SESSION 3

Design and Development

SAILRAIL INDUSTRIAL APPLICATION UP-DATE

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Abstract

SailRail is the trademark for the recently developed air cushion system for levitating and guiding heavy loads along extruded aluminium rails. It has been installed in a number of material handling applications and has now generated a world-wide interest. As a result of a very successful exposition at the International Material Handling Show in Chicago in May of this year some 1500 enquiries were processed by the Canadian and USA marketing organizations through 138 sales offices from coast to coast. However, offshore enquiries from many European countries and from Africa, Australia and Japan are difficult to handle expeditiously by a relatively small specialized SailRail staff. Sales arrangements must be put in place with care, and market expansion planned in a controlled manner, especially in the present economic climate.

Market Growth

Market potential is excellent, particularly in high density warehousing - clearly a high growth area due to an accelerated swing to automation and cost reductions in the manufacturing industry. Other applications such as lightweight ground transportation systems now being tested by the Urban Transportation Development Corporation in Kingston should have world-wide market appeal due to the extreme simplicity, the efficiency, and low cost of operation. (See UTDC presentation)

Product Development

With the expansion of SailRail applications and markets, the demand for technical changes is intensified. The early "test, try and see" type of growth no longer suffices. In the subsequent extended development stage, product improvements were not always clearly defined.

Three years of an organized program of research and development have shown that many improvements and modifications can be incorporated directly into the product or system when feasible for both customer and supplier.

Installations

Several warehouse installations have confirmed that the SailRail concept results in considerable savings and improved product flow. Maintenance is very low due to the absence of moving parts. Shoe damage is a problem with manual loading and unloading of racking systems, and therefore special guides have been developed to minimize the load positioning variances for low skilled fork-truck drivers. Shoe damage is not a factor however with automatic systems using stackers.

Operation

Field experience has shown that pneumatic control by air logics is superior costwise to solid state electronics which incur higher labour costs for wiring and conduits. The flow rack valves have been extensively tested in the field and have been adjusted under actual operating conditions. One finding is that product movement in flow racks is superior when the air pulses are very short.

Presentation

An up-to-the minute summary of this new Canadian technology will be presented at the Ottawa meeting. The special operation features and experiences of several installations will be described. This will not be a sales promotion presentation but, rather, an outline of the special problems, concerns and learning processes required when a new air cushion product, and in particular a new Canadian product, is being introduced to current world markets.

CANADIAN COAST GUARD ACIB - 1982/83 TRIALS

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INTRODUCTION

For the past decade, Transport Canada has been actively developing air cushion icebreaking technology in order to explore the technical, economic and commercial implications of this innovative icebreaking phenomenon.

Full-scale testing with an icebreaking bow platform was first carried out at Thunder Bay in 1975/76. The air cushion vehicle used was a 100 ton capacity Arctic transporter (ACT-100) provided by Arctic Systems Ltd. The ACT-100 air cushion platform was modified to fit the bow of CCGS ALEXANDER HENRY. Compared to her normal performance, the icebreaker with the air cushion platform attached was able not only to break substantially thicker ice, but did it while progressing at higher speeds, using much less fuel and leaving a wider track for other ships to follow.

A second series of full-scale tests was undertaken during the winter of 1976/77. The object of these tests was to demonstrate the commercial application of the air cushion platform, and to accumulate additional data on its capability under operational conditions with commercial type vessels. The technique for the demonstration was to use the commercial tug THUNDER CAPE or the CCGS GRIFFON to push the ACT-100 air cushion icebreaking platform to a vessel requiring a temporary icebreaking assistance. During the trial, the commercial vessel IMPERIAL ST. CLAIR was assisted in this manner. In addition, the ACV was attached to the bow of the ST. CLAIR to demonstrate the feasibility of such an operation. These trials showed a threefold improvement in the icebreaking capability of the combination ship and ACIB over that of the icebreaker operating alone.

In 1979, the Canadian Coast Guard contracted for a purpose designed Air Cushion Icebreaking Bow (ACIB) to be built by Hoverlift Systems Limited (HSL) in Calgary. When Hoverlift Systems were unable to deliver the ACIB to Transport Canada in fully operating condition, as required by their contract, the Transportation Development Centre (TDC) was tasked by Coast Guard to prepare the craft for testing and carry out initial tests of the design.

