SESSION 4

Operations and Economics

THE DESIGN AND CONSTRUCTION OF LIGHT HOVERCRAFT FOR USE IN COASTAL AND EXPOSED ENVIRONMENTS

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ABSTRACT

This paper presents the design, construction and safety requirements which the Hoverclub of Great Britain applies to all craft which are registered with it.

The Hoverclub of Great Britain (HCGB) has jurisdiction over hovercraft of less than 1000Kg dry weight which are used for purposes other than hire or reward in the UK. In line with the characteristics of craft built by its members, the Club has one rule book covering craft for racing or competing in protected environments, and a second for craft used in coastal or exposed environments.

The background to development of these standards is described, followed by a summary of what they contain and how the rules are applied in practise.

The rules for coastal craft are in an early stage of development, there being few craft, even on a worldwide basis, to which they might apply at present. The paper is concluded therefore, with a short discussion of future prospects for larger light hovercraft and how the HCGB requirements are intended to promote their successful and safe proliferation.

INTRODUCTION

The majority of light hovercraft constructed to the present time commercially or by owners for personal use have been under 250Kg dry weight, and intended for racing or rallying purposes. There has always been interest in larger craft capable of operating in coastal waters, though few have been built in the UK. So far, the smaller craft have been used, when weather conditions permit, to cruise in the more sheltered coastal waters, to explore estuaries and rivers, and even to cross the English Channel. These craft have not been designed and built with that use specifically in mind though.

As interest grows in using hovercraft for non-competitive recreation the need for guidance upon design, construction, and in the advisory sense, also operation of craft in more exposed or remote environments becomes important. It is with this in mind that the Scrutineering Committee of the HCGB, who are responsible for establishing and maintaining safety codes, have prepared a new set of design requirements to cover these craft.[1]

In the UK, the Civil Aviation Authority (CAA) is responsible for certification of all hovercraft. Since the Hovercraft Act in 1972 they have delegated the work of certifying craft of less than 1000Kg dry weight used for private purposes (not hire or reward) to the HCGB.

In the early days of the HCGB, its members built a wide variety of craft, but attention has focussed on racing craft and racing events over the last ten years, leading to development of craft tuned to a specific environment - the racing course. The Club's safety regulations followed this specialisation to the extent that since 1980 its published set of rules (the Blue Book) has been subtitled 'for craft racing or competing in protected environments'.

This is not to say that a member could not satisfactorily register an 8 metre, 900Kg dry weight cruising craft with the HCGB, it simply meant that such craft would be considered carefully by the scrutineers as a special case. At the same time work has begun on development of a new set of regulations which could be published, and thus prospective designers and manufacturers given guidance on acceptable standards without having to take up a great deal of scrutineers time.

It should be pointed out at this stage that since hovercraft for exposed or remote environments are synonymous with larger size, and the increased installed power that goes with that, design and construction need to be approached rather differently to building a small racing craft, and any rule book needs to reflect that.

The new regulations (the Red Book) demand much more work on the part of the designer to prove the adequacy of the hull structure, power transmission etc. under a series of design load cases which are all at least as stringent as those which the CAA itself applies to commercial craft.

This is due to a difference in philosophy. For racing craft it is accepted that structures, transmissions, and engines are highly stressed. Safety is approached in a manner such that should there be a failure, the failure itself will not injure the driver or any third party. It is not necessary that the craft remain operational or even be capable of being made operational on the spot, since rescue craft are available to tow it ashore, or help is available to get it back to the pits for attention.

If a hovercraft operates in a tidal estuary, the situation is very different. The design of such a craft must not only enable it to operate safely in its design limiting weather conditions, but also to return to a point where repairs can be effected in the event of certain credible damage or breakdown cases. Overall design of cruising hovercraft is therefore controlled to a greater extent by failure cases and their possible consequences, and less by the limiting speed case, than is a racing craft.

Before discussing the Red Book, it is appropriate to look back to the beginnings of the HCGB and trace the development of the Club's safety regulations to the present.

BACKGROUND TO HCGB SAFETY REGULATIONS

The HCGB has been in existence since May 1966. It began as a national club for 'amateur' enthusiasts of the air cushion principle, who wanted to spend their spare time experimenting in a practical manner by building small mancarrying hovercraft. Naturally such enthusiasts wished to meet each other and show the paces of their craft, so the rally events began. The first was at Apethorpe, near Peterborough, in June 1966. Competitions for craft speed and controllability were run at that meeting, and began the development towards the present day National Racing Championship.

The craft of 1966 could not be put in classes of engine size as can present racing machines. By their nature they were largely the result of inventive minds seeking new ways of building a mancarrying ACV. For some this meant building a large structure with a cabin for 2 or 3 people, employing two automobile engines, one each for lift and propulsion. Such a craft might have a dry weight of 1 tonne. For others it meant an aluminium fuselage just large enough for a person to sit on, with a forward mounted motorcycle engine driving a fan from which air was ducted for air-jet lift and rearwards for propulsion. One such craft looked very much like one of Sir Christopher Cockerell's models, and worked just as well.

Members brought craft to rallies driven by free air propellers, ducted propellers, ducted fans, wheeled and paddle wheel drive, oars, and even feet with small paddles attached for over water use.

Size, and installed power gave no clear measure of a craft's carrying capacity, design speed or controllability.

At that time, building and operating a workable machine was the primary goal. The more successful designs were developed into plans and kits from which others could build their own customised craft. This lead to a rapid growth in the numbers of craft brought to rallies and a narrowing of the range of size, power installed and so on.

During the 1970's the rallies have changed into full-blooded racing events in three engine size classes (less than 250cc, 250-500cc, greater than 500cc). The activities of hovercraft enthusiasts have widened meanwhile, to embrace river exploration, cruising in coastal waters and estuaries, and for a few work tasks where their amphibious qualities are helpful.

Some of the craft built with operation in more remote or exposed environments in mind have naturally been rather larger than the machines now used for racing, which have tended towards the smallest practical size on which the power units can be mounted.

The fact that the HCGB almost from its formation was involved in organising events to which the public was invited meant that its officers were conscious of the need to maintain standards of safety. An informal set of rules by which craft operators and event organisers should abide was put forward at the Club's first AGM. This set of rules was developed over the following two years, until they were formalised in 1968. In the meantime many discussions were held with the CAA, in order that the HCGB safety rules would be acceptable to them. It was hoped that the CAA would delegate the responsibility of maintaining safety standards for Light Hovercraft to the HCGB, and it was eventually agreed that this would be so, a Light Hovercraft being defined as any craft not used for hire or reward and having a dry weight of less than 1000Kg. This position was further confirmed in the Hovercraft Act of 1972.

Since 1968 the HCGB safety regulations[2] have been updated and revised annually, reflecting the development of craft designs, application of greater power, and achievement of rapidly increasing speed.

In the later 1960's a considerable number of craft were built with competitive sport in mind which used automobile engines and so were in the middle of the defined Light Hovercraft weight range.

The advent of lightweight industrial 2-stroke engines and the snomobile engine meant craft could be much smaller and lighter for the same payload capacity. The higher power to weight ratio of the aluminium 2-stroke engine lead directly to higher thrust to weight ratio hovercraft. This trend has continued, so that now a typical Formula 1 racing craft (over 500cc capacity) will have a thrust to weight ratio, operating, of 0.5, compared to about 0.15 for a typical craft in 1966.

THE BLUE BOOK

The HCGB Blue Book was developed on the basis of providing the kind of guidance that any enthusiast could follow. The accent is on practical matters such as providing adequate guarding around rotating machinery, and providing simple rules regarding, for example, buoyancy and its distribution together with adequate deadrise to the hull sides to prevent flipover in case of transverse plough-in. A summary of the aspects covered and proof of compliance required is given in Table 1.

How are these regulations applied? All prospective craft designers, builders from plans, or manufacturers, are, of course, encouraged to study and familiarise themselves with the Blue Book. A scrutineer is usually presented with a new craft for registration, and prior to it a 'full inspection' at a local or national racing meeting. Sometimes a scrutineer is called to the home of a builder and can therefore take much more time

over this important task, but this is the exception rather than the rule.

The basis for a full inspection is contained in a checkout list, figure 1. This gives the main areas to be inspected; details of the new craft are noted on the form and checked against the book. Most craft are now built to one of several 'standard' designs, and so a scrutineer can have confidence in the basic design and concentrate on the manner in which the builder has completed it; the quality of workmanship, and any non-standard items, etc.

The most common fault on new craft is that in the rush to get it operating the builder pays not enough attention to some details, so locknuts are not fitted, electrical wiring left unclamped or sharp edges left unprotected.

If a scrutineer wishes, a craft may be given a floating test to prove adequate buoyancy, this being simpler than obtaining accurate information on all masses in the craft and then calculating the floating waterline for himself.

One aspect which may well be checked by calculation is the thrust system transmission ratio if it is suspected that this would exceed the safe speed recommended in the Blue Book. This is rather rare, simply because both engine manufacturers and the builders themselves are eternally optimistic about power output, and so undergear their transmission!

Registration of a Light Hovercraft in the UK is signified by issue of a Log Book. Apart from containing details of the craft, the Log Book has entered in it details of every check inspection carried out, faults to be corrected and when these are complete, and any substantial modifications made. A check inspection is carried out by a scrutineer prior to operation at every race meeting or competitive event organised by the HCGB. The more a craft is used, the more it is checked over, therefore. Faults are dealt with on a two-tier basis, those that can be noted and corrected by the next meeting (minor problems and advisory rather than mandatory items in the Blue Book), and those that require correction before the craft can operate.

In all of this, a degree of judgement by the scrutineer is involved, and this is accepted in good faith. Unlike a manufactured consumer article, hovercraft built at home from scratch, or even those assembled from a kit all have many small alterations to the design, principally the power unit mounting, framework and internal outfit.

