SESSION II

CHAIRMAN'S COMMENTS - C.R. Silversides

The topics covered in this session dealt primarily with two elements of air cushion technology. The first was the local development in Alberta of an air cushion ferry to operate year-round in a northern environment.

The application and principles of air and water lift systems for very heavy loads was also discussed and their place in the hierarchy of applications of air cushion technology were considered. The use of air cushion assist on roads generated most of this session's discussion. There is very considerable interest expressed in such a development, particularly in western Canada and indications of strong support from provincial governments for its further development and application.

The potential benefits from air cushion assist have been recognized and if proven physically feasible and economic, the growth of its use should be exponential in the near future.

REQUIREMENTS FOR THE LA CRETE FERRY AN A.C.V. PROPOSAL

A.R. Rogers
Alberta Transportation

AIR CUSHION VEHICLE FERRIES

Will They Tame the Peace?

During the winter and early spring of 1967, Alberta Research Council in conjunction with Alberta Transportation and Hoverlift Systems, Limited of Calgary, carried out a series of field trials and evaluations with a prototype, ACV cable operated ferry. The purposes of the trials were to observe and gain experience in the winter operation of an ACV towed ferry, and to evaluate the technical feasibility of such a ferry under Alberta operating conditions.

The prototype ACV cable ferry which you will see in the following film is 35' long by 18' wide, has a tare weight of 12 1/2 tons and will carry a payload of 9 tons. The cushion pressure is less than one psi, with a hover height of 18". During the river trials of this machine, it was affectionately dubbed the "Rubber Duck". The surprising performance of this little "critter" was largely responsible for our enthusiasm in further ACV studies and the decision to investigate the use of a full size, ACV ferry in Alberta.

(At this point the film "Winter Trials of an ACV Ferry over the Bow River in Calgary and the Red Deer River at Dorothy", was shown).

Alberta Transportation is a newcomer to the ACV field. In December of 1975, a submission was made to the Department by the NRC Associate Committee on Air Cushion Vehicles to encourage full scale applications of ACVs for use as river crossings and air assist packages. The Department acted on the proposal, and we feel that a great deal of progress has been made in the past ten months.

Alberta Transportation foresees a very real potential for ACVs, not only as river ferries, but as air assist packages for transportation of heavy loads, for providing rapid access to developing northern areas, and as a future means of transportation in conjunction with our highway and railway systems.

With a little imagination, we can see ACVs in the 1980's, doing for Transportation what the model "T" Ford did for the auto industry in the 1920's. We indeed may be at the doorway of a transportation revolution! In any event, you never know until you try!

As stated earlier, the decision to consider the use of an ACV ferry in Alberta was contingent upon the "Rubber Duck" trials. These trials convinced us that ACV ferries could provide a worthwhile contribution to our transportation needs.

The mighty Peace River has long been noted for its spectacular ice flows (Figures 1 and 2). It is also noted for its extreme river level fluctuations. This mighty river immediately came to mind as a challenging location for a full scale ACV ferry operation. We feel, and I'm sure you will agree, that if it will work here, it will work anywhere.

The La Crete ferry crossing over the Peace River is located some 350 miles northwest of Edmonton (Figures 3 and 4). Like other crossings it has presented many problems over the years. Access to the crossing from the west is on a steady 7% gradient changing to 9% for the final 100 yards (Figures 5 and 6). The river at this location is some 2,200 ft. across. Conventional ferries have been providing access across the river for many years. Interruption of service, however, is common during late fall and early spring, when adverse river conditions make river crossings impossible (Figure 7).

The existing La Crete ferry consists of a rigidly fixed tug and barge arrangement and handles some 10,000 vehicles during its six months of operation each year (Figure 8).

An ice crossing provides service for another four months, and for the brave and adventurous (Figure 9) a bit longer.

During the remaining two months, no crossings of any kind can be made; this is during the freeze-up and break-up periods each year. In a developing area, with the only alternate route over 100 miles further, this can present a serious problem (Figure 10).

We expect that an ACV installation at this site will provide almost uninterrupted service, with only a few days during extreme conditions when it would not be feasible to operate the ferry.

The size of the proposed ferry is of prime importance - since it must be large enough to accommodate a standard tractor-trailer unit of some 80,000 lbs, with an overall length of at least 60 ft., and yet be small enough to economically handle single car and pick-up type vehicles. A deck length of 66 ft. with an overall width of 36 ft. has been selected to best suit these requirements.

Design parameters also call for dual, independently operated motor, fan and winch units, each unit capable of maintaining the ferry service without assistance. The proposal suggests a 16' 6" wide central hull which will provide the basic structure and required buoyancy, as well as carry the heavier loads. Two full length side structures each approximately 10 ft wide will carry the power units, fans, winches, control centre, storage facilities and light vehicles such as cars and pick-ups.

It is planned to winch the ferry along two fixed, river bottom cables, attached to shore anchors and fed through on-board squeeze-type winches, one fore and one aft. We foresee no problem conforming to the Navigable Waters Act in using this system.

Tare weight will be in the neighbourhood of 50 tons with an overall operating weight of some 100 tons, and power will be supplied by two standard diesel engines. Since the ferry is planned as a one-man operation, all controls for both power units will be inter-connected and operated from a common control center.

The preliminary design also calls for the ferry to traverse the river with its longitudinal axis parallel to the river flow.

This method, a bit unconventional, has several advantages.

(1) It will allow improved approach gradients to the ferry landing, especially from the west bank, which we would prefer to be no greater than 7%.

(2) It will also simplify the problem of maintaining service during extreme water conditions economically.

(3) Better craft stability in the direction of river flow and in the direction of the prevailing winds at this site is an important benefit as well.

(4) With this system, vehicles which lose control can cross the docked ferry and proceed onto a run-off road parallel to the river, instead of having to ditch the vehicle in the river as is the case in conventional docking river ferries.

(5) It also eliminates conflict between ferry traffic and the ferry winch lines.

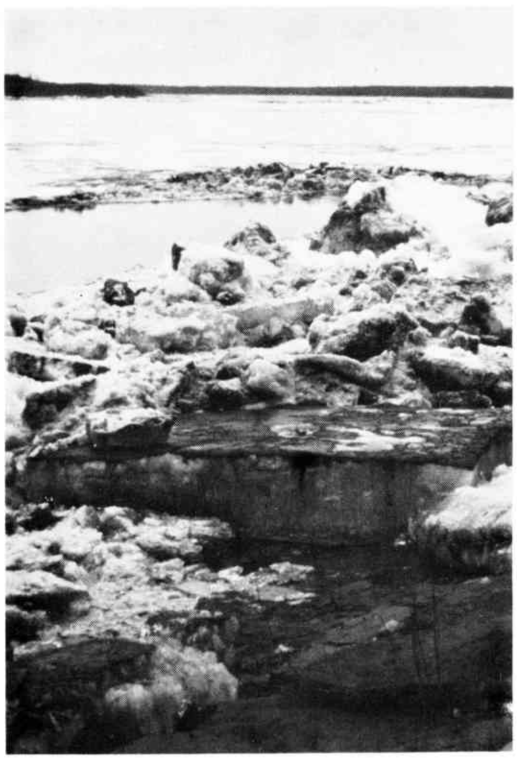
It is expected that trial runs of the proposed ferry will begin in the late spring of 1977, and will be completed by late summer with the ACV ferry then going into full-time public service.

For reasons of economy, it is not planned to operate the ferry during the winter season, when an ice bridge crossing located 300' upstream can be put into service and maintained quite economically; however the ferry will operate until the ice bridge is put into service.

I have been given the task of co-ordinating the project for Alberta Transportation, working in close co-operation with Brian Shields of the Alberta Research Council.

We also hope to have the continued assistance and the benefit of experience from the people in NRC, so that our first uncertain steps in this new field will rapidly develop into a strong, steady, march forward.

And that - in a nutshell - is our plan for the Peace River crossing at La Crete.