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In the Fall of 1981, the ACIB was moved from Calgary to Thunder Bay, the site of the earlier ACT-100 trials. The craft was completed and limited tests were carried out late in the 1981/82 winter season. These tests achieved a performance which was, in some respects, similar to that of the earlier icebreaking platform. they also identified a number of design deficiencies which required correction prior to further testing.

In order to complete the evaluation, and to explore the full operating envelope of the ACIB, it was planned to carry out certain essential repairs and modifications to the craft and to conduct a further test program over varying ice thicknesses, using one or more host ships, during the 1982/83 winter season. The proposed plan of action was to select a prime contractor for the evaluation, who would be responsible for the establishment of a test plan, the implementation of the essential repairs and modification of the ACIB, the day-to-day maintenance and operation of the craft, the direction of the trials (in co-operation with TDC and the Canadian Coast Guard), the collection of data, the analysis of test results (including extrapolation of these results to describe an ACIB suitable for use in the Arctic), and the preparation of reports. A contract was awarded to German & Milne Inc. on 22 November 1982.

The objectives of the 1982/83 trials were:

1. To explore and define, in quantitative terms, the performance parameters of the ACIB.

2. To gain operational experience with the ACIB to the greatest extent practical during the 1982/83 winter season.

1982/83 TRIALS

The 1981/82 trials were carried out under environmental conditions which could not be related to a properly planned ice management program. Inconclusive results were obtained in very flexible ice and consequently the potential of the ACIB was not revealed. Thus the 1982/83 ice management program for Thunder Bay district was planned as usual, assuming a conventional operation using the CCGS ALEXANDER HENRY, with use to be made of the ACIB on an availability basis. It was not appreciated by the trials personnel that since the ACIB/ALEXANDER HENRY combination would break ice at over ten times the rate achieved by the ALEXANDER HENRY alone, acceptable down-time

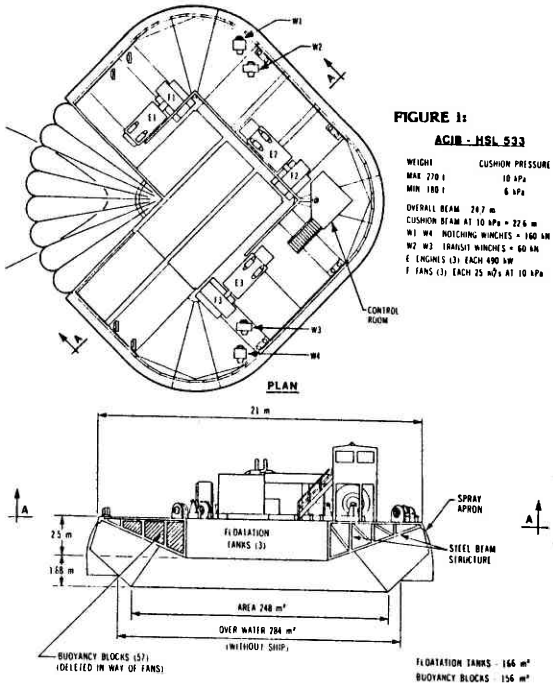


FIGURE 1:

ACIB - HSL 533

WEIGHT — CUSHION PRESSURE
MAX 270 t — 10 kPa
MIN 180 t — 6 kPa

OVERALL BEAM 24.7 m
CUSHION BEAM AT 10 kPa = 22.6 m
W1 W4 NOTCHING WINCHES = 160 kN
W2 W3 TRANSIT WINCHES = 60 kN
E ENGINES (3) EACH 690 kW
F FANS (3) EACH 25 m³/s AT 10 kPa

could take on a different meaning. As a consequence during the trials, too much emphasis was placed on every day availability of the ACIB and additional cost was incurred as a result in rushed and overtime work. However, the objectives of the trials were met.

