trial service, eventually evaluate the establishment of other trial routes for air cushion craft, and continue the inquiry into the above-mentioned problems, in order, finally, to be able to make further proposals for a law and final regulations on air cushion craft.

It should also be mentioned in this connection that IMCO (the International Maritime Council Organisation) has appointed a working committee to study the possibilities of arriving at international agreement on air cushion craft.

The Committee has pointed out, however, that, in view of the events of the trial service with air cushion craft in this country, it would be desirable to have a law that could give the authorities clear powers to issue the necessary safety regulations concerning the construction, arrangement, equipment, safety measures, maintenance, control, manning, registering and marking of air cushion craft, and to stipulate conditions for concession and for approved insurance or other approved security for coverage of compensation liability for damage and loss arising from the use of the craft.

The question of whether this law should also include rules about registration and mortgaging in order to allow sub-mortgaging of air cushion craft, and about compensation liability towards passengers, owners of goods and outside third parties, has been submitted by the Directorate of Shipping to the legal department of the Ministry of Justice, who in a letter of December 15th, 1965, stated *inter alia*:

"Under any circumstances the Ministry of Justice consider it unfortunate that rulings of a civil legal nature as mentioned above should be given by means of delegated legislative authority.

"Until the questions connected with air cushion craft service are further clarified and there is a better basis for passing suitable rules of law, it should, in respect of compensation problems, be left to the courts to decide on any cases which may arise.

"Nor is there considered to be such a pressing need for the financing of the service of such craft that the usual legislative channels should not be used in giving rules for sub-mortgaging. The same applies to rules of registration in civil law — on the registering of title in aircraft (as a condition of legal protection). For your information, we can tell you that we have learned that the Committee on Maritime Law in a preliminary draft for revision of the legislation of the shipping register, etc (recommendation VI), have proposed admission of air cushion craft to the shipping register (among other things).

"There is, however, no objection to rules on registering for public purposes being given by means of delegated legislative authority, and such powers should be included in the proposed law if such registration is considered necessary."

The Committee then prepared a proposal for a temporary law on air cushion craft giving the Sovereign powers to make the necessary rules. The draft has been submitted by the Directorate of Shipping to:

The Ministry of Transport,
The Directorate of Aviation,
The Ministry of Fisheries, and by this Department to:
The Director of Harbours,
The Director of Lighthouses,
The Director of Pilots, and
The Director of Fisheries.

The following are among the comments received:

From the Ministry of Transport:

"We have no objection in principle to the draft. With regard to the rules of concession for air cushion craft, it would be an advantage if the same terms are used as those used in the new transport law. The Ministry of Transport would therefore propose that para 2, section 4, should read:

" 'The Sovereign can decide that a licence, against payment of a fee, shall be required in order to run a regular air cushion craft transport service between places in Norway and between Norway and other countries. The expression "regular transport" is to be understood as this concept is defined in the law dated June 19th, 1964, No 7, on Transport, para 2, section 2. The terms mentioned in para 3 of the same law can be established for such permission.

" 'The Sovereign can also decide that air cushion craft cannot be used for other business activities within Norwegian territory without permission. . . .' "

From the Inspector of Coastal Shipping, K. L. Bugge, Ministry of Transport (deputy on the Committee for Traffic Chief. Olav Haugvik, Ministry of Transport):

". . . I note the absence of rules allowing for making conditions in the certificate about speed limit, maximum permissible load, height of waves and wind force, and a limitation on the range of travel. Even though there is a warrant in other laws and regulations for stipulating such conditions, they should be included for the sake of completeness in order to have the rulings collected together under one heading."

From the Directorate of Aviation:

"In contrast to the law on aviation, which has no definition of the concept of an aircraft, the submitted draft law contains a definition of the concept of an air cushion craft. The criterion of definition is supposed to consist in the technical/physical system — manifest in an air cushion — whereby the craft in motion is held up from the earth's surface. Such a system, however, might occur in many connections which have hardly been intended to be included in the field of application of the new law. It is reported, for instance, that an undercarriage for aircraft has been designed on the air cushion principle to replace the usual undercarriage with wheels or floats. Further, something similar is said to have been tried with rail vehicles. In other fields, too, the air cushion system has been utilised, for instance in connection with loading and stowing and other examples of handling goods. If the law on air cushion craft is to have a definition, it should perhaps be considered that it be given a limiting rule. . . .