FIGURES 1 and 2
Ice flows on the Peace River

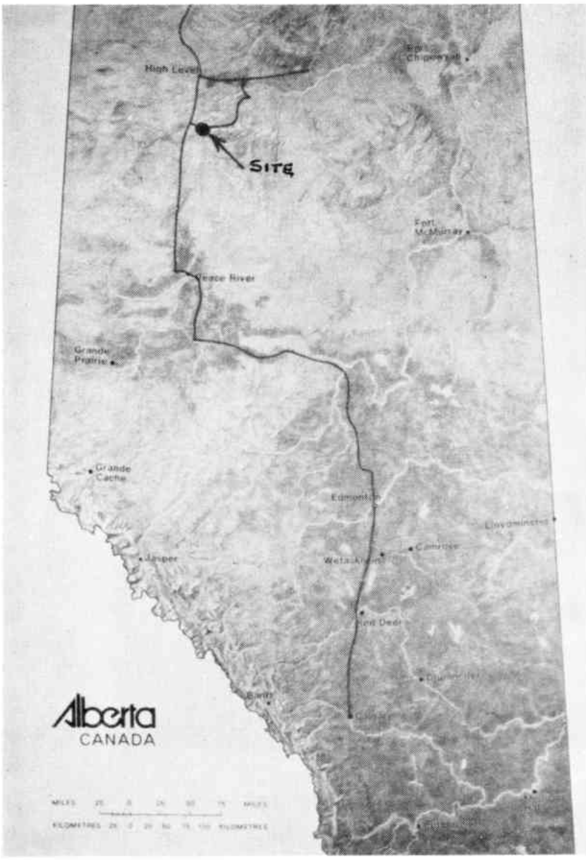


Figure 3 - Location of the La Crete ferry site, 350 miles northwest of Edmonton

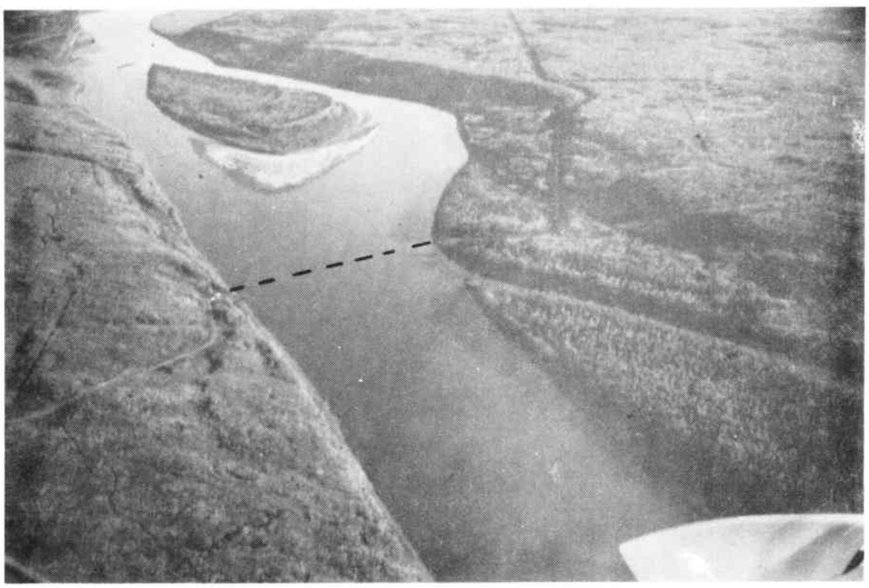


Figure 4 - La Crete ferry site from the air

Figures 5 and 6 - Steep access road to existing ferry site

FIGURE 7 - Adverse ice conditions on river

FIGURE 8 - The existing La Crete ferry

Figure 9 - Final trip on the 'ice bridge' in Spring

Figure 10 - Traffic on the route served by the ferry

AIR AND WATER CUSHION LIFT SYSTEMS

G.M. Parkes
Hoverlift Systems Ltd.

INTRODUCTION

In 1966 a decision was taken by the board of Hovercraft Development Ltd., to establish a special group to apply marine hovercraft technology to the movement of large industrial loads, mainly overland. From the work undertaken by this group between 1966 and 1968 the majority of industrial applications of air cushion technology have been derived.

AIR CUSHION LIFT SYSTEMS

The first commercial application of a pure air cushion lift system was the movement of two oil storage tanks for Esso Petroleum Ltd. in Manchester in 1967. For this move a modified segmented skirt was specially designed and made. The skirt was attached round the base of the tank utilizing special bolted attachment rails, and air from mobile diesel-driven fans was fed into the skirt through flexible hoses.

The design of the skirt was such that any size of tank could be accommodated by adding additional segments to the system and providing an appropriate volume of air.

The initial lifting of the tank is achieved by percolating air under the tank until sufficient pressure is generated to raise the tank from its foundation. Hence the tank is transformed into a temporary air cushion vehicle. No platform is utilized during the move, and the load is reacted directly onto the bottom of the tank. The stability of the tank when on cushion is obtained directly from changes in skirt geometry. All tanks are moved on a monocushion system, and no cushion compartmentation is used.

Once on cushion, the tank may be towed or winched to its new location, and due to the omnidirectional capability for movement of a load moving on an air cushion, precise location of the tank can be achieved.

Since the inception of the system in 1967 over 65 tanks have been relocated using the air cushion technique in 10 different countries of the world and four of the five continents.

With the advent of oil and gas exploration in the North Sea a growing need was generated to find a method of moving large indivisible loads, such as steel fabrications and reinforced concrete structures. Following the success of air in the movement of oil storage tanks, the industry looked at the air cushion as a possible solution. However, unlike the oil tank which can be moved on a cushion at a pressure of about 1/2 p.s.i. (70 mb) these structures required pressures in the order of 5-10 p.s.i. (350-700 mb), and in many cases, because of the configuration of the load, and the offset of the C.G. relative to the planform area, multi cushion systems were required to achieve adequate stability.

In addition, the high pressures required on large structures required the design and manufacture of special diesel-driven fans capable of developing both high flow and high pressure. To this end, four fan units were produced, which, when seriesed in pairs could produce 23,000 cfm (651 m^3/min) per pair at 10 p.s.i. (750 mb).

Special segmented skirt units were designed which could operate at such elevated pressures whilst still giving hoverheights of the order of 18-24 inches (450-600 mm).

In an attempt to achieve a degree of flexibility of application, these segments were mounted on frames, which could be pin-joined onto a variety of different loads, requiring only one make-up length per side to complete the appropriate length.

A load of 730 tons (820 tonnes) was successfully moved using this system. During the trials to develop the technique for moving this load, it became obvious that the use of air as a cushion fluid for such loads would be very restricted for a variety of reasons:

1. The cost of the skirt system, and especially the cost of providing the air blowing machinery would be very high.

2. High pressure cushion systems with relatively large cushion areas required the provision of specially prepared concrete runways on which to operate unlike the low pressure systems which operate over compacted soils.

3. As pressures increased, the danger from the stored energy in the cushion system in the case of a skirt failure became more critical.

WATER CUSHION SYSTEMS

From the foregoing, it became obvious that if cushion systems were to be commercially viable for large dense loads an alternative to air as a cushion fluid had to be investigated. The most obvious choice was water.

Experimental work was undertaken using water as a cushion fluid in a monocushion system having a deep segmented skirt designed for air operation. On a test rig having an all up weight of about 40 tons, movement was obtained using about 1/20th of the lift power required for a comparable air cushion system.

During these trials the idea of using a number of small discrete cushion systems having a low profile and a small, 3" (75 mm) rise height was conceived. Three small test pads were made and tested and it was found practical to lift and move loads on pad pressures of 40-50 p.s.i. (2.7 - 3.4 bar).

These early pads had very conventional segmented skirt systems, and whilst showing considerable economic advantages over comparable air cushion systems, they suffered from two disadvantages namely, high water consumption and short segment life.

In certain circumstances, when loads had to be moved, both these faults could be tolerated, as moves were generally over relatively short distances and often close to or into water. In these cases the economic advantages more than compensated for the shortcomings.