The 1982/83 trials may be summarized as follows:

SHIP	THUNDER CAPE	ALEXANDER HENRY
OWNER	Western Engineering Service Ltd., Thunder Bay	Canadian Coast Guard, Ottawa
BUILT/COUNTRY /YEAR	UK/1944	Canada/1959
TONNAGE/GROSS /DWT (t)	239/0	1518/973
LENGTH/DRAFT (m)	32.6/3.7	60.3/5.9
REMARKS	Tug, general towing & harbour.	Light icebreaker/supply & buoy ship/SAR.
POWER/FUEL (kW)	1058B/Diesel	1322B x 2/Diesel
SPEED (knots)	12.0	12.0

TABLE 1: SHIP CHARACTERISTICS

1. PREPARATION:

A very extensive program of repairs and modifications was carried out and initial, unnotched tests completed by mid-January. That this was possible was due entirely to very mild weather and to the enthusiastic commitment of Vulcan Machinery & Equipment and Rematech Industries to the project. No significant difficulties were encountered except with the hydraulic system control valves and winch brakes and, in general, the design changes, principally in the notch area and to the attachments of the skirt segments, were very successful. Hover testing over land produced the expected heave instability, but the craft performed satisfactorily over water, and the absence of major air leaks and the smooth inflation of the notch segments was apparent.

DATE	EVENT
19 Jan 83	Checkout over land.
20 Jan. 83	Launched.
21 Jan. 83	Checkout over water. Static hover tests at 282.4 tonnes.
27 Jan. 83	Small vessel tests. Hover time: 8 hours. Icebreaking time: 4.5 hours. Distance: 23.1 km (12.5 nautical miles)
28 Jan. 83	Notching and functional checks with the ALEXANDER HENRY. Hover time: 6 hours. Icebreaking time: 2.5 hours. Distance 8.3 km (4.5 nautical miles)
31 Jan. 83	Icebreaking performance with the ALEXANDER HENRY. Hover time: 4.75 hours. Icebreaking time: 4 hours. Distance: 25.9 km (14 nautical miles)
1 Feb. 83	Icebreaking performance with the ALEXANDER HENRY. Hover time: 10 hours. Icebreaking time: 9.25 hours. Distance: 63.0 km (34 nautical miles)
2 Feb. 83	ACIB beached for repairs to skirt soles.
24 Feb. 83	Static hover tests over land. Clutch failed.
3 Mar. 83	ACIB launched.
4 Mar. 83	ACIB ballasted to 260 tonnes.
7 Mar. 83	ACIB notched with the ALEXANDER HENRY and hover tests performed.
8 Mar. 83	ACIB/ALEXANDER HENRY operational trials. Hover time: 8 hours. Icebreaking time: 7 hours. Distance: 22.2 km (12 nautical miles)
9 Mar. 83	ACIB/ALEXANDER HENRY operational trials. Hover time: 6 hours. Icebreaking time: 3.6 hours. Distance: 25.9 km (14 nautical miles), (197 tonnes)
10 Mar. 83	ACIB/ALEXANDER HENRY operational trials. Hover time: 15 hours. Icebreaking time: 11.5 hours. Distance: 72.3 km (39 nautical miles)
11 Mar. 83	ACIB beached for inspection and essential repairs.
15 Mar. 83	ACIB launched and notched with the ALEXANDER HENRY.
16 Mar. 83	ACIB checkout moving astern. Hover time: 1.75 hours. Icebreaking time: 1.0 hours. Distance: 1.85 km (1.0 nautical miles). ACIB/ALEXANDER HENRY icebreaking inside the breakwater (66 cm ice). Hover time: 2.5 hours. Icebreaking time: 2.0 hours. distance 4.4 km (2.4 nautical miles)
17 Mar. 83	ACIB/ALEXANDER HENRY icebreaking in the harbour and open water tests. Hover time: 6.5 hours. Icebreaking time: 1.0 hours. Distance over ice 3.7 km (2.0 nautical miles). distance over water 20.4 km (11.0 nautical miles).

TABLE 2: SUMMARY OF EVENTS

2. SMALL VESSEL TESTS

The tug THUNDER CAPE (Western Engineering Service Ltd.) was selected for small vessel tests, largely because of availability. Its characteristics are given in Figure 1. Charter cost was $500/hour. It was necessary to remove the bumpers from the THUNDER CAPE and to fair over various attachment points as well as the heavy strake. Notching proved to be straightforward and the test went very smoothly. 4.5 hours of icebreaking time was achieved, during which 12.5 nautical miles were covered in 30-35 cm of ice. Maximum sustained speed was 5.4 knots, and the CCGS ALEXANDER HENRY, breaking ice on its own, was unable to keep up. The turning circles were particularly impressive, a minimum of 25 m radius being clearly indicative of the potential for breaking leads and dock areas.