The scrutineer of racing craft is therefore almost totally concerned with details, apart from the initial inspection when he may wish to check the craft in front of him against the original plans or design data, or request such information from the builder. Since it is much easier to obtain and check such information if the first inspection is made away from a racing meeting members are strongly encouraged to get their craft registered at home, or to take their craft to a scrutineer for inspection.

The Blue Book is not intended to provide design cases which a scrutineer must analyse for every new craft before it can be registered. If a craft is designed from scratch the regulations provide a framework within which a designer can work, and then in most cases checked out by a scrutineer in a practical manner.

Influence of the Rules on Design

The rules have an important influence on design, but by no means a restrictive one. The three most important areas which have influenced design of new craft are:

- Guarding of rotating assemblies
- Mounting of machinery and equipment to hull
- Floating buoyancy and stability

A number of incidents in the early years of the HCGB involving propellers encouraged increasingly stringent standards for guarding. For large efficient propellers these standards were difficult to meet, as the guarding became very heavy to retain broken blades. The obvious choice was to build a solid duct around a propeller with mesh guarding at the intake. Once this route for design was selected, the alternative of using a plastic bladed axial fan instead became more attractive due to lower cost for a fan than a propeller, lower weight compared to a propeller, and improved thrust due to the fact that available propellers were not designed for use in a duct.

The fans used today are by no means optimised for hovercraft propulsion, but have been proven safe in failure, all blade pieces being adequately restrained by guarding to HCGB standards. In an average race meeting about 50 fan failures will occur, mainly due to the hull hitting the ground at high speed when going over a hump, or landing from temporary flight, and so there is no lack of practical experience!

Most Light Hovercraft employ a welded tubular steel space frame to mount the engine(s) and transmission, usually a toothed rubber belt, to the fan(s). In most Formula 1 racing craft this framework also supports the propulsion ducts independently of the hull, see figures 2, 3 and 4. This component may therefore comprise rather more than 50% of the total craft dry weight. The mounting of this frame to the hull is usually at four points. The weight of the system therefore applies considerable concentrated loads to the hull, while application of full power applies a turning moment increasing the download on the front mountings but reducing that on the rear mountings to a tension load.

In order to minimise vibration, resilient mountings are used to attach the framework to the hull. These units, and their attachment to the hull and to the framework must be adequate to sustain the working loads safely, and to ensure that the hull and propulsion unit do not part company in the event of an accident.

If a craft were to hit a bank, a tree, or overturn due to a sudden gust of wind, at high speed (all these have happened) decelerations of up to 6g may be experienced, and so mountings are required to be designed for this loading from any direction. Specification of the resilient mounting itself is easier than proving that the hull structure around the mounting will be adequate.

Scrutineers will usually carefully question the design of a craft when such mountings are not

directly to hull primary girders or to reinforced pads supported directly back to such primary structure.

Floating is something few owners of racing hovercraft do except by accident. Most racing courses are nevertheless at least 50% over water, and with the regular incidence of fan failure and engines stopping due to fouled plugs or water/salt in the ignition, craft do often have to prove their floating stability.

In the early days of the HCGB the rules for buoyancy were oriented around providing adequate freeboard and safety for operation on the sea, as several early race meetings were held at coastal sites. This is not now the case, as racing meetings are held on inland sites where the water expanse is limited, and rescue by boats or other craft is very close to hand. Buoyancy is needed to be adequate in two cases therefore. Firstly, a craft should be able to be restarted if an engine should fail, which defines the 'intact' buoyancy, and craft freeboard. Secondly, the craft should not actually sink if it is damaged, or overturns, thus buoyancy to support the craft in a reasonable attitude has to be provided by some sealed medium (foam, buoyancy bags or tanks). This rule, combined with the deadrise requirement for the hull sides to prevent sideways flipover following a plough-in limits the hull design to some extent. If the hull is to be made thin in order to minimise aerodynamic drag, it must be wider in order to provide adequate sealed buoyancy and the hard body clearance must be reduced as a percentage of width so that rotation on plough-in can be restricted and the planing surface maintained sufficient to stop flipover.

THE RED BOOK

Until 1979, interpretation of the Blue Book regarding the provisions for buoyancy and freeboard did not differ regardless of whether a craft might be for racing or coastal cruising. The impetus to make these rules more appropriate for circuit racing also gave the impetus to develop separate rules for cruising craft, and in particular to draft rules which would be appropriate to registration of craft up to 1000Kg dry weight.

The purpose of the new rule book is to cover all craft within the jurisdiction of the HCGB which might be used for operation in open environments. It is instructive therefore to take a look at the range which is represented by existing craft as shown in figures 5 to 13 which may be covered by these regulations.

Taking the craft in turn, the Osprey Hovercraft Ltd. Kestrel GT, figure 5, is probably the smallest size craft one could consider taking to sea. While this craft is successfully used for racing, its designers aimed at general recreation use and so the hull is deeper than the craft in figures 2 to 4, and sealed foam buoyancy built into the floor rather than the sides or using buoyancy bags strapped to the craft. A craft identical to this crossed the Channel in July 1979 though as Table 2 shows, its limiting waveheight capability is relatively small.

The BBV2 shown in figure 6 is another designer's approach to a craft for two persons, or the driver and a considerable amount of equipment. Again a reasonable freeboard is provided by raised sides, and here a canopy over the bow area provides more protection to the driver.

Figure 7 shows the Light Hovercraft Freedom 3, as its name suggests designed for 3 persons or equivalent. Following a similar layout with a single engine and fan providing lift and propulsion this craft is longer but has no greater hoverheight than the smaller craft. Each of these three craft use a one-piece mounded glassfibre hull.

The Pindair Ltd. Skima 4, figure 8, has a similar arrangement to the previous craft, but uses an inflatable rubber outer hull, honeycomb material floor below the cockpit and a glassfibre fan duct and power unit support. The transmission framework is of aluminium bolted sections. Its hoverheight, almost twice that of the Kestrel, gives it equivalently greater capability in partially developed seastates and breaking waves coming ashore.

The craft shown in figure 9 is privately built. It is based on the Simple Cyclone hull, scaled upwards, and outfitted with a Kyoritsu 225 driving two lift fans, and a Renault automobile engine driving the propulsion fans.

The River Rover/Skima 6, shown in figure 10, is also powered by a single Renault 20 automobile engine driving a lift fan and two outboard propulsion fans. This craft is rather longer than the Scott Cruiser, it has a fully enclosed cabin, and employs elevons as well as rudders for aerodynamic control. It is craft of this size and type which really mark the major departure from design approach typical of the smaller craft.

The Skima 12, figure 11, and Air Vehicles Tiger, figure 12, show a further progression away from the design methods used for small craft. The prototypes of both these craft had dry weights within 1000Kg, achieved by employing wood/glassfibre/foam hull constructions. Later production units have employed welded aluminium hull structure within the outer inflatable enclosed buoyancy units, to give greater durability in the utility environment. The Skima 12 as shown in the cutaway, without an enclosed cabin still comes within the limit.

Figure 13 shows a slightly smaller craft, an 8-seat ACV built in glassfibre and employing a single power unit to drive a lift fan and two propulsion fans in a similar manner to the River Rover. This craft has a deeper skirt and greater freeboard than River Rover even though being a little shorter. This should give it an improved seakeeping performance compared to River Rover in the same manner as Skima 4 compared to Kestrel/BBV2/Freedom.

At the lower end of the size range therefore we should consider the regulations for craft used in open environments to be of equivalent simplicity to the Blue Book, but taking account of the different usage.

The regulations should at the same time provide guidance on design and construction of hull structures up to about 8 metres in length, power units of about 250bhp now, and possibly 500bhp in the future. These larger craft, which are likely to have cockpits or cabins capable of accommodat-

ing up to 12 people or the equivalent in equipment may require ballast shift systems to adjust CG and will most certainly have rather more sophisticated electrical systems, fire extinguishing systems, instrumentation, control systems and internal outfit.

Above the level of the Scott Cruiser, craft are unlikely to be built from scratch or even from a basic kit. It is more likely that a private owner would wish to buy a completed commercial 'hull', including main machinery, and then complete the outfitting himself, perhaps including the skirt system. This then avoids the daunting task for a private owner of designing the hull structure and transmission system. This means that the number of times a scrutineer is likely to be faced with checking the design calculations for such craft structures will be limited. It also means that once the first craft of any type has been thoroughly checked and documented by the scrutineering committee, future craft of that type can be inspected against that standard rather than repeating the process entirely.

The HCGB Design, Construction and Safety Requirements for craft used in open environments is therefore an expansion of the Blue Book, using the same rules and guidance where appropriate.

A summary of the requirements contained in the Red Book is given in Table 3. It can be seen that for a small craft such as the BBV2 most of the items covered in the new document which apply to it are also in the Blue Book. The main difference is a rather more stringent requirement for floating buoyancy, stability and freeboard.

The new regulations specify design load cases for the hull structure and machinery in much greater detail, a series of 12 cases being described. This is appropriate when the wide range of conditions such a craft is likely to meet is considered, together with the need to optimise the structure to minimise weight for larger craft. For smaller craft it is likely stiffness overrides the strength requirements due to the limited range of structural arrangements possible without making the structure very complex with tiny stiffener sections behind thin panelling.

The requirements for buoyancy and stability are in line with the need for a craft to remain afloat in an attitude suitable to contain survivors in a major accident.

Rotating assemblies have to fulfil the same design requirements as in the Blue Book, but more detailed guidance is given on specification of components to have a reasonable life before replacement. This is necessary in view of the extended periods of operation such craft may complete, compared to a racing craft which is (presently) rarely run at full power for more than 15 minutes at a time.

Main machinery is also specified more closely, particularly where multiple units are fitted. Here, it is advisable that each unit of a twin propulsion system should be independent so that operations are not stopped completely by the failure of a single power unit.

Systems and controls are covered in detail assessed sufficient for the likely complexity of a 12-seat craft or equivalent.