After one or two moves with this equipment it was agreed that if the system was to gain wider acceptance, efforts had to be made to reduce water consumption, not only to economize on power input but to minimize mess.

Skirt life, whilst less important never the less had to be considerably improved to give an acceptable working life. Both these objectives were achieved by the complete redesign of the skirt system, and the use of specialized wear resistant materials. As an added bonus, the redesigned skirt system was found to be capable of operation at pressures up to 80 p.s.i. (5.5 bar) thus enhancing its load carrying capacity.

The first customers to adopt the water cushion system were the ship-building industry, and the first commercial move in the U.K. was the movement of a new hovercraft from build area to test site.

The system has been found to be very useful for the movement and location of prefabricated ship sections during manufacture, and on at least two occasions, the use of water cushion launchways has enabled barges to be built on reclaimed land with no concrete or permanent foundations and launched into the sea over sheet steel launchways laid on the beach. One such barge weighed 18,000 tons.

CONCLUSION

The progression from air to water as a cushion fluid has been logically developed to meet the needs of a few specialized industries. As the use of water as a cushion fluid becomes more widely known, more applications will present themselves. However, like the air cushion before them, they are not the sole answer to everybody's problem, and many applications still exist, and will continue to appear for which air is a more suitable fluid.

To summarize:-

1. Air is ideal where the base area is large in relation to the weight, enabling low cushion pressures to be used.

2. Air is more readily available than water, and where the distance to be moved is large, is probably the only possible fluid. (Water cushion moves across a desert are bad news!!).

3. Where the ground preparation is small or non-existent air is preferable.

4. Air can readily be used in an amphibious mode.

The advantages of water as a cushion fluid are as follows:-

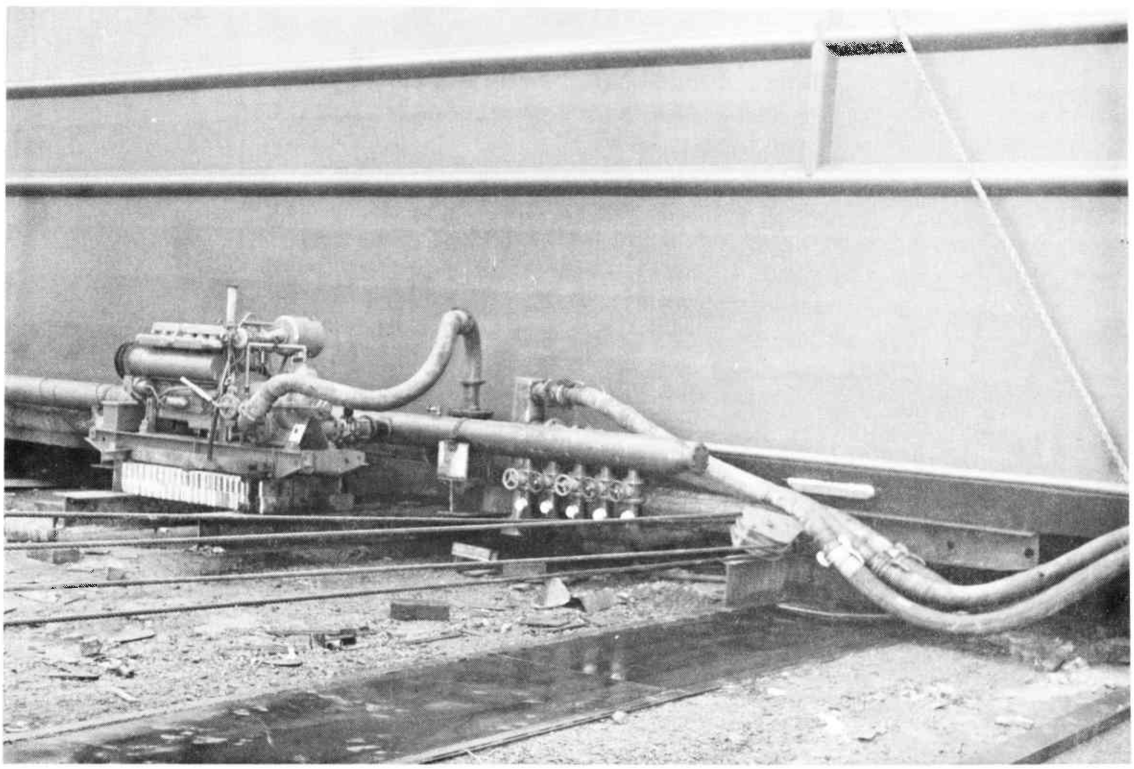
1. Lift power requirements are considerably reduced in comparison to an air cushion system for a similar load, typically 1:25.

2. Much higher pressures can be used provided that a suitable surface on which to react the pressure is available.

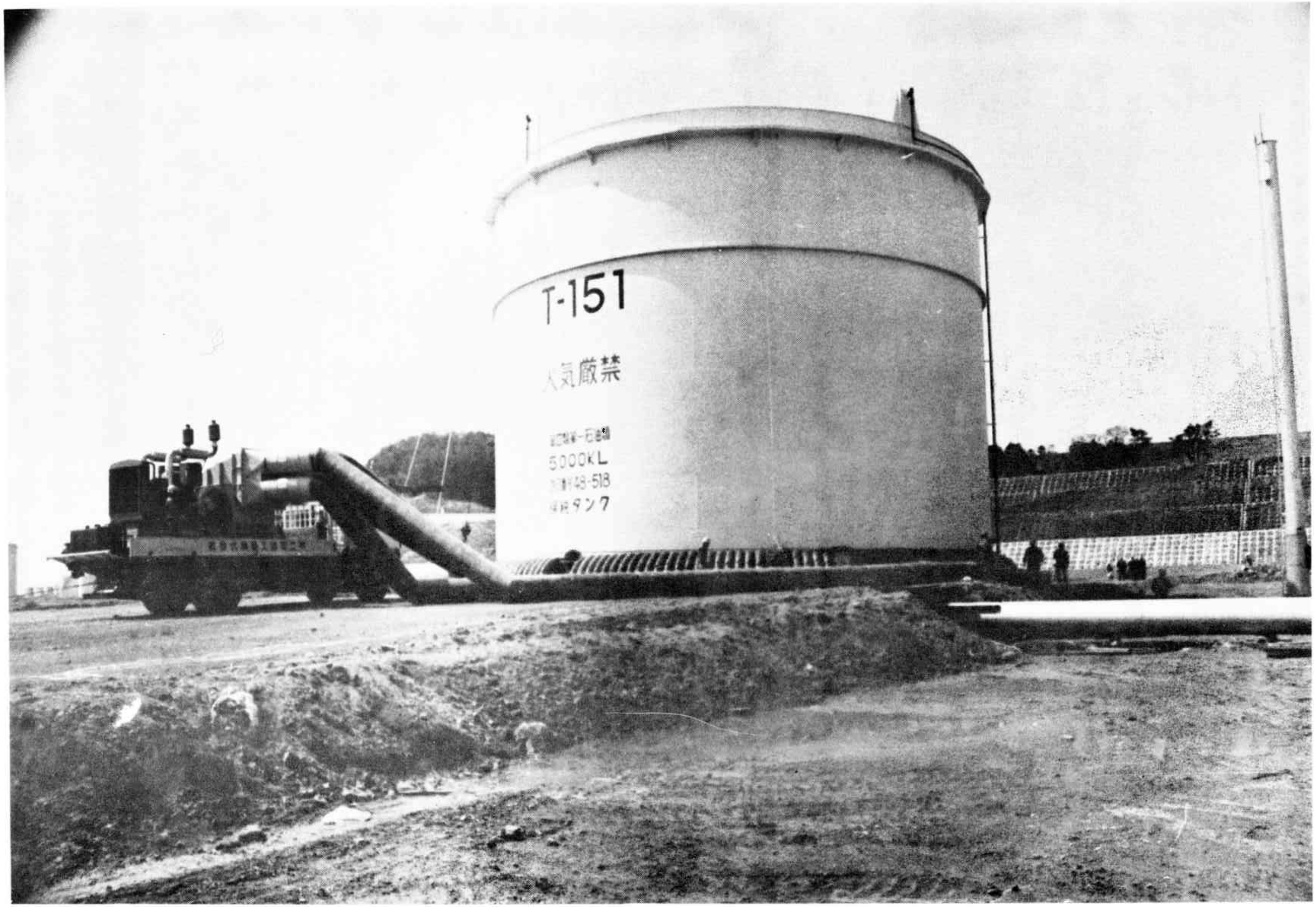
3. Large dense loads can be more readily moved on water cushions and asymetrical loads can be accommodated.