"The draft has no ruling that fully corresponds to the aviation law rulings on airworthiness, see Chapter III of the law. It would thus appear that there would be no powers to stipulate requirements relating to the operating conditions of the air cushion craft, such as requirements on minimum weather conditions, loading, etc.

"Finally, we mention that there is a notably stricter penal framework in aviation conditions than the one proposed in the draft, compare Chapter XIII of the law of aviation."

From the Ministry of Fisheries:

"The draft Odelsting Bill has been submitted to the Director of Harbours, the Director of Lighthouses, the Director of Pilots and the Director of Fisheries.

"The Director of Harbours, in a letter dated January 24th, 1966, stated among other things that he is in some doubt as to whether the existing legislation is sufficient to enable the making of all the rules which might prove necessary in connection with the take-off and landing stages for air cushion craft. He refers to a letter dated May 31st, 1965, from the Legal Department of the Ministry of Justice to the Ministry of Fisheries, stating that it is possible that the rule in para 19, section 1, point 3, in the law on Port Authorities of June 24th, 1933, concerning the Harbour Board's power to issue rulings about 'dimensions of materials, building method and necessary safety measures' for buildings which are intended for or are open for general traffic, only gives powers for rulings needed in respect of the general traffic and not in respect of the air cushion craft itself.

"The Director states that it is not thought possible to regulate further aspects of general significance in ports and waters in this connection satisfactorily with reference to existing legislation. He is, therefore, of the opinion that there is a need for special legislation, as proposed, for this means of transport. According to para 2 of the draft the Sovereign can issue rulings concerning the construction, arrangement, maintenance, control of, and equipment for landing stages for air cushion craft. The Director of Harbours assumes that the intention of the law is not to limit the competence of the Port Authorities, but only to have a supplemental effect where the field of competence is insufficient.

"The Director proposes that the term 'landing stage' in the draft be replaced by 'take-off and landing areas, etc', as the former expression in his opinion appears somewhat restricted . . .

"The Ministry of Fisheries will, like the Director of Harbours, propose that the term 'landing stage' in the draft be replaced by 'take-off and landing areas, etc'. We further assume, like the Director, that the intention of the draft bill is not to limit the competence of the Port Authorities, but to have a supplementary effect in those cases where the competence of the Port Authorities is inadequate. In order to exclude doubt we would propose that a rule which would read as follows 'For the establishment of take-off and landing areas, etc, the necessary permissions must be obtained in accordance with the law on Port Authorities dated June 24th, 1933, paras 19 and 20, compare para 18' be included as a new section 4 of para 2 of the draft, or in the rulings which will be given with reference to para 2, section 3, of the draft. The same consideration may also apply in relation to other laws, for instance the building law."

In preparing the draft bill, the statements submitted have been taken into consideration and will be further considered under comments on the separate paragraphs.

2. Comments on the Separate Paragraphs of the Draft Bill

On para 1

The paragraph defines what is meant by air cushion craft. It renders the law applicable to air cushion craft both on water and on land. Within Norwegian territory the law applies whether the owner or user is Norwegian or a foreigner. The rulings in para 2, sections 1 and 2, also apply to craft which are registered or owned in Norway and are used outside the kingdom.

The Directorate of Aviation appears to consider that the definition of the concept "air cushion craft" may prove to be too wide, and it is pointed out that an undercarriage for aircraft is said to have been constructed on the air cushion principle, and further that something similar is said to have been tried with rail vehicles. The Directorate of Shipping, however, has on its part stated that there is little danger of doubt in interpretation in the cases mentioned. We consider that it would be natural not to consider either an aircraft during take-off or landing, or a rail vehicle, as an air cushion craft. However, should an aircraft manoeuvre on an air cushion undercarriage over land or water, not in connection with take-off or landing, it is considered that it would be natural to regard it as an air cushion craft.

On para 2

It is proposed in this paragraph that the Sovereign be given powers to issue any rulings that might be necessary to ensure a safe and reliable air cushion craft service in this kingdom and between Norway and foreign ports. The paragraph gives powers to prepare the necessary regulations concerning the construction, arrangement, equipment, maintenance, control, manning, piloting, registration (for public purposes) and marking. Furthermore, it is proposed that the Sovereign be empowered to issue rulings concerning landing stages.