An important aspect for all such systems is that they should be of fail safe type.

Skirt systems are covered in detail most particularly with regard to construction, materials, and damage which might be sustained during operation.

Handling, performance and operational safety are areas mostly covered by recommendations rather than rulings. For safety in operation it is required that the driver should have all round vision directly or indirectly, that adequate arrangements are made for evacuation and for handling the craft etc. Appendix B to the regulations gives guidelines for operation of craft in coastal waters and estuaries. The main theme of these guidelines is that operators should prepare themselves and their craft adequately for a breakdown where no other vehicle can get to them in a hurry. Also it is recommended that drivers build experience of operation in open conditions slowly, preferably with others who have greater experience.

The clause requiring most of builders of cruising craft is that defining specific items for proof of compliance required for certification. Here it is stated that documentation to prove the following is necessary:

- Hull structural strength
- Power plant and transmission system independent structural framework and mountings to hull
- The transmission system and rotating assemblies
- Craft buoyancy
- Craft freeboard

This documentation in full will only be necessary for the first craft of any new design, and as noted above there are likely to be fewer of these in the cruising craft range of sizes than there are racing craft designs.

In order to assist the individual designer, nevertheless, three appendices to the regulations give guidelines for design and fabrication of GRP hulls and ducts, welded metal space frames, and material specifications which may be used for design. With this guidance it is expected that scrutineers can be presented with documentation in a reasonably standard format easing the checking process.

Implicit in design of an ACV hull is the necessary algorithm to size it for required payload, determine the buoyancy and its distribution, and so on, the principle design procedure as summarised in figure 14. This procedure will be expected to be documented in a manner as close as possible to that followed in the regulations appendix, so that rather than carrying out a full analysis from scratch, the scrutineer can check the analysis carried out by the designer and verify it.

The implication of a designer presenting calculations to the scrutineering body for cruising craft is that the procedure for registering such a craft should begin before manufacture.

Where scrutineers of the HCGB can accept small craft to be registered under the Blue Book regulations at a race meeting, and after a de-

tailed inspection, send the owner off to run his new craft little more than an hour later, this will not be possible for cruising craft. The owner will have to provide documentation or be able to provide reference to the design documentation for that craft type together with the differences between his craft and the basic design. The scrutineer will then have to spend some time with the analysis and the results of his inspection before clearing the craft for registration. The craft shown in figures 5 to 13 already exist, though none of them are designed specifically for the regulations contained in the Red Book. Once the first issue of these new regulations comes into force in 1984 therefore, there is a ready made population of craft to be tested.

Since the Red Book is a more specific and limited version of the BHSR's[3], and both the Tiger and Skima 12 have been certified by the CAA already it may be assumed they will also fulfil the requirements of the Red Book.

The Kestrel, BBV2, Freedom 3, Skima 4 and Scott Cruiser have all been registered under the Blue Book regulations to date.

The Skima 6/River Rover and Surveyor have both been designed to conform with the requirements of the BHSR's, as well as the Blue Book, and so should be found to conform with the regulations contained in the Red Book when it is issued.

PROSPECTS FOR LIGHT HOVERCRAFT FOR OPEN ENVIRONMENTS

A number of design types, and individually designed craft for cruising and open environment use already exist. Design checks are being carried out on one of the small craft (the BBV2) in preparation for issue of the regulations, and to validate the standard procedures on a real craft rather than the 'example design' originally used.

It is hoped that the designers and owners of craft such as the Freedom 3, Skima 4 and other examples given will also request registration with the HCGB, since this will be meaningful once again.

Establishment of these regulations forms a useful bridge between the requirements for racing craft, and the stringent requirements appropriate to a craft operating for commercial purposes.

Successful implementation of the Red Book will depend very much on the co-operation of designers in providing adequate data for scrutineers to carry out a standardised analysis, or providing a documented analysis themselves.

In the same way that registration of racing craft is not charged for by the HCGB, except for issue of the Log Book or travel expenses for a scrutineer, the cost of registering cruising craft is not expected to be charged on a commercial basis. During 1984/85 while a dossier of standard design checks are being built up much of the analytical work is expected to be carried out by the scrutineering committee itself. Beyond this timescale the dossier should contain a wide enough range of craft for analytical work to be limited to modifications rather than complete new designs.

In the same manner that the HCGB Blue Book is now the accepted basis for safety standards on racing hovercraft in most parts of the world, it is hoped that the Red Book will become a world accepted standard for cruising and utility craft below 1000Kg dry weight.

The rules are not yet in force, and so cannot influence design. When they are published it is expected that designers of larger Light Hovercraft will be influenced to think much more carefully of the wide range of design conditions that such craft may meet, and through analysis rather than 'suck it and see' experience improve the performance and reliability of their craft.

Reliability has not been a byword with small hovercraft in the past, and the growth of the market has tended to suffer because of that. Perhaps there is a chance that the existence of these regulations, independent as they are from any commercial organisation, will also encourage the confidence of the public in these vehicles, whose potential has so far not been adequately exploited.

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3. 'British Hovercraft Safety Requirements', Issue 4, August 1981, Civil Aviation Authority, Greville House, 37 Grattan Road, Cheltenham, England. ISBN 0.86039.128.0

TABLE 1 - SUMMARY OF REQUIREMENTS FOR CRAFT
RACING OR COMPETING IN PROTECTED ENVIRONMENTS

ITEM	PROOF OF COMPLIANCE
GENERAL	- CALCULATION OR TESTING. Proprietary equipment may have manufacturer's certificate or other proof of design. - PRESENTATION OF HCGB CRAFT LOG BOOK where craft is to be checked.
STRUCTURE	
- DESIGN LOAD CASES	- CRAFT LOADED to 1.5 x Maximum operating weight cushion borne or floating. Test carried out to prove plough-in is safe.
- CRASHWORTHINESS	- MOUNTING OF COMPONENTS AND EQUIPMENT to sustain 6g in any direction including removable items such as batteries. - CABIN OR STRUCTURE to be sufficient to act as a roll bar. CABIN OR COCKPIT to have no sharp edges.
ROTATING ASSEMBLIES	
- DESIGN	- FAN TIP SPEEDS are limited below 137m/s for plastic blades, 168m/s for glass filled nylon, and 85m/s for centrifugal fans. PROPELLERS are limited to 137m/s tip speed unless a manufacturer's certificate is available, when 200m/s is permissible. - FAN BLADES or propellers must be replaced if signs of damage are visible. - POSITIVE LOCKING (wire, split pins, etc) to be employed on all connecting elements. - FLAIL GUARDS in all shafts above 20bhp throughput.
- GUARDING	- WIRE MESH GUARDS to be fitted over all rotating assemblies with appropriate mesh size and guard rigidity. - DUCT or radial guard shall contain failed blades of fan or propeller.
CONTROLS	
- DESIGN	- CONTROLS shall be grouped around driving position in a safe manner, operation shall be without undue strain. - ENGINE THROTTLE (thrust engine(s) if more than one) shall have spring return to idle.
FIRE PRECAUTIONS	
- FUEL SYSTEM	- FUEL TANKS and LINES to be safely positioned and mounted, no leaks. Driver must be able to cut off fuel from his seat.
- ELECTRICAL	- Design not to create fire hazard. There must be a cut-out operable by the driver, and an external isolation switch for any batteries.
- GENERAL	- All hot parts must be adequately cooled and protected from touch. - BCF FIRE EXTINGUISHER at least 0.6Kg to be present. - ENCLOSED ENGINES shall have access for extinguisher. - Rear bulkhead of cabin or cockpit to be fireproof.
SKIRTS	
- DESIGN	- To be STABLE, in general hoverheight craft width/8. - CUSHION PRESSURE to be appropriate to maximum speed. - HULL to be designed with DEADRISE at sides to give a planing surface on sideways plough-in. - Appropriate TEAR RESISTANT MATERIAL to be used.
BUOYANCY	
- DESIGN	- 150% maximum operating weight shall be provided as buoyancy for floating undamaged. Distribution shall be adequate to main stability in damaged condition. - Buoyancy sufficient to keep craft afloat when cockpit swamped shall be provided as foam, airbags or sealed compartments.
OPERATIONAL SAFETY	
- GENERAL	- Driver to wear approved Crash helmet, Life jacket, and sensible dress to prevent unnecessary injury in accident. - Enclosed craft to be designed for evacuation when inverted in shallow water. Glazing to be of safety glass. - A lanyard type ignition cut-out to be worn by driver. - Sufficient handling points shall be fitted to craft. - Engines must be able to be restarted when craft is floating on water.

TABLE 2 - SEAGOING CHARACTERISTICS OF SELECTED HOVERCRAFT

CRAFT	CUSHION LENGTH (m)	CUSHION HEIGHT (m)	INSTALLED POWER BHP	DRY WEIGHT Kg	H_1	H_2
KESTREL	2.95	0.2	55	155	0.61	0.4
BBV2	3.45	0.23	40	163	0.7	0.47
FREEDOM	3.84	0.23	55	200	0.76	0.5
SKIMA 4	4.29	0.38	40	500	0.88	0.59
SCOTT CRUISER	3.81	0.30	112	340	0.76	0.5
SKIMA 6/ RIVER ROVER	5.41	0.30	102	780	1.03	0.69
SKIMA 12	6.65	0.51	250	995	1.37	0.91
TIGER S	6.37	0.50	200	1272	1.34	0.89
SURVEYOR	5.0	0.50	130	675	1.00	0.66

NOTE:

H_1 = Highest Significant Waveheight in fully developed sea offshore unprotected coastline which will allow craft to platform largest waves and traverse smaller waves.

H_2 = Highest Significant Waveheight in a fully developed limited fetch (coastal) seastate allowing craft to traverse waves above humpspeed.

Cushion Height = Highest breaker which will not knock craft off cushion.