4. Water cushion systems make ideal temporary launch-ways as long as the reaction tracks go far enough into the water for the load to float off under its own buoyancy before the water cushions run off the end of the track.

Barge ready for launch at Pembroke Dock, U.K.



Water cushion pads in position under the barge showing the water distribution manifold and individual feeder hoses.



Route being ramped over a pipeline
during the movement of an oil storage tank in Japan.

AIR CUSHION ASSIST - PRACTICAL APPLICATION IN ALBERTA

H.H. Hendrickson
Alberta Transportation

Load to road regulations across Canada are quite uniform when speaking of normal truck gross vehicle weights. The detail or approach, however, varies widely and this is natural because of the diversity of geology across the land. Ontario and Quebec enjoy an abundance of limestone and solid subgrade in many areas. The limestone offers easily accessible concrete aggregates, so concrete pavements are economic. British Columbia has rock underlying much of their road system and where the valleys do occur they can afford substantially thicker base course construction than the Prairie Provinces. The Prairie Provinces by and large, have poor clay, silt subsoils on which to build roads. This requires great care in the design approach of how a load is transmitted to the highway. Alberta pavements are generally referred to as flexible pavement designs with asphaltic material as the main strength component.

Much loading research has been done in Alberta through actual "on site" sensing of a variety of wheel configurations. This is a joint venture of the Department of Transportation and Alberta Research Council.

The essence of this research proves that axle spacing and the shape of the bearing area (tire contact) must provide the basis in regulation to reflect the engineering findings. This is shown by Alberta Regulation.

Also a very important fact of life is the wide range in road strength when related to the seasons. In "spring break-up", the roads are extremely vulnerable while frozen winter roads are extremely strong. The most critical spring period improves very slowly throughout summer and the roads do not really "bounce" back until September. In short, we have about <u>five</u> seasons with respect to loading.

About 60,000 overload permits are issued in Alberta each year, including a large number of construction equipment moves. There is about a six week to two month period in spring when many movers are prohibited and the ones that are allowed movement require expensive special hauling equipment such as 16 wheel loa bop, dollies, etc. The nature of heavy construction is such that the heavy demand for equipment is at the critical period.

Most loads of construction equipment range from 90,000 lbs. G.V.W. to 130,000 lbs. G.V.W.

If an air assist package can be developed that can make 20,000 lbs. to 40,000 lbs. "disappear" it would make it possible to drastically shorten the prohibition period for overloads and reduce the demand for exotic hauling equipment.

The challenge is there - develop a relatively simple hover package that can be attached to your normal low-boy or hi-boy trailer at a reasonable cost and capable of relieving say 20,000 lbs. minimum to 40,000 lbs. maximum.

I am positive the market is waiting within the heavy haul industry - construction equipment, lumber haul, oil field services, well services, mobile cranes, etc.

The strong inpetus is the possibility of eliminating or drastically curtailing the yearly load ban period.

ON-ROAD AIR CUSHION ASSIST; WHERE IS IT WHEN WE NEED IT?

D. Eyre
Saskatchewan Research Council

INTRODUCTION

The primary aim of this paper is to review briefly the existing on-road transportation practices in Saskatchewan and to show that, on paper at least, there are several practices that could benefit from the application of air cushion technology. Whether or not such applications prove to be viable will depend on a number of technical and economic factors, of which the most important are:

a) Why should the air cushion vehicle industry diversify into the area of on-road air cushion assist? What are the incentives?

b) Can the technology be developed to an acceptable level of competence?

c) Would the new designs of on-road vehicles, using this new technology, be economically competitive?

d) Would these vehicles be acceptable on our roads and, if so, under what conditions?

This brings us to the secondary aim of this paper, which is to review these factors and propose a rational program of development.

BACKGROUND INFORMATION

The advantages of an air cushion assisted vehicle over a conventional one are twofold: first the air cushion assist allows shipment of greater single loads; secondly it can allow the simultaneous reduction of axle load. Therefore, there are potential benefits both to the trucker and to highway construction and maintenance budgets. In view of this, it is instructive to look at the statistics of highway construction and commodity shipment, using the province of Saskatchewan as an example.

Saskatchewan has 11,200 miles of highway (1) and 114,000 miles of municipal roads. The highways are classified into six subsystems according to load design limits, traffic demand and anticipated population growth. Pavement designs range from 3/4" asphalt concrete on prepared grade up to a three-layer system consisting of 3.5" of asphalt concrete with 5.5" of base and 6" of sub-base. Also, there are specialised pavement structures with high load-bearing capacities; catering to intensive shipment of specific commodities. Construction costs range from $40,000 to $500,000 per mile, and maintenance costs range from $3,700 to $4,500 per mile per year.

Figures published for 1971-72 (2) give some idea of the commodities produced by the province in a single year: over 600 million bushels of field crops, about 430 million dollars of raw and processed minerals, and 45 million dollars of assorted lumber products. A large proportion of these commodities are shipped by rail within the province, but most are shipped by truck at some stage. For some commodities, more ton miles are shipped by road than by rail.

Commercial vehicles logged more than 393 million miles on provincial highways in 1975 (3). Equivalent figures are not available for the mileage on municipal roads, but there are indications that the figure is approximately 300 million. Of the total tonnage of commodities shipped by road in 1974 (4), 80.36% was shipped by five-axle semi-trailers. The nearest rival was the three-axle truck with a shipment of 7.24% of total tonnage. Therefore, the five-axle semi-trailer can be regarded as the most popular and, probably, the most economic method of shipping bulk loads on-road. As such, it will provide a useful standard against which to compare the economics of any air assisted vehicle.

Vehicle loads in Saskatchewan are controlled by a network of weighing stations. Size and load restrictions are laid down in the Highway Act (5), and a system of load permits has been formulated on the basis of this Act. On higher quality highways the gross vehicle weight is restricted to 110,000 lbs, with load limits of 35,000 on a tandem axle and 20,000 lbs. on a single axle. On other highways the gross vehicle weight is restricted to 74,000 lbs. with load limits of 32,000 lbs. on a tandem axle and 18,000 lbs. on a single axle. A system of overload permits has been established for some specialised roads, with permit costs varying according to season. On all highways in the province, special permits are needed for vehicles exceeding 8.5 ft. in width or 65 ft. in length.

WHY ON-ROAD?

It should not be assumed that the truckers and the railways are in competition. Neither sector has any desire to compete with the other, and they should be regarded as complementary arms of the transportation industry.

Railroads have the capability of shipping large quantities over large distances at competitive cost. On the debit side, they suffer from scheduling problems and slow turn around. Also, they are restricted to loading and unloading at specific terminals (a problem known as 'spotting'). On-road transportation makes up for these shortcomings by fast turn around, efficient scheduling and minimal spotting problems, but is restricted to comparatively smaller single loads.

The railroads have fallen into disfavour with several industries in Saskatchewan (potash, steel, farming machinery, etc.) primarily because of slow turn around and spotting. To give a brief example; consider the shipment of 80 tons of scrap steel from the Warman subdivision to the Ipsco steel plant in Regina - a distance of about 200 miles:

	Rail	Truck
Cost:	$775	$912
Time:	4 to 8 days	1 day

- the conclusion is obvious.

Generally, therefore, road transportation will always take precedence over rail where there is:

a) A small-load, short-haul problem.
b) A turn around or scheduling problem, either on short-haul or long-haul.
c) A spotting problem.