FIGURE 2: ACIB/THUNDER CAPE

3. PERFORMANCE TESTS WITH CCGS ALEXANDER HENRY

The light icebreaker ALEXANDER HENRY is assigned to the CCG Sub-Base at Thunder Bay for ice management during the winter season and had been used as the partner for the ACT-100 and for the initial trials of the ACIB. Notching was good and testing was carried out on three days, during which 53 nautical miles were covered in a total of 16 hours. Ice thickness varied from 16 to 26 cm, with occasional thicker ridges and some snow cover. Speeds up to 6.5 knots were achieved and no problems were encountered, although it was noted that there was some deceleration through ridges, a marked increase in resistance with snow cover and that wind speed and direction also affected performance. Although the behaviour of the craft had not been affected, some skirt segment damage was found to have occurred and ironically, because all the tests were with the ship going ahead, the damage was all to sole plates and flaps designed to prevent ice entering skirt segments when going astern. Damage was almost entirely confined to forward segments; in the rear, the sole plates and flaps had worked well.



FIGURE 3: ACIB/ALEXANDER HENRY

4. MAINTENANCE FOLLOWING PERFORMANCE TRIALS

After some philosophizing on the requirement for sole plates and flaps on forward segments, prudence led to an extensive and hurried modification and repair program during which the flap was eliminated and the sole extended to lower lip of the segment. This would probably have been successful, but the work was rushed, carried out in very cold conditions, and it was not appreciated that sub-freezing temperatures arrested the curing of the rubber bonds. During hover tests after repairs, a catastrophic fan drive clutch failure was experienced. This was due to overheating, and the clutch was replaced, the other two clutches being inspected at the same time.

5. OPERATIONAL TRIALS WITH CCGS ALEXANDER HENRY

The object of these trials was to make the ACIB available to the Captain of the ALEXANDER HENRY as an accessory to assist in the ice management task, and to operate the craft with CCG personnel. These trials also went well, and some 28 hours of icebreaking time were put in during which over 70 nautical miles of ice was broken. The craft was operated in both the manned mode, controlled from the ACIB control room, and the unmanned mode, controlled from the Bridge of the ALEXANDER HENRY. CCG personnel had no difficulties.

During these trials a number of sole pieces came adrift. However, at this point the icebreaking was virtually complete and it was decided not to make any further repairs until the problem had been studied further. One further day was required, during which a run of 11 nautical miles out and back over water was also made and a speed of 7.4 knots was reached (limited by ship's power). No additional damage appeared to be incurred.

6. STORAGE:

Following the operational trials, the craft was beached on a pad formed from the ballast blocks and decommissioned to a caretaking status pending decisions regarding its future.

TEST RESULTS

Since the primary objective was really to demonstrate the viability of the ACIB, it was decided in the interests of reliability and cost to use the simplest instrumentation commensurate with ease of use and accuracy. The only continuous records taken were the speeds of the shafts on either side of the fluid couplings in the ALEXANDER HENRY's propulsion units in order to obtain an indication of slippage across the couplings. It was hoped that this might indicate the frequency of ice strikes on the propellers.

During the program a distance of 250 km was covered in 9 days of operations in ice thicknesses ranging from 25 to 66 cm. The major events are listed in Table 2.

For convenience in relating cushion pressure to ice thickness, these have been given in centimetres of water, gauge. Hover heights are distances in metres from deck level to the ice, water or ground level as appropriate.

The following performance parameters of the ACIB/ship combination were measured:

- o Ship's propeller shaft RPM versus speed
- o Width of the broken path and size of the ice pieces
- o Turning radius capability in ice of various thicknesses
- o Change in ACIB trim versus speed
- o Fuel consumption
- o Open water performance

Tests on the ACIB alone were also required to determine:

- o Hover height and trim angles versus cushion pressure
- o Freeboard versus ballast weight

SHAFT RPM VERSUS SPEED

The shaft RPM versus speed data was obtained as an intermediate step in determining the thrust required to propel the ACIB at various speeds. The thrust determinations will be made from the results of future bollard pull tests in which the ship's thrust and shaft RPM will be measured under varying load conditions. This information will be combined with the shaft RPM/speed data obtained during the ACIB trials to provide the required thrust/speed curves.

The shaft RPM and speed data obtained during the trials are tabulated in Table 3 together with information on ice conditions, path width and piece size.