TABLE 3 - SUMMARY OF REQUIREMENTS FOR CRAFT
FOR USE IN OPEN AND COASTAL ENVIRONMENTS

ITEM	PROOF OF COMPLIANCE
GENERAL	- CALCULATION OR TEST CERTIFICATES OR TEST CARRIED OUT BY SCRUTINEER
HULL STRUCTURE	
- DESIGN LOAD CASES	- Analyse maximum design load conditions for:- (1) Manoeuvring, 3 rads/sec, 3 rads/sec^2 rotation and 0.5g linear. (2) Floating, limiting height wave of craft length. (3) Water Impact, due to loss of lift at full speed. (4) Transition, due to a clear drop from cushion height to solid surface. (5) Wind loading, 80 knot wind or 25 knots + craft top speed. (6) Solid Surface impact, skid stop due to loss of lift, or 2g (greater value). (7) Parking, due to parking on rough ground, 3 point support. (8) Mooring forces, due to wind, current, waves on mooring points. (9) Towing, at least 2g applied to tow points. (10) Slinging or Jacking, 1.1 x operating weight while slung. (11) Machinery loads, due to machinery failures, on hull. (12) Collision, 6g deceleration. - Proof and ultimate load.factors are specified. - Fatigue life to be estimated, not less than 15 years. - Inflatable structures to BS MA 16.
- CRASHWORTHINESS	- As Blue Book.
- BUOYANCY AND STABILITY	- 100% reserve for intact buoyancy in closed compartments. Buoyancy distributed so that max floating trim less than 7^{o}. - Damaged cases specified, craft to have no downflooding of compartments in these cases at 20^{o} roll, 10^{o} pitch whichever greater. 75mm freeboard in these cases before downflood. - Outer hull surface to give planing surface if skirt collapses on one side, with dihedral angle between 5^{o} and 25^{o} sufficient to prevent roll over.
ROTATING ASSEMBLIES	
- DESIGN	- Shafts, fan hubs and flexible couplings to be designed for craft life. - Fan blades, belts, etc may be designed for replacement, with guidance given on periods in the regulations. - Extreme and fatigue loadings to be analysed as specified. - Fans and Guarding - As Blue Book. - Propellers limited to 137m/s.
MAIN MACHINERY, MOUNTING AND TRANSMISSIONS	
- GENERAL	- Hull Design cases also to apply to Machinery. - Machinery to fail-safe. - Multiple power units shall be configured to allow safe navigation to shoreline in event of failure of one unit. - Powerplants to be able to be cold started without assistance when craft floating in max environment.
- MAIN MACHINERY	- Each power unit to have separate lubrication and cooling. - Intakes are to have filters for water, salt, grit, etc. - Exhausts to be safe away from craft and to have drains if upward facing.
- MOUNTINGS	- Design to Hull load cases. - 50% of mountings failed not to cause progressive failure, or stop operation.
SYSTEMS AND CONTROLS	
- GENERAL	- Design to fail-safe, and to conform with hull loadings. - Design appropriate to damp, salty, gritty environment. Sensitive instruments etc. to be avoided.
- AERODYNAMIC CONTROLS	- Specification given for design loads and retention of aerodynamic shape.
- ENGINE AND PRIMARY CONTROLS	- As Blue Book. Guidance given for design loads applied to controls manual or powered.

ITEM	PROOF OF COMPLIANCE
- BALLAST SYSTEMS	- Ballast piping to be proof of leaks, tankage to be baffled, and level instrumented. Craft to be fitted with trim instrumentation.
- FUEL SYSTEMS	- To be proof of leaks, tanks to be baffled. - Fillers to be marked. - Vents and drains to be clear at all times. - Fuel to have positive shut-off. - Fuel to be positively pumped, not gravity feed.
- ELECTRICAL SYSTEMS	- To conform with BHSR Chapters B6-7. - Driver to be able to cut off all systems. - Batteries to have external breaker switch.
- INSTRUMENTS AND COMMUNICATIONS	- To be adequate for safe craft operation without causing confusion to driver. - Communications to conform with Seaway Code. - Radio and Radar to conform with BHSR B6-9.
- FIRE SAFETY	- Any enclosed fire zones to be bounded by 15 minute resistant boundaries and to have remote fire extinguishing if greater than $2m^3$. - Fuel systems should not be able to leak into hot parts for rotation minimum 30^{o} any direction. - Enclosed hot areas to be cooled. - Craft less than 500Kg to have at least 0.7Kg Extinguisher, above this, minimum 1.4Kg Extinguisher(s).
SKIRT SYSTEMS	
- GENERAL	- To be stable under all operating conditions. - Hard structure clearance to be less than 12.5% craft width. - Cushion or bag pressure not to be less than equivalent to hull structure wind loading design case.
- MATERIALS	- To be sufficient for design life of greater than 12 hours. - Ripping not to cause damage to craft attachments. - Bags to have vertical rip stops (minimum 4 each side).
- DAMAGE	- Craft to be able to return to shore minimum 5 miles away with rip between rip stops, or 15% of segments lost in any configuration.
HANDLING, PERFORMANCE AND OPERATIONAL SAFETY	
- GENERAL	- Craft to be operated with due respect to capability and driver experience. - All round vision required for driver by direct or indirect means. - All persons to wear life jacket. - Below 500Kg crash helmet to be worn. - Seat belts to be worn in cabin craft over land. - Windscreens to be of safety glass. - Enclosed cabin craft to be designed for safety of personnel in roll over, and for quick egress. - Craft to have adequate external handling points and grab handles, particularly for persons overboard. - Craft to carry appropriate equipment when travelling offshore as recommended by Board of Trade for small craft (flares, lifebuoy, bailers, first aid kit, radar reflector, tools, torch, oars, etc).
CERTIFICATION	- Full inspection to be augmented by design documentation where appropriate. - Log Book will be issued, and may define limitations on craft operation.

APPENDICES TO THE REGULATIONS:-

(A) Definition of Terms.
(B) Guidelines for safe operation in open environments and coastal waters.
(C) Guidelines for design and fabrication of GRP Hulls and Ducts.
(D) Guidelines for design and fabrication of Welded Metal Space Frames.
(E) Material Specifications for Hovercraft Manufacture.

SCRUTINEERING CHECKLIST MEETING ..... DATE .....SCRUTINEER .....

OWNER ..... HCGB No..... CRAFT NAME .....L.....B.....H.....

ADDRESS..... ..... WEIGHT .....SEATS.....

..... CRAFT TYPE .....

Craft Log Book No.											
HULL	H1	Structure/material									
	2	Buoyancy type/vol.									
	3	Planing Surfaces									
	4	Roll Protection									
	5	Handling Points									
	6	Sharp Edges int/ext.									
	7	Evacuation									
SKIRT	S1	Type/height/damage									
	2	Material/Attchmnt to craft									
CONTROLS	C1	Rudders/craft attachment									
	2	Rudder control linkage									
	3	Lift/Thrust throttle op.									
	4	Throttle flyback									
ELECTRICAL	E1	Ign. Cut off lift/thrust									
	2	Battery/restraint									
	3	Wiring/isolator switch									
LIFT/INTEGRATED SYSTEM											
*	L1	Engine/cc/cyl/mts to frame									
	2	Frame mounts to craft									
*	3	Transmission/belt condition									
*	4	Fan condition/shaft mtg.									
	5	Guards area/strength									
	6	Silencer type/mounting									
	7	Locking and security									
	8	Hot spots/hazards									
PROPULSION SYSTEM(S)											
*	P1	Engine/cc/cyl/mts to frame									
	2	Frame mts to craft									
*	3	Transmission/belt condition									
*	4	Fan condition/shaft mtg									
	5	Guards area/strength									
	6	Silencer type/mounting									
	7	Locking and security									
	8	Hot spots/hazards									
MISC.	M1	Fire extinguisher									
	2	Crash Helmet									
	3	Lifejacket									
	4	Overwater restart									
	5	Noise level dBA @ 25m									
	6										
	7										
	8										

NOTES : Note faults in log book, ref. no./details or overleaf with craft Log No.

* For full scrutiny enter Engine type/cc/cyl, Transmission ratio/pulley diameters/teeth/belt type/width, Fan Type/dia/blades/angle.

SCRUTINEER SIGNATURE FOR CHECK.										

FIGURE 1 - HOVERCLUB OF GREAT BRITAIN SCRUTINEERING CHECKLIST



FIGURE 2 - A BBV. 11 FORMULA 1 HOVERCRAFT



FIGURE 3 - AN ECCLES 2 FORMULA 1 HOVERCRAFT



FIGURE 4 - A SCARAB 11 FORMULA 1 HOVERCRAFT



FIGURE 5 - AN OSPREY HOVERCRAFT KESTREL GT



FIGURE 6 - A BBV. 2 HOVERCRAFT

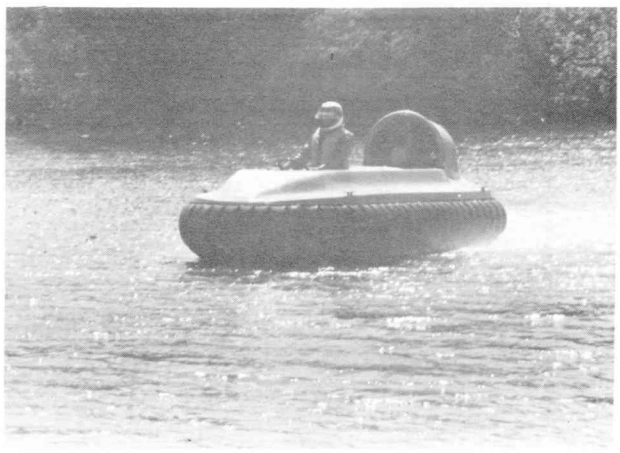
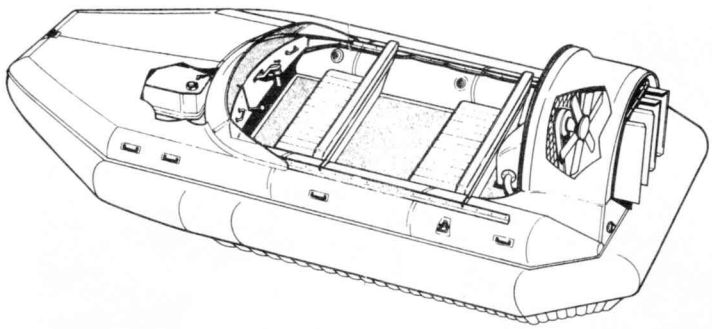