If the proposed rail line abandonment becomes an established fact, the prairie provinces will be seriously affected. Problems of short-haul, turn around and spotting will be aggravated, and road transportation will assume a much greater importance in consequence.

WHY AN AIR-ASSISTED VEHICLE?

If we look at on-road air assisted vehicle in a general way, without considering their application to specific problems, the picture is not encouraging. We can envisage a five-axle semi-trailer fitted with a complex air cushion package and we instinctively reject the concept - neither the technology nor the economics appear to be realistic. The concept only begins to look promising when it is viewed against specific problems.

There are three on-road transportation problems in Saskatchewan that could probably benefit from the application of air cushion technology, and at least one of these is common to all the prairie provinces:

a) Grain Transportation

Rail line abandonment will have serious social and economic consequences across all three prairie provinces. The immediate effect will be to cut off the links with local grain elevators and replace them with a sparsely distributed network of large throughput elevators at selected rail terminals. Farmers will be obliged to ship their grain over greater distances to the new elevators, as demonstrated in a typical submission to the Hall Commission (6) which summarises increased haulage costs likely to be experienced in several municipalities. Taking two examples from this submission; the first municipality is quite fortunate, average haulage distance will be increased from 11 to 21 miles and the average annual haulage cost to each farmer will be increased from \$649 to \$1006. The second municipality is less fortunate; the distance is increased from 14 to 57 miles, with a consequent cost increase from \$764 to \$2063. These figures are probably as relevant in Alberta and Manitoba as they are in Saskatchewan.

In view of such data it is to be expected that contracting grain truckers will spring into existence as a service to farmers. Whether or not this happens is not particularly important; the main issue is that the municipal roads will experience a much greater volume of traffic - probably with higher axle loads. A dramatic example is furnished by an incident near Yellow Creek, which made it necessary to transport 90,000 bushels of grain over 13 miles of oil-surfaced municipal road. This involved 109 passes by loaded trucks, and on completion of the exercise an expenditure of \$2072 per mile was needed to restore the road to its former condition.

At the same time, the social factors of rail line abandonment are not entirely irrelevant. The grain elevators are the focal point of numerous small prairie towns. If these become redundant many towns will tend to die. The rapid deterioration of the roads around and within the towns will certainly accelerate this process.

There are several other factors, but the point should be fairly obvious by now - on-road air cushion assist offers a simultaneous solution to at least three problems created by rail line abandonment:

i) Grain can be shipped in larger quantities at, presumably, a more competive cost.

ii) Municipal roads would not be exposed to excessive wear.

iii) As a result, the threat to the existence of several towns would be diminished.

b) Lumber Transportation

The Prince Albert Pulpwood Company (PAPCO) supplies lumber to the Prince Albert pulp mill, and has to ensure that an adequate stock is always maintained at the mill site. Transportation is sub-contracted to truckers who move the lumber from northern cutting areas to the mill in a single haul. The traffic is regulated by the Department of Highways through a system of weight checks and permits. Overload permits can be purchased at reduced cost during winter when the highways are more resistant to damage. Lumber transportation is banned on the main supply routes for several weeks during Spring, and this is a major factor in the economics of the PAPCO operation since it introduces a widely-varying rate of activity. In this situation, on-road air cushion assist could benefit PAPCO in two ways: first it would allow transportation of greater single loads; secondly, it could be instrumental in reducing the length of the banned period. PAPCO are very alert to the potential benefits and are lobbying enthusiastically for the development of an air assisted logging trailer.

c) Reduction of Construction Costs on Special Highways

New industries in Saskatchewan may need to ship heavy loads on the highways as part of their continuous operation. In such cases it is sometimes necessary to construct a special road with a high load bearing capacity. The special road from Prince Albert to La Ronge is an example, and was designed to accommodate the PAPCO operation. A similar road exists between Estevan and the U.S. border to accommodate transportation of potash from Estevan.

Where such roads exist, the application of air assist technology can do little except reduce wear and maintenance costs, which is not an insignificant factor. However, the main benefit of the technology would be felt if it were introduced during the planning stage of special roads. Clearly, the ability to reduce axle loads along a planned stretch of road would have a considerable effect on the construction costs. Typically, when such roads are planned, it is on an agreed cost-sharing basis between the Department of Highways and the industry concerned. Both participants would therefore experience a direct benefit.

ANTICIPATED DEVELOPMENTAL PROBLEMS

It is impossible at the present time to draft a specification for an air assisted vehicle that would meet any one of the above applications. It is even impossible to estimate basic design parameters such as the optimum percentage of load relief. A full specification can only result from a meticulous cost and design analysis, which is certain to be inhibited by the lack of a viable design or relevant operational costs. However, an attempt will be made here to point out the major obstacles that are likely to arise:

a) If air assist is to become a successful feature of on-road transportation, it must be every bit as competent, reliable and foolproof as the conventional vehicles now in use.

b) The stability and braking performance must be comparable with that of an equivalent conventional vehicle.

c) Even with the limited data now at our disposal, it is safe to predict that skirt wear will be a major factor in determining operational costs, unless there is a concerted attempt to develop a hard-wearing skirt design.

d) Air assist can be applied either to maximise the load or to minimise the axle load, or a combination of the two. A maximised payload would bring direct benefit to the trucker, whereas a minimised axle load would benefit the Department of Highways. The best operational mode would probably lie somewhere between the two limits, and the resulting economics of operation would depend on whether or not a revision of permit costs could be negotiated. A reduced axle load, with a consequent reduction in road wear and maintenance costs, would obviously be of interest to the Department of Highways - and they might wish to reduce permit costs as an incentive. This could have a considerable bearing on operating costs, and might be the deciding factor in assessing the viability of the technology. However, the required negotiation will not be easy.

e) New weigh scale procedures will have to be devised, and new methods of control will have to be developed to ensure that the stipulated degree of air assist is being maintained. This will require legislative changes, and presupposes a general acceptance of the technology.

f) Noise suppression, dust control and parking with or without air assist can be regarded as peripheral problems during the initial stages of development - these refinements are best left until there is a potentially marketable vehicle to refine.

In summary, there is no quick and easy path leading to the development of an on-road air assisted vehicle. Many of the requirements will stretch the technology well beyond its present limits - and past experience has shown that it is unwise to attempt to force development beyond its natural pace. The long term aim should be to develop a total vehicle design rather than to modify existing vehicles. The latter course, though expedient during the initial stages, will produce a vehicle that is neither one thing nor another - and it will certainly fail to reach the economic optimum that will be required if the technology is to be competitive.

THE MANUFACTURING ADVANTAGES

In this context we must accept that there are several types of air cushion vehicles, of comparable cost, competing for the attention of a small number of manufacturers (who can be counted on the fingers of one hand). The foremost examples are towed air cushion rafts (TACRs) for overland operation, air cushion ferries, air cushion lightering barges and air cushion ice-breakers. Bearing in mind the present state and limitations of the industry (if it can be so described), diversification is not welcome and should not be encouraged.

Since the industry is at present disposed towards TACRs and ferries, the prospects for on-road air assist development look slim. However, there is one compelling argument in favour of such development - the number of potential users is one or two orders of magnitude greater than the total number of potential users of all other vehicle types. At a time when the industry is seeking a firm foundation in the form of a production line, this factor cannot be ignored. Another forcible argument concerns the development of compatible towing techniques. This is a considerable problem in the competing vehicle designs mentioned above, but is a trivial consideration with on-road air assist.

A PROPOSED PROGRAM OF DEVELOPMENT

The history of air cushion vehicle development in Canada has been generally disappointing, though no useful purpose will be served by dwelling on this issue. However, it would be foolhardy to ignore the lessons of this history, which indicate that, in future developmental projects, there should be more emphasis on marketability, potential markets and pure development, and less emphasis on contrived development or research that is not related to the immediate problems of development.

Figure 1 outlines a development program aimed at producing an on-road air assisted vehicle, and incorporates the above factors. Note that there is a detailed projection phase before funds are committed to the manufacture of a prototype, and that the prototype is subjected to a rigorous technical and economic evaluation.