The speed of the ACIB/ship combination was highly sensitive to snow cover, ice thickness, wind velocity and cushion pressure. The combined effect of snow cover and ice thickness was particularly evident in passing over ridges where drifted snow had reached a depth of 30 to 60 cm and ice thickness

Date	Ship	ICE: Thickness (cm)	ICE: condition	SHIP: Shaft RPM	SHIP: Speed (kt)	ACIB: Height (ft) x; c.g. o. (m) y:	ACIB: Eng. RPM	ACIB: Cushion Press. (cm)	ACIB: Hover Height (m)	PATH: Width (m)	PATH: Piece Size (m)	TEMPS: Air (°C)	TEMPS: Water (°C)	REMARKS
27 Jan.	THUNDER CAPE	35	Clear with scattered snow patches	155 175 185 197	3.0 3.5 4.5 5.4	210 x: 0.0 y:0.47	1600	71.0	3.50	30	2.5	-12	0	
		75	Ridge - snow covered	180	4.0/ 1.5					27	3.0			Slowed but not halted by ridge.
		65	8 cm snow cover	155 185 199	1.5 2.5 3.0					27	3.0			
31 Jan.	ALEXANDER HENRY	35	10 cm new snow	100/100 150/150 210/210 220/225 225/230	1.2 2.5 4.5 5.4 5.9	201 x: 0.0 y: 0.78	1600	71.0	3.45	30 36	2.5 2.0	-7	0	
		65	8 cm old 10 cm new snow	210/215	3.0			69.5	3.40	30	3.0			
1 Feb.		40	10 cm snow	100/100 150/150 200/200 224/228	1.4 2.5 4.3 5.3	201 x: 0.0 y:0.78	1600	75.0 72.0	3.35 3.25	30 36	2.5 2.0	-11	0	
		40 to 75	Ridge - snow covered	150/150	2.0/0			73.5	3.25	27	3.0			Halted by ridge.
8 Mar.		50	Water covered	145/150 170/175 210/225	1.5 2.3 3.5	263.7 x: -0.26 y: 0.74	1800	92.5	2.95	30	3.0	+2	+3/4	
				220/230	4.2			85.0	2.45	36	3.5			Ice strikes on craft structure.
		65	Water covered	210/225	3.5			89.0	2.90	33	3.0		+1.0	
9 Mar.		50	Snow patches over clear ice.	190/195 190/195 225/225	5.4 4.2 6.5	199.7 x: -0.05 y: 0.73	1600	70.0 71.0	3.50 3.50	33 36	2.5 2.0	+9	+1.0	Following wind Head wind
		65	Frozen snow cover	215/220	4.3			68.5	3.40	30	3.0			
10/11 Mar.		50	Snow patches over clear ice	170/175 180/185 190/195	3.0 3.5 4.5	199.7 x: -0.05 y: 0.73	1600	68.5	3.40	33 65	3.0 2.5	-5	+1.5	
16 Mar.		65	Frozen snow cover	150/160	2.0	199.7 x:-0.05 y: 0.73	1600	72	3.40	30	3.5	+1		

* Centre of Gravity: Reference - Geometric Centre. X: Port/Starboard, Port Positive
Y: Fore/Aft, Forward Positive

TABLE 3: Icebreaking Performance Summary

approached or exceeded the cushion pressure. In one instance when the ACIB/ALEXANDER HENRY approached such a ridge at slow speed (2 knots) the craft was brought to a halt. In a similar instance with the ACIB/THUNDER CAPE, the craft was slowed from 4.0 to 1.5 knots. Also, minor variations in speed were noted as the craft passed from clear ice onto patches of snow. The effect of ice thickness alone on speed was apparent when comparing speeds obtained in 66 cm ice inside the breakwater with those obtained in thinner ice outside the breakwater. At comparable shaft speeds and cushion pressures, speed differences of up to 2 knots were recorded. However, reliable speed determinations inside the breakwater were difficult to obtain because of the short lengths of the runs and the lack of undisturbed ice. Frequent passages along the channels inside the breakwater had left a jumble of ice.

The effect of wind velocity was observed on runs with the ACIB/ALEXANDER HENRY on reciprocal headings at constant shaft RPM. With a following wind of 5 to 10 knots, a speed of 5.4 knots was achieved at shaft speeds of 190/195 RPM. On the reciprocal course, heading into wind, the speed was 4.2 knots.