FIGURE 7 - A LIGHT HOVERCRAFT FREEDOM 3



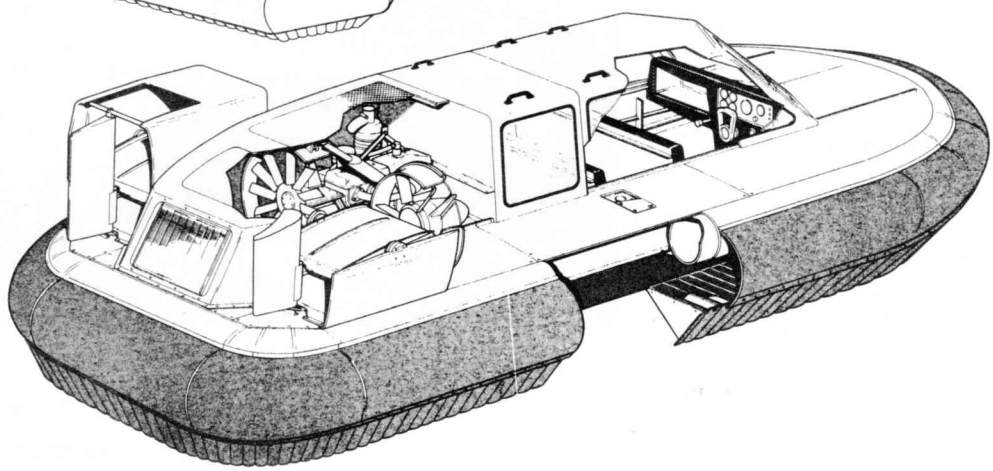


ABOVE, LEFT, FIGURE 8a The Pindair Skima 4,
RIGHT, FIGURE 9 The Scott Cruiser.

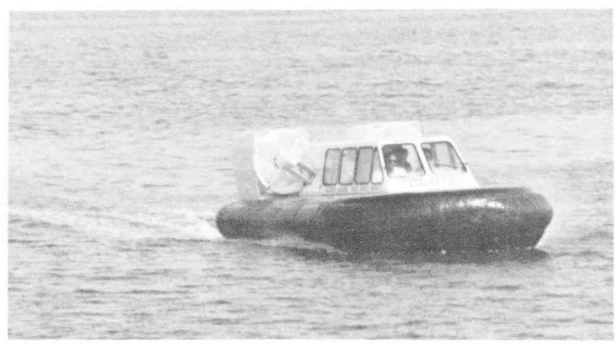


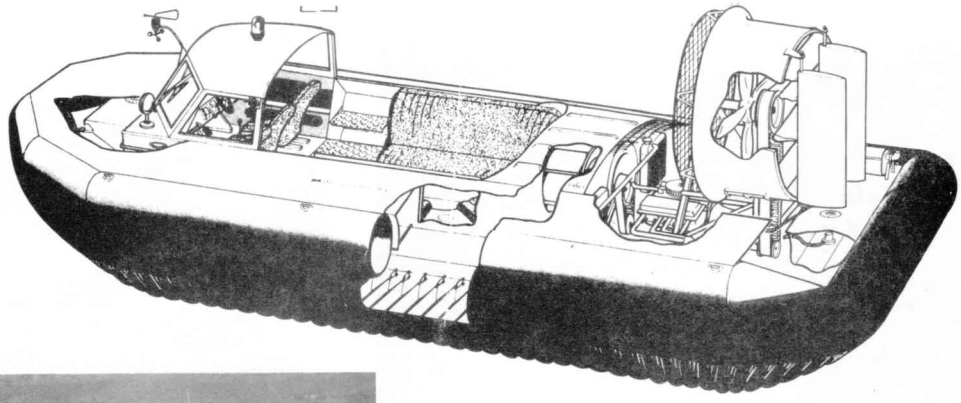
LEFT, FIGURE 8b A Cutaway Drawing of Skima 4.

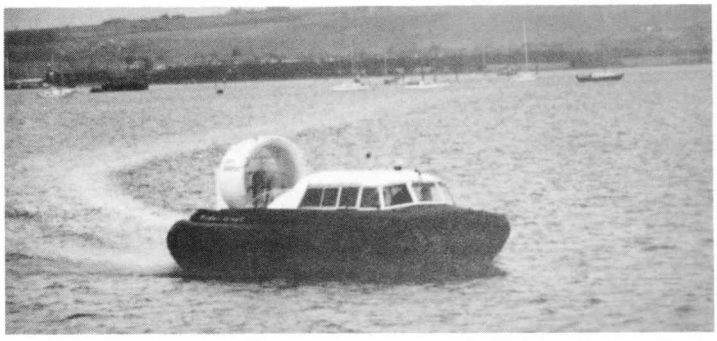
BELOW, FIGURES 10a,b, and c showing a cutaway of the River Rover, the craft with cabin roof slid forward, and at speed over water.











ABOVE, FIGURE 11a A cutaway of the Pindair Skima 12 Open Top Version.

LEFT, FIGURE 11b The Skima 12 with soft top fitted at speed in Portsmouth Harbour.



FIGURE 12
The Air Vehicles Tiger S

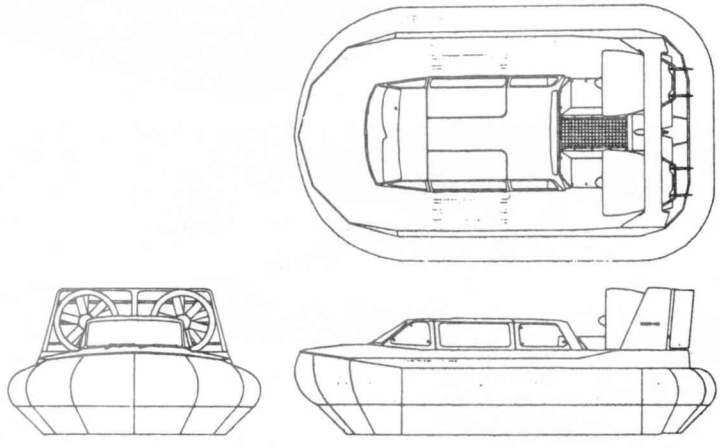


FIGURE 13 - The Riverland Hovercraft Surveyor

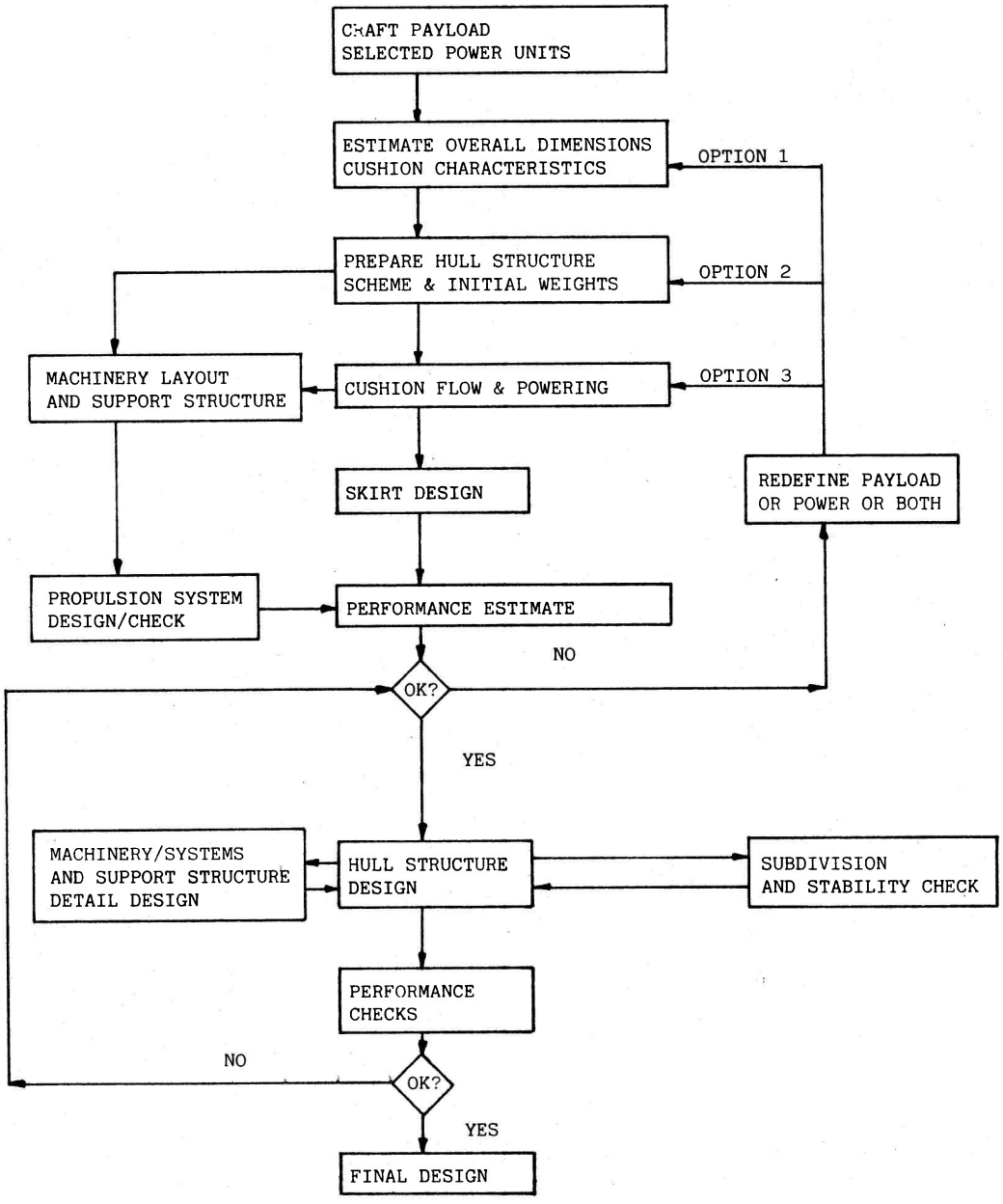


FIGURE 14 - DESIGN PROCEDURE FOR AN AIR CUSHION VEHICLE

WÄRTSILÄ NEW GENERATION AIR CUSHION VEHICLES

Seppo Korppoo

Project Manager, Wärtsilä Helsinki Shipyard

1 ABSTRACT

A quarter of a century of evolution in air cushion technology has brought about a new generation of craft. The use of well-proven shipbuilding techniques and components facilitates the production of vehicles of improved reliability and economy.