The roles of the federal and provincial governments are indicated. Note that the funding from the provinces becomes available during the prototype stage, and then only in modest amounts. This reflects the present reluctance of the provinces to invest in a technology which is still essentially unproven.

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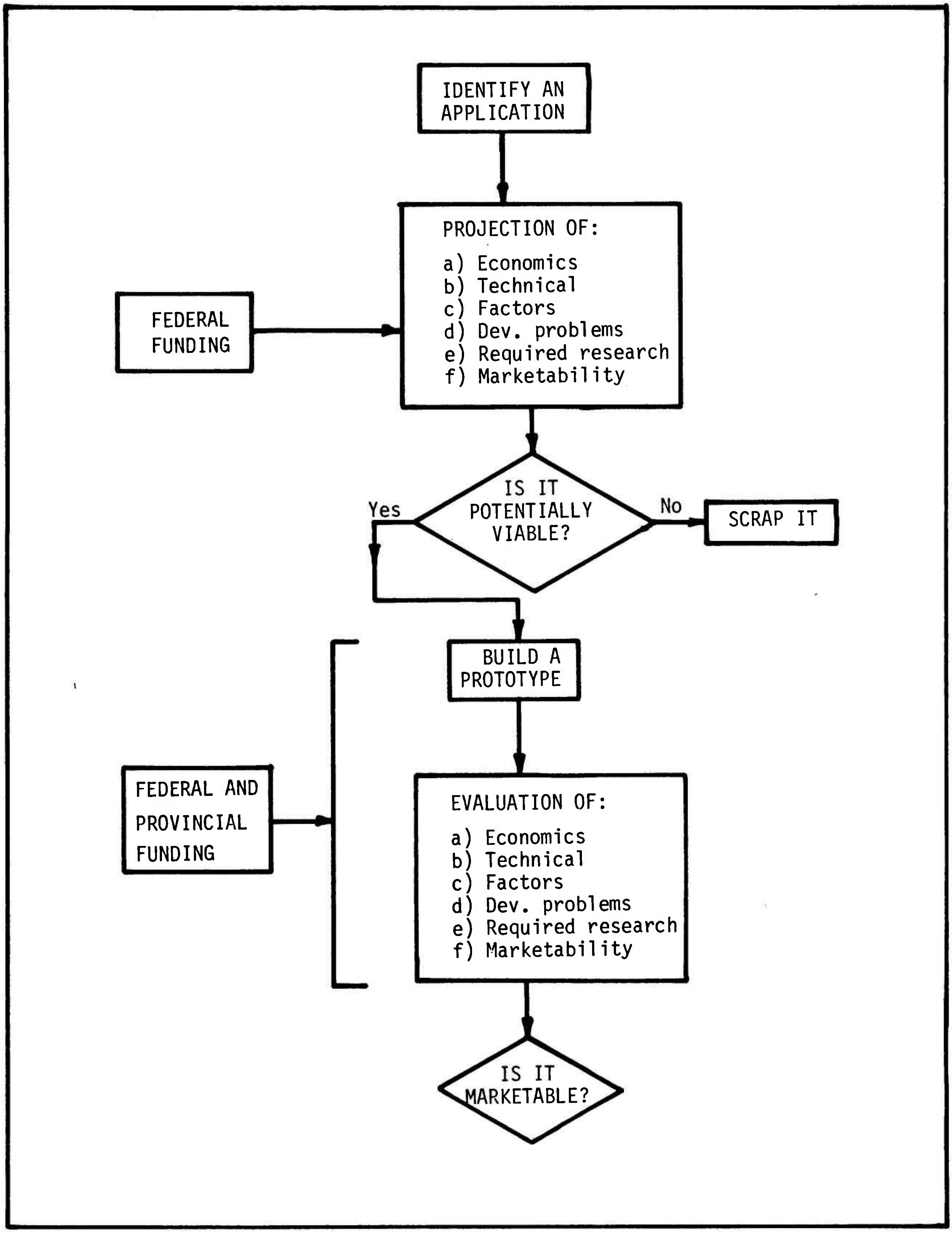

FIGURE 1
Proposed Development Plan
(Continued over page)

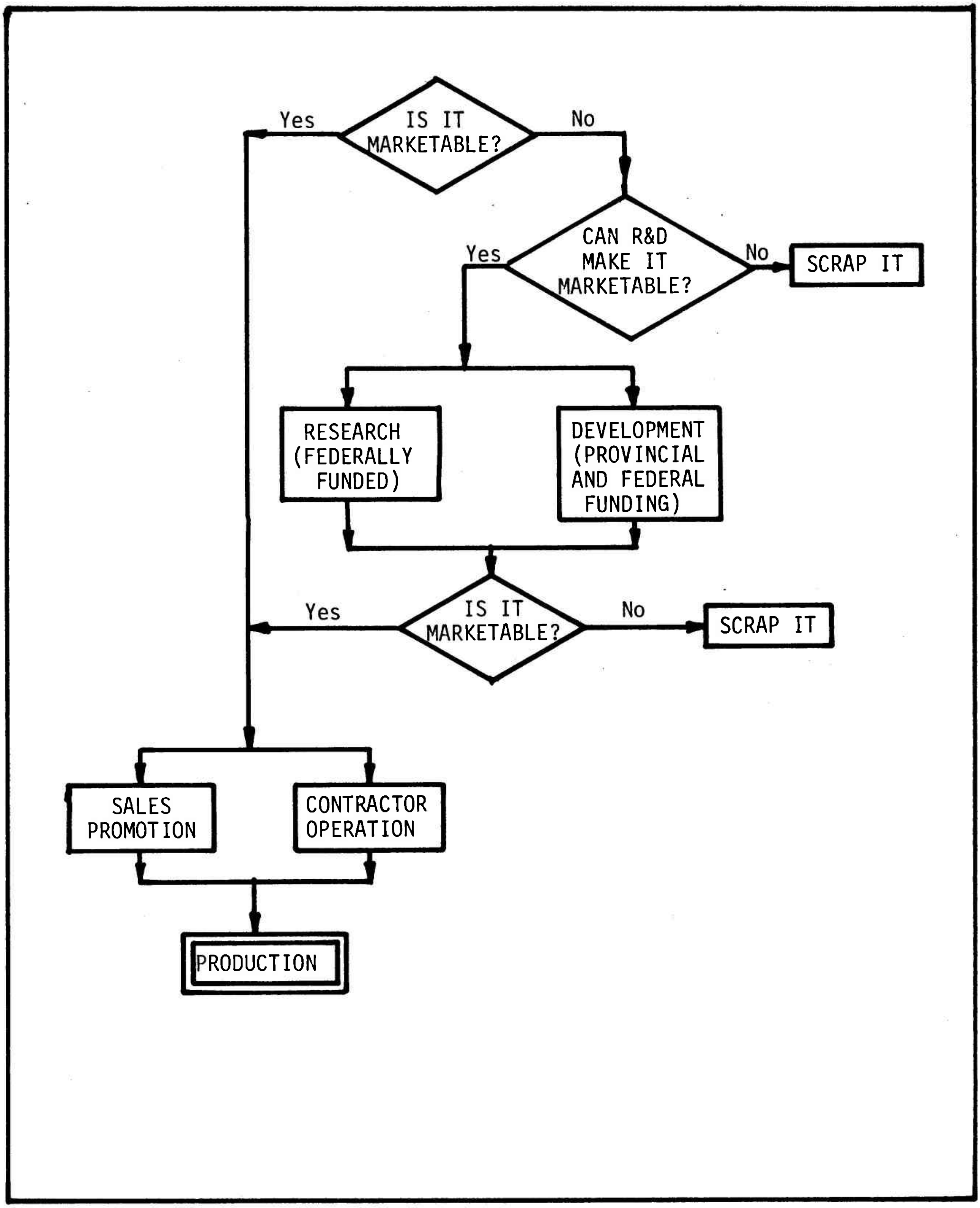

FIGURE 1
Proposed Development Plan
(Continuation)

THE PRESENT STATUS OF AIR CUSHION ASSIST IN CANADA

D. Jones
Jones, Kirwan & Associates Ltd.

1.0 Introduction

The technique of placing an air cushion under a road vehicle to relieve the weight on the wheels has been in use in England for some time, primarily to permit the movement of heavy loads for short distances. For instance, over weak bridges.