In connection with the remarks of the Directorate of Aviation and Director of Coastal Shipping, K. L. Bugge, about powers to stipulate requirements for the operating conditions of air cushion craft, for instance requirements relating to minimum weather conditions, loading, speed, etc, the Directorate of Shipping has referred to para 2, section 2, in which it says that the Sovereign can issue rulings, *inter alia*, governing the *piloting* of air cushion craft. In the opinion of the Directorate of Shipping the term "piloting" covers the right to specify such requirements relating to the operation conditions of the air cushion craft.

With regard to the proposal from the Directorate of Fisheries and the Director of Harbours about replacing the term "landing stage" with "take-off and landing areas", the Directorate of Shipping maintains that the term "landing stages" must be considered sufficiently comprehensive. The Directorate of Shipping has also remarked, in connection with what was said by the Ministry of Fisheries and the Directorate of Harbours, that the intention of the draft bill is to obtain powers to prepare the necessary regulations to ensure safe operation with air cushion craft, and that there is no intention thereby to limit the field of competence of the Harbour Authorities.

A member of the Air Cushion Craft Committee, Director R. Torgersen, in a statement to the Directorate of Shipping, remarked:

". . . In the third sentence it is emphasised that the law also applies to landing stages, as air cushion craft as a rule will not land at a quay, but will have to be driven up on land at the end of a crossing. It is, therefore, of special importance to ensure that the landing stages are an appropriate condition.

"During the trial service consideration was given to using air cushion craft also for shorter traffic distances over land, for instance up to Vigra airfield from the seashore. In this connection we wish to point out that the new road traffic law of June 18th, 1965, presupposes that the law's concept of a vehicle can also include air cushion craft, compare Odelsting Bill No 23 (1964-65), page 36, col 2. Some of the conditions which it is intended to govern by the present bill can thus to some extent be regulated with reference to the road traffic law. This will not, however, apply to air cushion craft insofar as they are used at sea. It has, therefore, been found most practical for the time being to give joint rulings for air cushion craft both when they are used at sea (on water) and on land, thus for any operation overland which might temporarily occur, for instance from landing stages to any nearby airfield or other terminal or stop for land traffic or other traffic media. Should the question arise of traffic rules in the ordinary sense for the more extensive use of air cushion craft on land — including the question of such craft in relation to other vehicles — it is assumed that it would be natural to base such rules on the road traffic law and its regulations."

The Directorate of Shipping agreed with Director Torgersen with regard to what was said about landing stages.

On para 3

The paragraph was formulated following a proposal from the Minister of Justice. It is proposed that the Sovereign be given powers to establish conditions for concession and for approved insurance or other approved security to cover compensation liability for damage and loss which might arise through the use of the craft. As an example of the kind of condition in question, reference is made to the law on transport dated June 19th, 1964, No 7, para 3, in respect of regular transport, and to para 5, last section, and para 6, fifth section, of the law concerning goods and passenger transport respectively outside regular transport.

On para 4

The paragraph contains penalties for infringement of the law or regulations made under the law. The proposed penal framework for infringement of rulings on air cushion craft is in accordance with the one which applies to a number of penalties concerning maritime conditions, compare Chapter 42 of the penal code. Offences in maritime conditions, as regulations in this chapter read according to the law of February 15th, 1963, on alterations of regulations in the penal code, are (1) offences against morality, (2) crimes and misdemeanour in maritime matters.

On para 5

This paragraph contains regulations about the coming into force of the law and its duration.

A draft for temporary law on air cushion craft has been submitted to the Ministry of Justice for examination of the legal technicalities. In preparation of the final draft the comments of the Ministry of Justice have been taken into consideration.

The Ministry of Trade and Shipping recommends:

That Your Majesty approve and sign the submitted draft Bill to Parliament relating to a temporary law on air cushion craft.

We OLAV, King of Norway,
hereby make known that:

Parliament is invited to take measures for a temporary law on air cushion craft in accordance with the submitted draft.

Recommendation from the Ministry of Trade and Shipping is attached in print.

Issued at Oslo Palace, March 18th, 1966.
Under Our hand and the seal of the realm
OLAV
(L.S.)

Per Borten — E. G. Asbjørnsen
kst.

DRAFT OF TEMPORARY LAW ON AIR CUSHION CRAFT

Para 1

An air cushion craft (hovercraft) is understood in this law to be a craft which, when in motion, rests on compressed air between the underside of the craft and the surface over which it is moving. The law applies to the operation of such craft both on land and on water.