The new air cushion vehicles render themselves as being a feasible proposition for extended use in different duties on land and sea, including operation in arctic and antarctic regions.

2 INTRODUCTION

Wärtsilä, an experienced builder of icebreakers and other specialized ships, has applied its expertise to the technology of air cushion vehicles, to develop craft capable of negotiating the rugged terrain and extreme conditions encountered in the cold regions. The result is a new generation of air cushion vehicles where well-proven shipbuilding techniques have been applied to achieve more economical and reliable craft.

3 A NEW GENERATION OF CRAFT EXPANDS THE USE OF AIR CUSHION VEHICLES

The new craft have been developed for operation not only in open waters but on ice, snow and land. Greater stress has been put on operational economy. Therefore, even further possibilities are available for operators to utilize the ACV's exceptional capabilities.

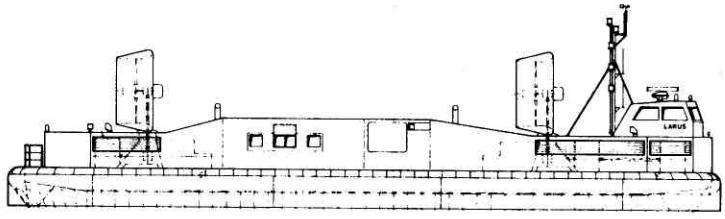


Fig. 1. PUC 22-Type

Expedient transportation of passengers and roll on - roll off cargoes over water, ice and snow.

Length, max.	33.0 m
Breadth, max	14.7 m
Speed in calm water	25 knots
Payload	30.0 tonnes
Passengers	50
Engine rating	2600 kW

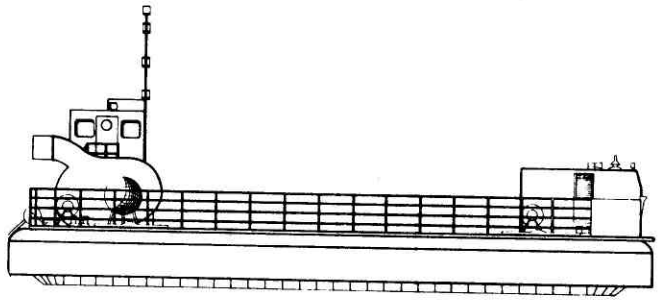


Fig. 2. TAV 40-Type

Towable craft designed for ferrying heavy cargoes in otherwise impassable regions under arctic conditions.

Length, max.	19.2 m
Breadth, max.	9.9 m
Payload	40.0 tonnes
Engine rating	625 kW

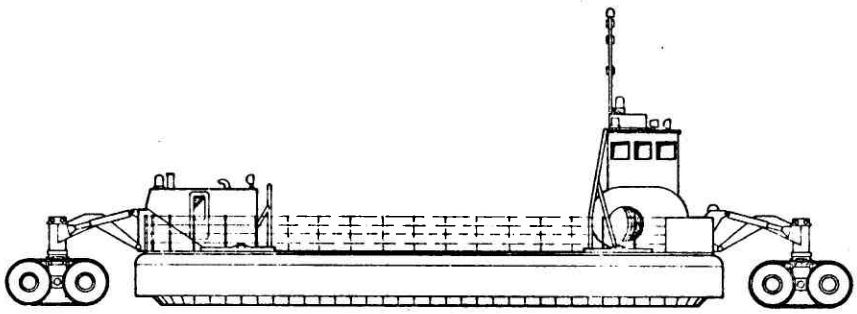


Fig. 3. VECTOR-Type

Track-driven craft for heavy cargo transportation over firm and swampy ground, open water, ice and snow.

Speed on even ground	20 km/h
Speed in calm water	4 knots
Slope gradient capability	6 degrees

4 ECONOMICS OF NEW GENERATION AIR CUSHION VEHICLES

Transportation economy has been the basis on which the vehicles have been developed. New vehicles must be capable of competing economically with other means of transportation, not to mention air cushion vehicles of the previous generation.

In general, the total transportation costs of the ACV are well below those of the helicopter, though other means of transportation offer hard competition. In a number of cases the ACV's high speed, amphibious characteristics or comparatively high loading capability can be successfully utilized. In arctic regions the ACV can operate in areas devoid of any roads without damaging the permafrost. Operation is also possible in very shallow waters.

To obtain a clear understanding of these aspects, the shipyard's total economy calculation model has been extensively employed.

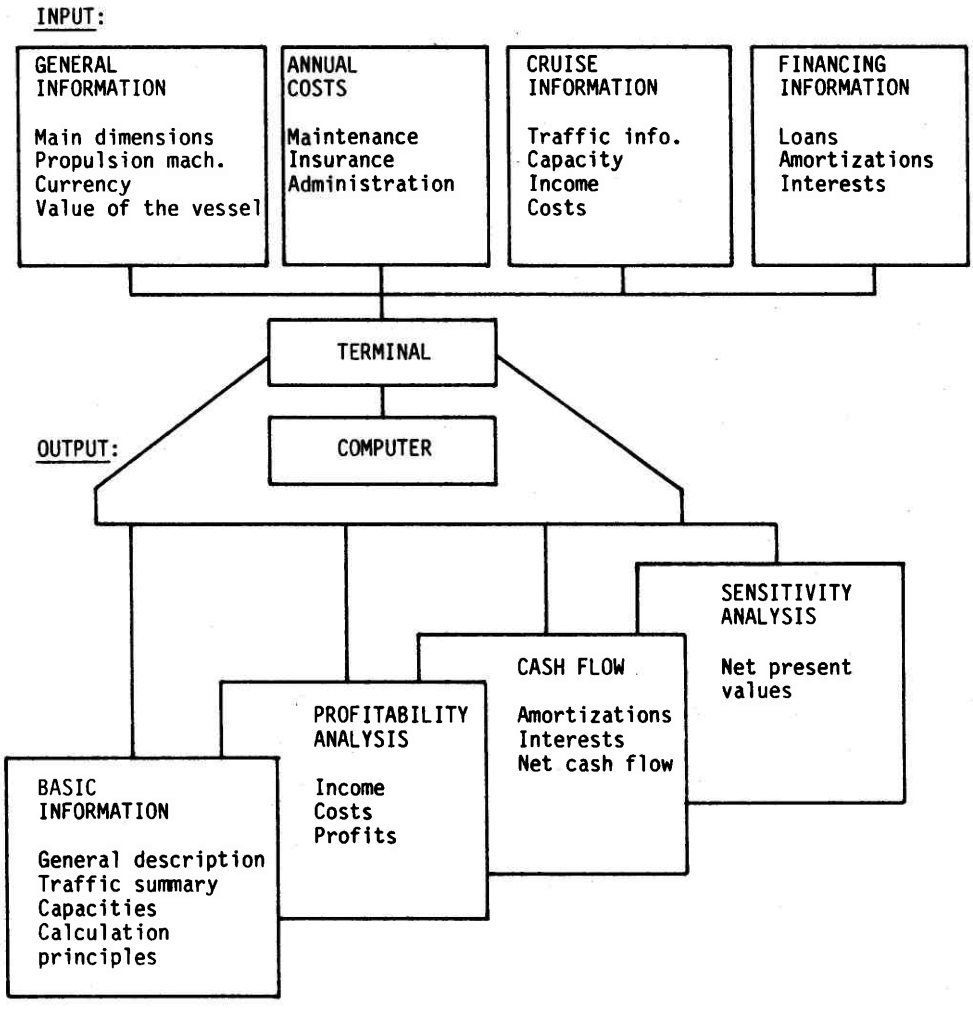


Fig. 4. Total Economy Calculation Model

5 TRANSPORTATION COSTS OF VECTOR-TYPE

As an example of the application of the total economy model, some results obtained from the Vector-type vehcile have been presented herein.

Basis of calculation:

1 A major part of the voyage traverses flatland or icefields. Some river crossings, steep banks or other difficult terrain have been included. Cargo is transported in only one direction with a load factor of 0.7. Average speed 18 km/h.

2 Manning with two crews each comprising one driver and one assistant.

3 Annual operation time 2200 hours.

4 Economical life 10 years, discount rate 10 %, resale value 0.

5 Fuel, insurance, administration, maintenance and other costs are quoted at the rates prevailing in 1983. Annual escalation rate of 5 % for all costs and revenues.

6 Loan terms according to OECD agreement.

7 Revenues are quoted to achieve the break-even point for the present value of costs and revenues.

The results are shown in Figure 4. As an example, should 5000 tons of cargo be transported annually over a distance of 150 km, a transportation capacity of 750 000 ton km will be required. From the figure it can be seen that a Vector-type vehicle with a payload of about 60 tons is required, resulting in an annual transportation cost of 750 000 ton km x CAD 2.1/ton km = CAD 1.575 million.