The application in Canada is different and involves the reduction of axle loads over weak roads, especially during the half load season imposed by Provincial Highway Authorities in the Spring. The required journey length is therefore much longer, and experience gained in the U.K. may not be applicable to the Canadian environment.

Jones, Kirwan & Associates Ltd. became involved in this field some six years ago when two air cushion assist contracts were awarded to them, one from Ontario Hydro, and the other from Gaymor Trailers as part of a P.A.I.T. program.

This paper outlines the progress of these programs and attempts to forecast the future for this new technology in Canada.

2.0 Air Cushion Assist Categories

A Company market survey, together with the results of The Working Group on Heavy Load of the Air Cushion Sub Committee of the National Research Council suggested that the probable applications would fall into the three following categories:-

a) Heavy Load
b) Conventional High Bed Road Trailer
c) Special Off Road Vehicles

3.0 Heavy Load

3.1 Definition

The definition "Heavy Load" relates to large pieces of equipment, such as transformers, refinery components etc. that are moved once or infrequently. The moves may well entail special precautions such as a police escort and the temporary closing of sections of the highway.

These and additional provisions may be acceptable for air cushion assist moves. Furthermore, the high pressures required to support a heavy load within reasonable cushion dimensions preclude the use of this equipment over terrain other than a prepared surface.

3.2 100 Ton Ontario Hydro Unit

The unit was to be fitted under an existing low bed trailer to meet the following specifications:-

Maximum forward speed = 5 M.P.H.
Air cushion lift = 100 Tons
Journey length = 20 Miles

A review of the then available skirt systems suggested that the Bertin concept would have the best chance of success. However it was difficult to install the ducting to feed the internal cells, and therefore only the outer skirt was used. It was rigidly attached to the trailer frame.

The trials were not a success, although 90 tons were lifted statically. Two main problem areas were identified. The first concerned the deflections of the trailer body under load, which caused excessive skirt ground contact, resulting in a high wear rate. The second involved the mechanical difficulty of joining sections of the highly stressed skirt together.

3.3 Centipede Skirt System

The solution to the trailer deflecting was to place an inflated air bag between a rigid air cushion pallet, containing the skirt system, and the trailer body. This would allow the pallet to move in the three degrees of freedom without being restricted by the trailer frame. The air bag transferred the cushion lift to the trailer.

The question of reducing the stress levels in the skirt material was more complex, and finally resulted in the abandonment of the Bertin concept. It was replaced by a number of oval cells which touched each other to form a peripheral seal which contained the cushion. The number of cells, together with their shape, were chosen to bring the stress levels well below that allowable on the skirt material. They have been designated "Unicells".

A large number of tests at double the normal working pressure confirmed the design. They also showed that a distance of 30 miles could be travelled at five M.P.H. and a cushion pressure of 2.5 P.S.I. before the lift would deteriorate.

The average hovergap was calculated from the measured air flow, cushion pressure, skirt periphery and discharge coefficient at 0.05 inches, which would result in reasonable power levels.

A survey of typical public roads in the Hagersville area showed that there could be a considerable camber and undulation within a typical cushion area. This would lead to extensive skirt wear, if the average hovergap of 0.05 inches was to be maintained in order to achieve reasonable power levels.

One solution was to split the cushion up into a number of loosely connected smaller units, so that the undulation of the surface under each pallet will be small. This concept, together with the Unicell, forms the basis of the Centipede System which is being used by this Company for all the high pressure cushion applications.

3.4 Permissible Road Pressures

During this development period the Ontario Ministry of Transport and Communication had been keeping a watching brief on the progress of this new technology, expecially as some form of licence or permit would be required to operate on a public road.

The stage had now been reached where some idea of the permissible cushion pressures and other limitations were needed so that time and funds would not be wasted developing concepts that would be unacceptable to the Licencing Authority.

A program was therefore carried out in conjunction with O.M.T.C. and the Transport Development Agency in which cushion pressures up to ten P.S.I. were tested over various road surfaces. The results are described in papers published by both O.M.T.C. and T.D.A. and in summary suggest a limit of 4.0 P.S.I. for a gravel road, and 6.0 P.S.I. for an asphalt surface.

The damage to the asphalt surface was caused primarily by the hot fan discharge air, melting the surface. J.K.A. considered that this problem could be overcome by a suitable cooling system, and chose 7.5 P.S.I. as the maximum working pressure for future designs.

3.5 300 Ton Unit

Now that the skirt geometry had been selected and the pressure limits defined another market survey was carried out to identify the size of the unit that would have the best sales potential.

The study resulted in the following specification:-

Payload	=	300	tons
Forward speed	=	5	M.P.H.
Cushion pressure	=	7.5	P.S.I.
Journey length	=	30	miles
Unladen height of low bed	=	12.0	inches

The design study gave a cushion length of 42 feet and width of 14 feet, together with a power requirement of 1,300 H.P. This size would be difficult to handle and it was therefore split into five smaller pallets 8.4 feet long by 14 feet wide.

Before any sales campaign could be started, it was imperative to make sure that the theoretical performance could be met in the field, and although many of the components had been tested a complete rig had not. Funding considerations precluded the design, manufacture and development of a full size unit at this stage, but sufficient information could be gained from one of the pallets. Unfortunately, this size stretched the available air supply to the limit, and a half scale model of a pallet was selected, operating at full cushion pressure.

3.6 Tests on a Half Scale Pallet

The unit was tested statically up to the design cushion pressure of 7.5 P.S.I., although this value was reduced to 6.0 P.S.I. for the forward speed trials, because at the higher value there was insufficient weight on the trailer wheels to provide adequate breaking.

The tests were carried out over a rough concrete floor having a camber of 1.5 inches and random undulations of 1.0 inches. The cushion temperature was reduced to 110^{o}F by water injection, which also acted as a lubricant to reduce the friction between the skirt and ground, thereby extending the skirt life.

The skirts were inspected for wear and damage every 5,000 feet during the 12 mile test distance. The data has been analysed and shows that a journey of 80 miles can be travelled before the cushion will deteriorate to a point where it will no longer maintain the lift. The other components in the system did not show any signs of wear.

The results indicated that the basic design of a 300 ton air cushion assist unit had been established.

3.7 Alternative Devices

There are several other air cushion devices that may be considered, for instance, the track laying A.C.V. and the moving belt. In my opinion they pose complex mechanical problems, expecially if higher speeds are to be considered later. They should be viewed more for second generation vehicles, once the general concept of air cushion assist has been accepted by the transportation industry.

3.8 Cost Data

A preliminary design study was carried out to determine the unit costs, which were as follows:-

Initial cost = \$150,000
Installed power = 1,300 H.P.
Skirt replacement distance = 80 miles
Skirt replacement cost = \$ 15,000

No attempt has been made to compare these costs with alternative methods, because unless an in-depth survey is undertaken in conjunction with a potential user, the results could be biased and misleading.

However it is worthwhile noting that the projected cost of a conventional 300 ton trailer is twice that of upgrading an existing vehicle with air cushion assist.

3.9 Heavy Load Future

The potential market is encouraging, especially as upgrading an existing low bed trailer with air cushion assist shows a marked economic advantage over the purchase of a new vehicle. The position will further improve when this new equipment is considered in the planning stage of a project. For instance, costs could be saved by designing an approach road to take normal traffic rather than build a stronger road for one or infrequent moves. Furthermore the ability to deliver equipment all year round will obviate the necessity to plan moves on a seasonal basis and thus reduce the requirement to stockpile spares.

However, the future will depend to a large extent on funds being available to develop a unit prior to commercial use, together with the attitude of the particular Provincial Government towards adopting legislation to permit the use of air cushions on a public road.