The operation of air cushion craft in this kingdom, including Norwegian territorial waters, can only take place in accordance with this law and the regulations given under the law.

This applies even if the craft is registered abroad or the owner or user is a foreigner.

The regulations issued according to para 2, sections 1 and 2, apply also to air cushion craft which are registered or owned in Norway, and which are used outside the kingdom, when nothing else has been decided, and this is compatible with foreign law.

Para 2

Air cushion craft shall satisfy the regulations issued by the Sovereign concerning construction, arrangement and equipment.

The Sovereign can issue regulations on the registration, marking, maintenance, control, manning and piloting of air cushion craft.

The Sovereign can also issue regulations on the construction, arrangement, maintenance, control of, and equipment for landing stages for air cushion craft.

Para 3

The Sovereign can decide that permission against payment of a fee shall be required in order to operate a regular transport service with air cushion craft between places in Norway or between Norway and other countries. "Regular transport" has the same meaning as in the law of June 19th, 1964, on Transport, para 2, section 2. The Sovereign can decide also that air cushion craft cannot be used for any other activity within Norwegian territory unless permission is granted and a fee is paid.

Permission will be granted by the authority designated by the Sovereign. It is granted for a definite period and on the conditions deemed necessary. Unless the Sovereign decides otherwise, it shall be a condition that there exist approved insurance or other approved security to cover compensation liability for any damage that might arise through the use of the craft.

Para 4

Deliberate or negligent infringement of this law or of the regulations or conditions laid down in accordance with the law, will be punished by fines or up to three months' imprisonment.

Para 5

This law comes into force from the time of the Sovereign's decision and applies until further notice, but not exceeding December 31st, 1970.

A Revolution in Transport

by Toivo J. Kaario

T. J. Kaario of Finland built and tested his first ground effect machine in Finland in 1935. The machine was 6 ft by 8 ft and attained a speed of 12 knots over ice on its first flight in late 1935.

All bodies, except when on ballistic trajectories, are borne by auxiliary forces counteracting gravity. These are the forces at contact points with other solid bodies or fluid static or fluid dynamic forces.

In the past the introduction of steam power for propulsion of ships and trains, the internal combustion engine, the aeroplane and the mass production of automobiles, were some of the most marked cornerstones in the development of transport.

Compared with the classical systems, wheeled carriages, ships and sleds, the air cushion combines and advances some of the most desirable properties. It behaves from some reasonable speed upwards, on water surface as on a solid body.

It is not readily conceived that the ground effect has already been in everyday use. The ground will reduce or prevent vertical velocities of air currents and will thus make the take-offs and landings of aircraft possible.

For compensating a pressure differential in a gap there should be a flow of fluid. The blow power per unit area of a perfect nozzle is:

$$P/A = \sqrt{2} \cdot \frac{\Delta p^{3/2}}{\sqrt{S}}$$

where S = density of fluid
Δp = pressure differential.

By use of inwards inclined peripheral jets the power is reduced to 30-50% of the value given above.

The power to keep a given weight at a given height is proportional to the wing loading, and, at a given height and wing loading, the power loading is proportional to the square root of the weight.

At locomotion the dynamic pressure of ambient air stream will decrease differential at the leading edge gap and the jet of the trailing edge delivers thrust power. On certain assumptions (unretarded longitudinal flow) the side gap blow power is independent of speed.

In a ram wing the cushion pressure is upbrought by retarded air flow. Pressure is reconverted to velocity before outlet. In theory, leading and trailing edge blow powers are zero.

The lift coefficient of a spherical half-ball lying on a plane surface is 0.68. Lift of spherical segments should be nearly proportional to the relative thickness. In a potential flow the lift will not induce any drag.

A lifting wing in a space is a circulation generator but in close proximity to the ground, lift is achieved by ram and displacement effects.

A single cushion will apparently have a stable attitude position. By combining several compartments, stability about two horizontal axes is added into the system. At super-critical speeds, however, transverse walls would prevent the proper air flow. Experience with man-carrying craft and models has shown that a single, continuous wing of such aspect ratio (below one) has enough inherent stability for practical purposes. When the nose ascends, the out-flow through the forward parts of the side gaps will increase as well as the pressure at the rear bottom and the equilibrium will be re-established.