The effect of ACIB weight and cushion pressure on speed was observed during operations on two successive days in ice of comparable thickness and surface condition. On the first day the craft was operated at its maximum authorized weight of 264 tonnes and a cushion pressure of 90 cm. On the second day, the weight was 200 tonnes and the cushion pressure 70 cm. The speeds achieved in the heavy weight, high cushion pressure condition were approximately 2 knots lower than those achieved in the light weight, moderate cushion pressure condition.

When operating in 50 cm ice in the heavy weight condition with cushion pressures of the order of 90 cm, a marked decrease in cushion pressure occurred when the speed was increased to 4 knots. At this speed, the ice sheet was extending under the craft far enough and high enough to strike its structure near the sides of the buoyancy tanks. It appeared from the underdeck video camera coverage that the intact ice sheet was rising as it moved further under the craft. In the interest of safety, it was necessary to keep the speed below 3 knots for the remainder of the day's operation.

The maximum speed achieved during the icebreaking trials was 6.5 knots. This occurred operating with the ALEXANDER HENRY in predominantly clear ice, 50 cm thick. The practical speed of icebreaking in comparable ice conditions was considered to be about 4 knots. At higher speeds, it was felt that skirt wear would be markedly accelerated, however, insufficient testing was done to confirm this. At lower speeds, there was a tendency to be slowed excessively as the craft encountered areas of drifted snow or other surface irregularities. Further, at low speed there was an increased amount of spray as described in the following section.

PATH WIDTH AND PIECE SIZE

At no time during the trials was the width of the broken track less than the width of the ACIB. Minimum path widths occurred at slow speeds in the 60 to 66 cm ice encountered inside the breakwater. Under these conditions, the average path width was 30 metres. The maximum path width occurred during sustained runs at 4.2 knots in smooth, relatively snow-free undisturbed ice 50 cm thick. The width achieved was 45 m with the initial fracturing of the ice occurring along a line comparable to a bow wave.

At slow speeds, the initial fracturing occurred ahead of the craft. As speeds reached 4 to 5 knots, breaking occurred inside the skirts. This resulted in a marked decrease in the spray in the bow area.

The size of the broken pieces varied widely. At low speeds in the 60 to 66 cm ice, the major dimension of the larger slabs was as much as 3.5 m. At higher speeds in 30 to 35 cm ice, the piece size was of the order of 1.5 to 1.0 m. Throughout the trials the ice remained relatively brittle even though the air temperature rose above 0°C on occasion. A marked decrease in piece size occurred when passing over previously broken and refrozen tracks.

TURNING RADIUS

Turning radius tests were performed with the ACIB/THUNDER CAPE and the ACIB/ALEXANDER HENRY. The turning performance of the ACIB/THUNDER CAPE was particularly impressive. In 40 cm ice, its turning radius was 25 metres - equivalent to the width of the ACIB. This capability would be of particular value in icebreaking operations in and around the harbour slips.

The initial turning radius tests with the ACIB/ALEXANDER HENRY were performed in 40 cm ice with subsequent checks in 50 cm ice. Meaningful tests in the thicker ice inside the breakwater could not be performed because of the limited width of the navigable channel.

The ACIB turning radius with both engines at full speed and the rudder hard over was 600 metres. The turning radius with one engine stopped, the other at full speed and the rudder hard over was 185 metres. As a comparison, the open water turning radius was checked. With both engines at full speed and the rudder hard over, the radius was 185 metres.

TRIM ANGLE VERSUS SPEED

Very little change in trim angle was observed during the icebreaking trials as speed was increased. Over the speed range of 0 to 5 knots, the change was +0.5° (nose up). Similarly, the trim angles measured during the open water trials showed little change over the speed range of 0 to 5.5 knots, however, a +1.0° (nose up) change occurred as the speed was increased from 5.5 knots to 7.4 knots.

FUEL CONSUMPTION

Fuel consumption runs were made with the ACIB/ALEXANDER HENRY on 1 February 1983 for the purpose of determining the optimum speed of operation insofar as fuel economy was concerned. The results of these runs are tabulated in Table 4.