The development costs will be in the order of \$1,250,000.00 and it is highly unlikely that this level will be forthcoming from the private sector.

4.0 Air Cushion Assist to a High Bed Road Trailer

A program to place an air cushion under a conventional high bed standard road trailer has been running concurrent with the heavy load activities, and was originally part of a P.A.I.T. grant.

4.1 Specification

The specification required sufficient cushion lift to permit a fully loaded trailer to operate in the half load season. The unit must fit under a standard trailer, must not be wider than 8.5 feet, and have less than a 200 H.P. engine. The maximum road speed was 50 M.P.H.

4.2 Design

The principle of the bag/skirt combination with unicells was chosen for the basic design. However, the Centipede System was not suitable for this application because the power required to provide sufficient heavy stability to enable the cushion to follow the ground at 50 M.P.H. was uneconomical.

The cushion was therefore only split into two seperate units to facilitate ease of handling. It resulted in a pallet of 10.5 feet long by 8.5 feet wide having a cushion pressure of 2.0 P.S.I. and a hovergap of 0.10 inches.

This relatively small hovergap caused some concern but could not be increased because of the power limitation.

4.3 Test Program

The air cushion system has been installed under a logging trailer for some time, and has undergone testing both in house and by the National Research Council.

The last series of tests were carried out over a private road which was well maintained but had a somewhat wavy surface. There were a number of asphalt patches and eight transverse ridges approximately 1.0 inches high.

A total distance of 94 miles was travelled at an average speed of 35 M.P.H. The measured wear rate indicated that a distance of 1,700 miles could be driven on one set of skirts. However, it must be emphasized that these results pertain to one location only and could well change for different surfaces and speeds.

As a result of these tests some improvements have been made and the design is at a stage where it could be manufactured for field trials.

4.4 Cost Analysis

The cost for a complete air cushion assist package is $25,000.00 and comprises of $12,000.00 for the power unit, equiped with diesel engine, and $6,500.00 for each pallet. A set of replacement skirts cost $1,500.00 per pallet.

Based on the above data, a cost analysis was carried out which showed that the skirt life must exceed a distance of 1,500 miles in order to be competitive.

4.5 Alternative Methods

Over the last few years there has been a move to increase the payload of a truck by adding more axles under the mid section of the chasis. The regulations concerning the extra load that can be carried on these additional axles is complex, and two extra axles do not double the load of a tandem axle trailer. The economics of partially increasing the payload by additional axles should be compared against a larger increase using air cushion assist at a higher initial cost. Unfortunately, this would have to be done on a Province to Province basis.

4.6 Market Potential

There is a very large market for a device that will permit haulage contractors to carry greater loads on existing trailers and trucks. Although an air cushion can meet these needs technically, there is insufficient data on which to base any meaningful comparisons and the economic viability of this new equipment remains to be seen. Unfortunately, some of the advantages may be hidden in such items as the reduction of road damage, the clearing of ice and snow off the highway, etc., and a formula must be found to pass these savings on to the operator.

5.0 Off Road Applications

There are a large number of possible off road applications, ranging from moving heavy pieces of forest machinery to large agricultural vehicles.

I believe that this particular market will develop the fastest because it does not require the passage of legislation and provides equipment with an extra capability, rather than increase performance as with the road vehicle.

6.0 Conclusion

In the past the air cushion has been greatly oversold, resulting, in part, from the requirement to generate funds. This has soured potential customers to a point where new equipment must meet the manufacturers, specifications and the limitations must be clearly defined. Failure to do this may well put the industry back beyond the point of no return.

I believe the technology for air cushion assist has reached a stage where some basic skirt systems have been developed to the point where a reasonable performance and cost can be determined.

However, much more field testing and development is required before the present experimental units can be considered for production.

In the categories chosen for this report, the off road application would seem to have a bright future and the market will probably develop the fastest.

For the road vehicles much depends on the availability of development funding and the attitude of Provincial Legislators. The advantages of air cushion assist to heavy load trailers can be reasonably identified and the prospects for long term sales looks encouraging.

The future for the high speed trailer is not as clear. An in-depth study is required to compare the economics with alternatives and must be supported by much more test data, especially concerning the skirt wear over representative roads.

THE FUTURE OF AIR CUSHION (AC) ASSIST IN CANADA

H.S. Fowler
National Research Council of Canada

Crystal-gazing is a very risky business - but at least if you think ahead you can't be blamed for things that haven't happened yet!

At least let's take off from a firm basis: let's look at what A.C. technology really is.

It is a way of spreading the load, to reduce local ground pressure, to move heavy loads over weak terrain.

It depends on a moderate skirt-to-ground seal to maintain cushion pressure, which implies either a very flexible seal - or flat smooth ground.

So its ideal use is over flat, smooth, erosion-proof ground; in other words, a road.

Canada has plenty of weak roads; roads too weak to carry the industrial loads needed to develop the Northern Prairies. These roads are often over terrain which varies with the season, and is very expensive to stabilise for strong road beds.

So the A.C. PRINCIPLE fits Canada, and the NEED is clear.

A.C. assist has been developed in England, but for a very different purpose. The roads are good, but many elderly bridges have weak decks.

This device is, therefore, used mainly for short lifts over bridges at walking pace, the rest of the journey being run without A.C. assist. The air seal between skirt and road is by chrome/molybdenum steel plates, which last 20 miles or so at walking speed - and the vehicle needs 3 small gas turbine driven compressors to supply it with air.

In other words, the British system is not applicable to the Canadian requirement for long assisted hauls at reasonable speed, although even this limited system is the result of intense engineering effort.

A very serious attempt has already been made here to meet the long-haul moderate speed objective, and I have been quite closely associated with that work.

It is MY PERSONAL OPINION that we are on the horns of a dilemma.

Using skirts developed from marine and off-road technology, we find that EITHER we seal against excessive air flow by running with the skirt almost touching the ground, which means that a normally rough road abrades hell out of the skirt in a short distance; OR that we use so much air to keep the skirt clear of the road that almost the whole load relief is used to carry the blowers, engines, and fuel.

I can see no way THROUGH this dilemma; but I believe there are ways round it.

FIRSTLY: There is a demonstrated need for special hauls of heavy units, (transformers, excavators, etc.), for 50 miles or less, at low speed. I believe this can be met by existing technology, using a cheap, light, throw-away skirt. This will serve one haul, the empty float drives back without it, and a new skirt is used for the next job, at a far lower cost than any other way of doing the job.

But I belive we have shown that if lift is maintained, wear is roughly linear with distance, and proportional to speed or an even higher power.

This technique won't get us any further. What next?

SECONDLY: We can try to make an effective air seal without any physical contact with the ground.

There is a way of doing this which was tried for a different purpose quite a long time ago. It was no good for that purpose, and it was forgotten about. I think it's worth taking a second look at it. It seems to me to have quite a potential here, up to quite high speeds.

THIRDLY: We can try to use a seal which has itself no movement relative to the ground, and therefore very little wear.

There has been a proposal called the "track-laying ACV", in which the vehicle lays down a carpet, hovers along over it, lifts it and lays it down again, like a regular tracked vehicle or Cat, but running entirely on one very broad flexible track. The idea as it stands has some considerable problems, but one can apply the principle in a completely different way which I believe has surprising possibilities. I believe recent developments in other technologies may enable us to do this.

I believe that one or other of these ideas holds out hope of the 30 mph long-range heavy transporter for weak roads, but there is a lot of work ahead. We hope to start it soon. And since all our discussions seem to show that this is probably the most important application of the ACV in Canada, we intend to give it all the priority we have.

I therefore think that some of our heavy transport requirements can be met in the reasonably near future, with existing techniques. But you don't invent a system, get a prototype to do a hundred miles, and then sell it to all and sundry. You have to beat hell out of it for a year after that stage, - until you have a complete vehicle that the development crew just cannot bust. THEN it is ready to productionise.

And I also believe we have some good cards up our sleeves to meet the more advanced requirements, but that will take a little longer.