The stability in space, of a wing of such aspect ratio and rectangular planeform would be questionable, especially without auxiliary pitch stabilisators (Mr J. F. Mowbray, Bordertown, USA, may not join to this opinion). A triangular delta wing, on the contrary, has, as known, stability in a space. This configuration, however, is unusable as a ram wing, because the outlet channel or area is lacking, the two-dimensional extensiveness in horizontal plane is necessary for stability. Dr A. Lippisch has turned the delta back to front and found a form, the form of many flying animals, which is stable without auxiliary stabilisators both in a space and in the ground effect.

On great seas, for waves, some altitude capability would be desirable. Jumping over a ship could be a better proposal than turning or braking. The vehicle of Dr Lippisch has realised these outstanding features.

For many reasons air cushions on land are best suited for vehicles on special tracks. Curved track profile allows turns to be run without side forces on carriages. The free air gap can be quite small, ½ in or less. Elastic seals of labyrinth or some other design will aid in closing the cushion. At occasional touching of the seals, only small forces are generated. For stability, the air cushion is directed in compartments. Oscillations of the carriages sideways and about vertical axis may be prevented by small servo operated fins steered by gyroscopes, and friction couplings between the cars or by some other suitable means. In side winds the train will take an inclined position. Detracking barriers could be used on sides of the track. The very small aspect ratio of the locomotive will prevent the lift-off even at great super-critical speeds. For operations on plain yards the centre compartments could be in a plane. The small leakage from these cells on the curved track may be allowed or prevented.

Safety precautions of the common railways are not coping with the increase of speed. The safety height of a wheel flange is less than 1 in. There will always be a multitude of mechanical components, axles, springs, wheels, lines, rollers of bearings and rails, for example, all of them important for survival. In an air train these highly-stressed parts are substituted by a light envelope of the cushion and by some fans and electric motors, which can all fail safely. An air propeller is an efficient means of propulsion and good for braking also. Braking at small speeds could be effected by shoes. The lift power is small in relation to the propulsive power, 150kW per car, for example.

On water the gap between solid parts of the vehicle and irregularities of water surface is either closed by elastic skirts or sidewalls, or a vehicle, having generally fixed contours, will proceed above the wave crests. Especially in the latter case control of attitude and altitude is desirable. In close proximity to the ground a separate control of positions of leading and trailing edges may be required. A man-carrying vehicle of the author realised these design aims at super-critical speeds. The machine had a rectangular platform 10 × 15 ft. The centre of gravity was coincider with the geometric centre. In the front part of the wing was a controllable outlet and on the trailing edge a flap. Two quantities are to be controlled, altitude and pitch attitude, and there were two controls for the purpose, the tunnel flap and the rear flap. In this particular machine a part of the propeller disc was blowing into a tunnel or the front part of the wing and flaps were in the rear end of this tunnel. The craft was flown on ice, water and snow-covered hills. The possibility to use variable ground contact forces, too, at either end of the craft, was useful for driving curves in restricted areas, in sharp turning or driving up or down. The control of the pitch attitude is advantageous for attaining minimum drag. In the machine of the author this was fully exploited.

In a ram wing the streamlines are curving outwards and this is necessary for stability. For sparing power, peripheral jets could be used on sides or, in a delta planform, some longitudinal jets, and transverse jets for control. Regulated outlets in the forward part of the wing, as explained, could form the other component of the attitude and altitude control.

A great virtue of the peripheral jet is the compactness of the structure. A 20 ft gap of a large ship could be closed with a jet of 4 ft thickness, for instance. Such a jet is easily regulated by a flap valve.

If the space flight capability is needed once in a lifetime of a fleet the effort may be justified. The water involves aspects of efficiency and safety in a complicated manner. This complication does not indicate any presence of difficulties but the wide scope of the various possibilities.

An ocean-going fast ground effect vehicle shall be large enough in the North Atlantic, 40° latitude. In winter the significant wave height is given to be below 6 ft during half of the time. At wing loading 80 lb/sq ft, span 300 ft, average wing length 200 ft, free air gap 6 ft, lift coefficient of the upper surface 0.15, speed 300 knots, power in the peripheral side jet to power of a perfect nozzle 40%, efficiency in jet generation 70% and at the ratio calculated, turbulent skin friction drag to actual parasite drag 0.7, the lift to drag ratio, comparable to the gliding ratio of an aircraft in gliding, is 47. When the wing is of triangular form the actual span will be somewhat greater. The length must be specified for calculating the Reynolds number and skin friction.