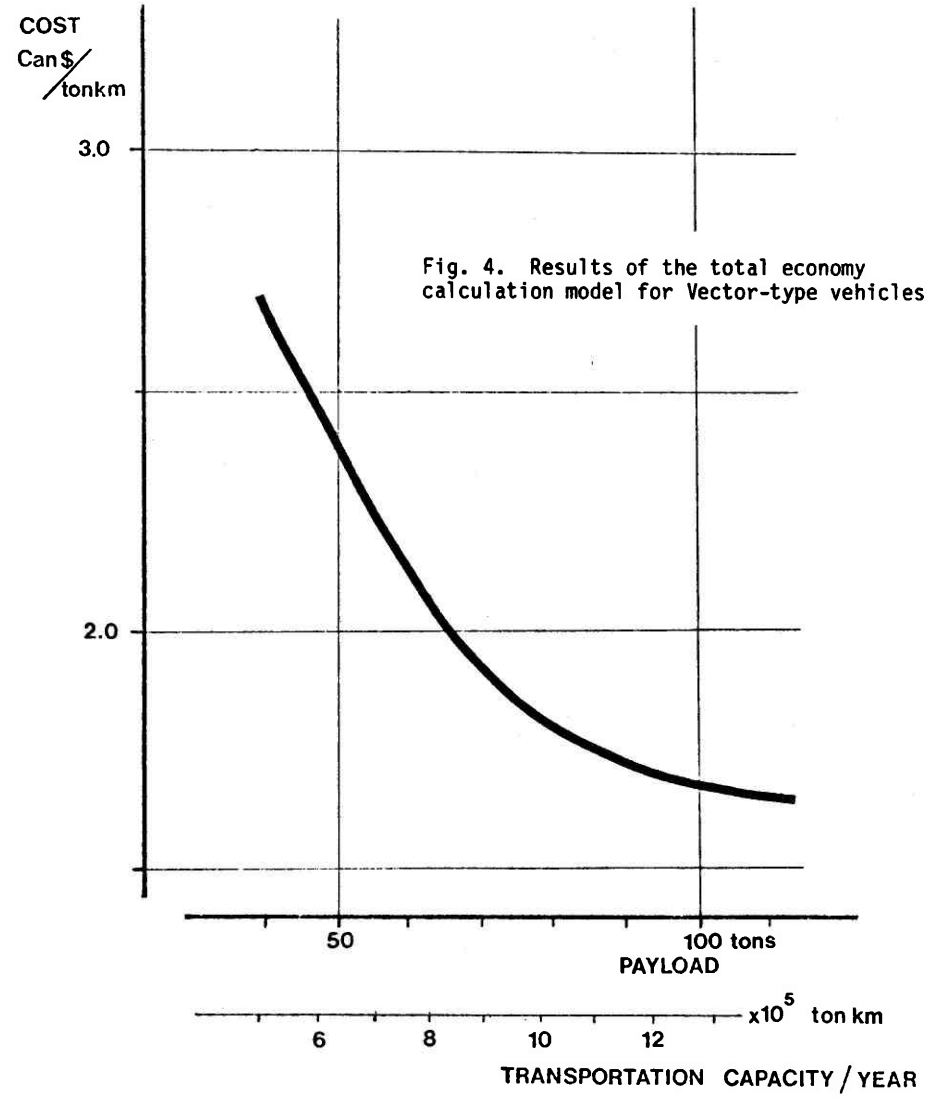


Fig. 4. Results of the total economy calculation model for Vector-type vehicles

6 CONCLUSIONS

The development work of the new generation of air cushion vehicles is firmly based on reliable and economical shipbuilding techniques, and thus ACV-technology has made progress in many essential areas.

As a result of this work, the PUC 22-type vehicle was designed and constructed. The "Larus" was delivered in 1981 and it is the first passenger ACV to employ diesel engines as a primary means of propulsion. A new skirt has been developed which is capable of withstanding the punishment usually received in arctic regions.

Fourteen TAV 40-type vessels have been ordered, some of which have already been delivered for service in cargo operations around arctic shores lacking port facilites.

The prototype of the Vector-type vehicle has been built and extensively tested.

Due to their unique characteristics, the new air cushion vehicles are often more economical than conventional means of transportation, e.g. for

- year-round operation over swampy and permafrost ground, where it is difficult to provide roads and railways
- year-round cargo handling around shores lacking harbour facilites
- service on lakes, shallow coastal waters and rivers even during freezing or thawing periods
- short-term transportation, where investment in roads etc. cannot be economically justified
- expedient offshore transportation

CANADIAN AIR CUSHION VEHICLE SAFETY STANDARDS - THE FLEXIBLE APPROACH

R.G. Wade

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ABSTRACT

This paper discusses and illustrates how,in a period of rapidly emerging technology,a rare opportunity presented itself and is being used,to develop appropriate safety standards keeping pace with that technology.

The current Canadian legislative authority which is applied stems from decisions made about 20 years ago;in hindsight, the delay may be a blessing in disguise since lessons learnt can be applied in developing new legislation with the benefit of experience. These lessons have been learned as a result of new and unforeseen applications of air cushion technology,and industrial inventiveness,posing problems relating to safety which required appropriate solutions.

These solutions frequently require a very flexible approach - flexibility which might not have been present if newly developed and untried measures had been in place. In using the experience gained,we can attempt to introduce such flexibility when developing the new safety legislation which will replace the existing authority.

INTRODUCTION

Canadian domestic legislation and international safety measures relating to A.C.V's have been extensively reported previously (Refs. 1 - 6), and it is not intended here to review history. Rather, the emphasis will be placed on the technical development of Canadian A.C.V. safety standards and their application. Reference will be made to three factors which,with the benefit of hinsight, have had a significant influence in this development. Several examples will be mentioned to lay to rest any lingering doubts that safety standards do affect safety and conversely, that they do respond to demonstrated need. Dialogue and rapport are most essential ingredients for the successful application of safety measures.

BACKGROUND FACTORS

Above all else,probably three factors have guided and influenced the development of A.C.V. safety measures in Canada - development which is still continuing.

The first factor was a combination of legislative decisions taken in the 1960's,when the need for some safety regulation was recognized. It was decided that amphibious A.C.V's should be regulated under the Aeronautics Act;that marine sidewall come under the Canada Shipping Act, and that all A.C.V's weighing less than 1 360 kg., and which are used purely for pleasure should be exempt from all Federal regulation. Although intended as interim measures, these decisions still stand, and have unwittingly created a very flexible framework within which it has been possible to develop safety measures to meet new situations as they arise with minimum delay. It is planned that legislation in the Maritime Code, which is replacing the Canada Shipping Act,will provide authority to regulate all A.C.V's within Canadian jurisdiction. The present situation has provided a rare opportunity to develop regulatory safety measures in advance such that when the new legislation becomes effective,the safety measures will already have the benefit of experience.

The second factor was the development, between 1972 and 1975, of the IMCO (now IMO) Code of Safety for Dynamically Supported Craft. This rather cumbersome title embraces A.C.V's, and while it applies to craft making international voyages and carrying more than 12 passengers, it does provide a cohesive minimum safety standard from which interested nations may develop their domestic requirements. Indeed,if their industry has export potential, the domestic standards must at least provide compliance with the Code. The Canadian invlovement in this development would have had little meaning had we not subsequently taken steps to review our domestic standards. Replacement of design,construction and equipment standards which were in place previously, and which left a lot to be desired, has now been completed, and additional standards relating to documentation, personnel, and operational procedures are under development.

The final factor has been the inventive genius of the industry - designers and operators alike. Some instances would appear to be completely impractical. Who, for instance, would contemplate owning and operating a 2-seat pleasure A.C.V. whose entire power transmission was by means of a 4,000 p.s.i.hydraulic system ? Or who would contemplate using an SRN-4 as a mobile gambling casino along a 400-kilometre stretch of the St.Lawrence. These, perhaps, are extreme cases of proposals which have tested our ingenuity at devising equally imaginative but appropriate safety measures. As can be imagined, such measures did not need to be fully developed or used. But the Canadian environment has generated some legitimate if limited peculiar applications _ I refer to ice-breaking and year-round river crossings.

It is not unlikely that Arctic operation of A.C.V,s will eventually become an established fact,possibly bringing with it the need for additional or revised safety measures.

BASIC PRINCIPLES

Given that safety measures must be purely objective,and that the objectives are clearly defined, successful development and application of those measures must have two essential ingredients - objective dialogue and rapport between the industry and the regulatory agency, and the application of objective common sense. Regulations and safety measures can only be developed in response to a demonstrated need. This need emerges from the industry, which is therefore always a little ahead of the agency. In attempting to arrive at an overall and consistent level of safety,the regulatory agency may percieve impacts of one design proposal which the designer had neither intended nor foreseen. It is therefore most important that effective dialogue commence as early as possible when a new or innovative feature is being contemplated. Equally, it is just as important that new safety measures be fully discussed with industry during the formative stages. Dialogue is a two-way street, and both participants must recognize and appreciate each other's concerns; although these are not always coincident,the end objective must be agreed and reached by agreed means. Industry somewhat naturally has economic concerns but these cannot be allowed to over-ride safety... the landscape is littered with the skeletons of A.C.V.projects that have been sacrificed at the altar of economy.

We - that is,the collective A.C.V.fraternity - have,I believe, learned that application of these principles work. To a newcomer to the industry, the safety standards which have resulted appear to be daunting, but close inspection should show that there is nothing in them that is not good, sound objective common-sense forming a cohesive whole. Before the IMO Code was developed, international standards were fragmented and resulted in inconsistent approaches to safety. IMCO, infinitely wise in the safety of ships that float in the water, have massive fire pumps and firemains, have large lifeboats, and passengers scattered all over a ship, found it difficult at first to appreciate the need for a new approach to over-all safety levels.They addressed the need for new fire safety measures in the absence of fire pumps and access to water,and they addressed the need for light-weight life-saving appliances and evacuation measures with passengers in dedicated areas at all times,and they addressed radio communication standards. But these new measures were not inter-related, nor were they related to the over-all safety to which they were intended to contribute. This has now been corrected in the Code,and is reflected in our developed domestic standards, interwoven with detailed requirements resulting from industrial initiatives and the Canadian environment.