Ice Conditions: 40 cm thick, 10 cm snow cover

SHAFT RPM		SPEED	DIST. TRAVELLED	FUEL CONSUMPTION (l)			FUEL (l/km)
P	S	(knots)	(km)	Ship	ACIB	Both	Both
100	100	1.4	0.83	36.4	70.9	107.3	128.5
150	150	2.5	1.54	50.0	83.2	133.2	86.5
200	200	4.4	3.26	113.6	100.0	213.6	65.5
224	228	5.3	5.93	222.7	141.8	364.5	61.5
200	200	4.1	3.15	122.7	100.0	222.7	70.7
150	150	3.2	1.48	36.4	62.3	98.7	66.7
220	220	4.7	6.58	295.5	187.3	482.8	73.4

TABLE 4: Fuel Consumption vs Speed - ACIB/ALEXANDER HENRY

Additionally, fuel consumption records were maintained on all of the other trial runs with the ACIB/ALEXANDER HENRY and on two runs with the ALEXANDER HENRY alone. These results are contained in Table 5.

DATE	ICE CONDITIONS	DIST. TRAVELLED (km)	FUEL CONSUMPTION (l) Ship	ACIB	Both	FUEL (l/km) Both
31 Jan. 83	30-35 cm thick 10 cm snow	25.9	1,064	818	1,882	72.7
2 Feb. 83	40 cm thick 10 cm snow	1.1	441	(A.H. alone)		397.0
5/6 Mar. 83	25-50 cm thick 10 cm snow	12.0	10,442	(A.H. alone)		870.0
8 Mar. 83	50 cm thick water covered	22.2	973	1,500	2,473	111.4
9 Mar. 83	50 cm thick snow patches	25.9	1,027	955	1,982	76.5
10 Mar. 83	50 cm thick snow patches	72.3	2,728	2,750	5,478	75.8

TABLE 5: Average Fuel Consumption - ACIB/ALEXANDER HENRY

Evidently, significant savings in fuel costs could be made by employing the ACIB in icebreaking operations; however, of perhaps greater significance is the speed with which such operations can be performed and also the marked reduction in wear on the ship's engines, fluid couplings and hull as compared to icebreaking operations alone. Alternatively, even greater savings could be realized by employing a smaller craft such as the tug THUNDER CAPE as the motive vessel.

OPEN WATER TRIALS

The open water trials were performed to determine the performance characteristics of the ACIB/ALEXANDER HENRY when operated under conditions that would prevail in moving the craft from one base of operations to another. Of particular interest was the maximum practical speed of operation and any change of cushion pressure, hover height and trim that would occur as speed was increased. Changes in trim angle were minimal. Similarly, only minor changes in cushion pressure and hover height occurred. The results of the tests are contained in Table 6. At the maximum speed attained (7.4 knots), no adverse performance characteristics such as porpoising were encountered. The bow wave formation at this speed was not pronounced.

SHIP SHAFT RPM	SPEED (knots)	ACIB WEIGHT (tonnes)	ENGINE RPM	CUSHION PRESSURE (cm)	HOVER HEIGHT (m)	TRIM ANGLE (fore/aft)	WATER DEPTH (m)
100/100	3.0	199.7	1600/1600/1600	70.5	3.45	+1.3°	18.9
120/120	3.6			71.0	3.40	+1.3°	20.4
150/150	4.4			71.0	3.50	+1.3°	20.7
180/180	5.6			71.0	3.45	+1.3°	25.0
210/210	6.6			71.0	3.45	+1.8°	26.5
230/230	7.4			71.0	3.45	+2.25°	21.0
150/150	4.4		1600/1600/0	69.9	3.40	+0.7°	20.4

TABLE 6: Open Water Trials - Test Results

STATIC HOVER TESTS

Static hover tests were performed over land, over water alone and over water notched to the ALEXANDER HENRY and to the THUNDER CAPE. The tests were performed as a functional check of the ACIB equipment and to measure its hover performance under various weight conditions and engine operating speeds. The results of the tests are given in Table 7.

Of particular interest is the craft's one and two engine hover capability. Evidently, the ACIB is capable of sustained operation in the light weight condition on two engines and may be capable of short term operation on one engine.

FREEBOARD VERSUS BALLAST

Freeboard versus ballast measurements were made on 4 March 1983 as ballast was being loaded aboard the ACIB in preparation for the heavy weight hover tests and subsequent icebreaking operations. The results are given in Table 8.