The lift-to-drag ratio at super-critical speeds and simplifying assumptions (neglecting the lift of the upper side) is a function of the speed ratio $\varepsilon =$ critical speed (lift coefficient = 1) to actual speed, of the gap ratio $\mu = 2 \times$ effective gap (perfect nozzle) to span and of the parasite drag coefficient Cf.

$$L/D = \frac{\varepsilon^2}{\mu\varepsilon^3 + Cf}$$

At about 6 ft chord the induced drag in a space would be the same as the equivalent gap blow-power drag. Such a wing would be, however, quite impractical in all other considerations. There are other quantities as important as the gliding ratio; stability, steerability, empty weight ratio and starting ability, for instance, may be mentioned.

Aircraft destined for oceanic ranges need fuel loads up to half of the gross weight. Thus a small weight fraction only is left for payload. When the possible aerodynamic configuration would allow enough space for payload without drag or weight penalties, all spared weight could be allocated for payload and the ratio payload to gross weight would increase sharply at increasing gliding ratio. A pound of excessive weight in a long-range commercial aircraft may cost about £250 and a pound of drag £2,500 during the lifetime of the craft. Some proportional lift to drag ratios may be presented: helicopters 4-6, air cushion vehicles at sub-critical speeds and hydrofoils 7-10, aeroplanes 15-20, trains on railways at 60 miles/hr 200 and cargo ships 600. The minimum value for bridging the Atlantic with conventional power plants should be about 10.

On every flight an aircraft will experience two periods when accurate control in the proximity to the ground is necessary. These periods are short but the circumstances are adverse. The aircraft must follow a closely restricted path at its minimum speed whereby its aerodynamic controls are most sluggish. Side winds may yet complicate the manoeuvres.

There are fundamental differences in the functions of aeroplanes and correspondingly of air cushion vehicles. The latter are inherently stable in a plane and should respond most immediately to the demands of altitude and attitude corrections.

The poor gliding ratios of hydrodynamic planing boats and floats and their great weight have restricted their use. The first transoceanic aircraft were, however, flying boats. The excellent all-metal Junkers planes with floats and single 300 hp engines were operated in scheduled international passenger traffic in Finland, for instance, from the year 1923.

At increasing speeds, benefits of the elastic members may become questionable; but compared to the days of the piston engines, there is an abundance of cheap power available for installation. A new philosophy may be needed in evaluation of air cushion systems for open seas. They may be considered to take the role of bridges. The vehicles will have special duties and destinations. For take-offs and brakings the levelness of sheltered water areas could be used.

The last vehicle of the author had a form of skirtless pressure chamber or bell. It performed starts from water to super-critical cruising speed, 50 knots, at power loading 20 lb/hp. The power loading was not outstanding, but the span, 10 ft, was small for an airborne 1,000 lb vehicle and other conditions stated.

Floats, rigid pressure chambers, elastic skirts as flaps in periphery and in immediate positions for stability, possibly of air pressure, chamber construction, peripheral air jets exhausting from elastic bags, pace peripheral air jets or some combination of these are the very elements of the new art of generating lift during starts or at intermediate speeds. Satisfactory hydrodynamic gliding ability is, of course, always desirable in an emergency.

A low-flying aircraft or air cushion vehicle is the only means which will cross the Atlantic in twelve hours at better gliding and payload ratios than conventional aircraft. Twelve to fifteen hours is a time interval which a passenger will readily endure without sleeping accommodation. The present aircraft are not enjoyable as passenger transport and they have a tendency to become yet more complicated and unaccountable. Although the favour of the air cushion is dependent of the general pattern of traffic and may alter parameters, too, it presents paramount, fundamental benefits, small-power consumption, small structural stresses and levelness of locomotion, for example, unsurpassed by any other mode of transport.

The general standard of safety of present systems is poor. Especially private automobiles are dangerous to life and health. Some shift to common transport systems would be advantageous. Vertical take-off flight seems to suffer from severe limitations in cost, safety and noise attenuation. In theory only the straight line is the shortest one. Communities and their real communicative possibilities have always been in creative interaction. An air train represents general quality of transport unknown hitherto. Air cushions will increase safety, economy and convenience of passengers and light cargo transport. They will open up new areas for human habitation. They are to be used where they are best suited. The propulsive airscrews begin to show good efficiencies from speeds 100 knots or mile/hr upwards.