DEVELOPMENT OF CANADIAN STANDARDS

Up until about 1972, there was an appreciable amount of domestic activity - we had passenger operations on the West Coast and plans for more on the East Coast; plans for an SRN-4 service across Lake Ontario and the mobile casino on the St.Lawrence; we had the design and construction of Voyageur and Viking, and numerous small recreational craft. And we also had ACT-100, to which I will return shortly. Our standards for design, construction and operational safety were unashamedly plagiarised from those developed by the U.K.- they existed, they worked, and with the blessing of the U.K. agencies, we used them as a basis thereby establishing some consistency.

The smaller craft presented a problem - although they were exempt from all Federal regulation while used purely for pleasure, if they were used commercially, all safety standards had to apply. Since the manufacturer has no control over the end use of his product, this implies that design and construction safety standards should be complied with. Standards intended to apply to large sophisticated vehicles produced by major manufacturing organisations are clearly too deep and cumbersome to apply to a simple craft whose major complexity is usually a snow-mobile engine - but might be a 4,000 p.s.i. hydraulic system ! So, we produced more simple guideline standards for these vehicles ; in the early 1970's there were 17 or 18 companies trying to manufacture such craft,but this enthusiasm quickly died. A recent resurgence in interest in this market is now causing us to review and up-date these standards.

Returning now to ACT-100, this mobile structure represented the opposite end of the spectrum to the small craft, and proved to be the fore-runner of what appeared to be a new breed with applications needing yet further requirements. As a single prototype,we exempted it from many inappropriate requirements of our own standards. But given the Canadian environment, this concept indicated significant potential for application to year-round river ferries in Northern road systems, and for ice-breaking - applications which we actively supported, thereby re-inforcing the need for additional standards. The different features of such vehicles required new approaches - weight was no longer a problem; self-propulsion and directional control were no longer problems;lifesaving, fire safety, crewing standards - almost all aspects are different. Therefore, new standards were developed addressing these differences - initially for the ferry application and for the icebreaking platforms separately,but they were sufficiently similar that they have now been merged into one.

Following the publication of the IMO Code, and heeding the queries from, and problems posed by, industry over the years,it became evident that a major review of our existing standards was required,together with expanding their coverage. It should be emphasised here that such expansion has resulted from the requests from industry,not

from any desire on our part to impose additional requirements. Such requests can be regarded as exemplifying the dialogue and rapport which we have encouraged and established.

As a result,the major design,construction and safety certification standards have been completely re-written;crew qualification and certification standards are in an advanced state of re-development, and new standards are in the initial stages. Following those,the guidelines for small recreational craft will be reviewed and, if the need emerges, standards for ice-breaking platforms, river ferries and Arctic transporters will be initiated.

Design,Construction and Safety Certification.

With the need for major text revisions,the opportunity has been taken to totally revise the layout in an attempt to clearly identify each specific topic and make provision for easy future amendment when necessary. Separate,clearly identified appendices provide advisory background information to assist in interpretation;this information is not mandatory. The revision has inevitably resulted in a thicker document than the one it replaces, but the guiding principles of objectve common-sense and response to dialogue have been followed and the result should provide much clearer guidance for industry. Proof that this result has been achieved has yet to be gained.

Crew Qualification and Certification

Because of the diversified operations in Canada, the lack of training opportunities and of a pool of A.C.V.operating experience in the commercial field, the definition of crew qualifications is a particularly difficult problem to reconcile with the objective. Support operators, large and small, who provide valuable supply and emergency services to logging or mining camps in remote areas and have access problems with conventional transport, see the potential of A.C.V's to improve their operation. What requirements should apply to them ? Quite frequently, areas in which they operate are not covered by marine charts, have no proper buoys,and indeed may not be navigable. The operators know their area blindfold,so how are the normal basic marine knowledge examinations to be applied or be of use to them ? If their plans to operate an A.C.V. come to fruition, how are they to be trained and to what standard ? These are just some of the very elementary problems facing the development of crew standards.

At present,we are treating each case individually, setting knowledge requirements to meet the particular operation, allowing the operator to gain operating experience either under supervision of a certificated operator while operating in service or by self-training under guidance, and examining and certifying him operationally within limited geographic areas.

For larger operations,we aim to provide a more general standard, certificating the operator without geographic limits.

Given the impetus of considerably increased commercial operations planned over the next few months, we hope to finalise the crew standards during the summer of 1983.

New Standards

The responsibility of the manufacturer, and of ourselves does not and should not end when the vehicle has been certified and sold to the customer. Implicit in the safety certification is the adherence of the customer to operational limitations, emergency procedures,and to maintenance procedures. To guide the customer, the manufacturer should provide appropriate technical manuals, and in order to provide consistency these manuals should contain the appropriate information to a constant depth, and in logical readable format. We recently reviewed a manual from an established A.C.V.manufacturer which contained what we felt to be important operational limitations under failure conditions dispersed through the text. This was co-incidental with a request from a new manufacturer for guidance on developing a manual.

We are responding immediately to a demonstrated need by developing standards which,in very general terms, will give guidance as to the content, the depth of content, and in cases where operational safety is involved, format.

The guidelines for small recreational craft, developed originally with little experience, are rather rudimentary and require a similar wholesale revision. These vehicles present special problems; frequently they stem from designs originally intended for home construction - in such cases and in others where the design is developed for production, the depth of design analysis of the vehicle itself and of propellors, fans, etc., and of drawings, is usually beyond the capacity of the manufacturer. There is also the problem of where to establish the transition point,for standards, between 'large' and 'small', and on what basis. Development of these new standards will require very careful consideration of the balance between design and manufacturing capability and objective safety of the product.

HOW NECESSARY ARE STANDARDS ?

This may sound to be a niaive question, but frequently their necessity, either as a whole, or in point of detail, is called into question. Unfortunately, it can only be answered by pointing to examples of what has happened when they have been disregarded. We have had several cases of fan failures, due either to insufficient design, poor quality control, or disregard of manufacturer,s recommendations. We have had structural damage caused by incorrect positioning and inadequate insulation of engine exhausts; in one case, failure of an inadequate exhaust component caused the thrust and directional controls to jam. We have had major structural failures due to disregard for design, quality control and manufacturing inspection. We have had craft damaged or stranded due to either disregarding their limitations or by inadequate maintenance procedures.

These are just some of the examples which we know about; taken in the context of the level of Canadian activity, they cover a fairly wide spectrum of deviations from standards. There appears to be an underlying current of judgement, and in some cases, of common sense being clouded by economic factors. Such economy, when it results in an unsatisfactory product, usually results in disproportionately large adverse economic effects for the manufacturer. Some of the failures might have been foreseen and avoided had adequate design data or drawings been made available' that they were not has frequently been due to cost. In discussion,most designers and manufacturers indicate that they readily accept that safety certification standards are necessary, and are important for product acceptance and marketting,but still they attempt economic short-cuts.

DEVELOPMENT OF LEGISLATION.

The foregoing remarks have addressed the development of standards within the existing legislation; this development has to some extent been influenced by the knowledge that changes are planned in the legislation. Indeed, had it not been for a number of technical factors, A.C.V. safety would have been administered under the Canada Shipping Act several years ago. That Act is now being replaced by the Maritime Code, and provision has been made for the inclusion of A.C.V's in the development of that Code. Draft regulations,which are the instruments by which standards are authorised, were developed for the Canada Shipping Act amendment; these will form the basis for regulations to be made under the Maritime Code, but the experience which we have been able to gain in the interim will assist greatly in reviewing and revising these to provide appropriate authority. With this experience, and the careful scrutiny which new legislation has to undergo, the eventual provisions of the Maritime Code and regulations made under it should be able to be formulated so as to have little if any transitional impact upon the industry.

CONCLUDING REMARKS.

The intention here has been to convey the message that, contrary to some beliefs, regulatory agencies do not work in a vacuum and are not insensitive to the industry they strive to serve. Possibly, some new light has been shed on some of the problems which we face and the manner in which we attempt to resolve them. The process and principles which we have adopted and apply appear to have been at least not unsuccessful or unacceptable; it is certainly not intended to imply that this is unique to Canadian A.C.V's, neither that it cannot be improved upon. Provided that we can maintain responsive dialogue and objectivity, continued improvements should result.

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A FAN FOR ALL REASONS

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ABSTRACT

Multi-tasked ACV's can solve Coast Guard cost crisis. We are fortunate in North America that Coast Guard organizations have the mandate of responsibility for many inter-related marine disciplines. This mandate allows a single organization to look after Aids to Navigation, Search and Rescue, Icebreaking, Ship Safety as primary examples with many other related roles also being served.

The specialized nature of each responsibility calls for specific design features on respective dedicated vessels. Unfortunately what benefits one role can be detrimental to the other. For example, rescue vessels working coastal waters should be fast, yet hull design features of speedy vessels rarely lend themselves to the required characteristics of a buoy tender.

This specialization of tasks and designs has led to operational and administrative fragmentation with the advantage of single organizational flexibility being lost in the interdepartmental race for funds and loyalties.

No solution to this problem has been apparent yet multi-tasking has been endorsed and advocated for many years. The lack of a suitable multi-tasked vehicle has been the fundamental problem and this rather than attitudes has prevented efforts from succeeding.

A new generation of rugged, fast and cost effective ACV's is now appearing which could radically alter the attitudes of cost conscious administrators. Such vehicles ideal for multi-tasking may be able to reunite CG departments and fulfill specific departmental objectives without being detrimental to others. Stay posted.