Date	Test Conditions		One Engine				Two Engines				Three Engines			
21 Jan. 83	Checkout over water (ice)	RPM	1200	1500	1800	2100	1200	1500	1800	2100	1200	1500	1800	2100
		Cush. Press.	52.8	71.1	75.2	75.7	61.2	81.0	84.6	93.0	58.9	80.5	87.4	88.1
		Hover Ht.	1.07	1.83	2.19	2.26	1.31	2.56	2.80	2.83	1.37	2.51	2.99	3.17
		Trim - F/A	-3.4°	-2.5°	-1.6°	-1.6°	-3.4°	-1.6°	-1.6°	-1.6°	-2.5°	-1.6°	-2.5°	-1.6°
	Wt: 282.4T	- P/S	+0.5	0	0	0	+0.5°	+0.5°	+0.5°	+0.5°	0	0	0	0
27 Jan. 83	Hover Test - Notched to Thunder Cape	RPM									1200	1500	1800	
		Cush. Press.									45.7	73.7	76.2	
		Hover Ht.									2.10	3.32	3.50	
		Trim - F/A									+0.5°	+1.5°	+1.5°	
	Wt: 210T	- P/S									-1.0°	-1.0	-1.0°	
28 Jan. 83	Hover Test - Notched to Alexander Henry	RPM									1200	1600	1800	
		Cush. Press.									47.0	73.7	76.2	
		Hover Ht.									2.04	3.35	3.41	
		Trim - F/A									+1.0	+0.7°	+0.7°	
	Wt: 201T	- P/S									0	0	0	
25 Feb. 83	Checkout over land after repairs	RPM	1200	1350	1500	1800	1200	1400	1500	1600	1200	1400	1500	1600
		Cush. Press.	57.9	71.1	72.4	74.4	57.2	66.8	71.1	74.2	53.4	57.2	71.6	H
		Hover Ht.	2.50	3.54	3.60	3.78	2.62	3.26	3.57	3.69	2.56	3.11	3.63	E
		Trim - F/A	-1.0°	-1.7°	-1.7°	Some	-1.5°	-2.0°	-1.6°	-1.5°	-1.0°	-2.0°	-2.0°	A
	Wt: 219.8T	- P/S	-0.5°	-0.5°	-0.5°	Heave	-0.5°	-0.7°	-0.5°	-0.5°	-0.5°	-0.5°	-1.0°	V
														E
7 Mar. 83	Checkout over water (ice)	RPM						1500	1800	2000	1200	1600	1800	2100
		Cush. Press.						67.1	82.6	83.0	54.6	72.4	84.6	85.1
		Hover Ht.						1.07	2.44	2.50	0.94	2.10	2.71	MUD
		Trim - F/A						-3.5°	-2.5°	-2.7°	-3.4°	-2.7°	-2.7°	HEAVE
	Wt: 272.8T	- P/S						+2.0°	+0.7°	+1.2°	+0.5°	+0.2°	+0.5°	
7 Mar. 83	Hover Test - Notched to Alexander Henry	RPM			3600	1800	1200	1400	1600	1800	1200	1400	1600	1800
		Cush. Press.			76.9	80.3	41.9	62.2	72.9	88.9	49.0	64.0	77.7	91.2
		Hover Ht.			2.07	2.38	0.82	1.22	1.98	2.77	0.91	1.22	2.10	2.87
		Trim - F/A			+0.5°	+0.5°	+1.5°	+0.3°	+0.3°	+1.5°	+0.7°	+0.2°	+1.2°	+1.5°
	Wt: 263.7T	- P/S			+0.7°	+0.7°	+1.5°	+1.5°	+1.0°	+0.7°	+1.5°	+1.5°	+0.7°	+1.2°
17 Mar. 83	Hover Test - Notched to Alexander Henry	RPM						1600			1200	1600	1800	
		Cush. Press.						47.3			47.0	71.1	76.9	
		Hover Ht.						1.35			2.04	3.38	3.47	
		Trim - F/A						+0.7°			0.7°	+0.5°	+0.5°	
	Wt: 199.7T	- P/S						0			0	0	0	

Cushion Pressure - cm
Hover Height - m, deck to ice (ground) surface
Trim - Fore/Aft, + = nose up
- Port/Starboard, + = Port up.

TABLE 7: Static Hover Tests

WEIGHT (tonnes)		C. of G.		Freeboard	TRIM (°)	
Ballast	Total	X (m)	Y (m)	(m)	F/A	P/S
0	187.5	0.0	0.83	1.02	-1.0	-1.0
16.3	203.8	-0.04	0.71	0.94	-0.5	-1.0
32.3	219.8	-0.08	0.70	0.88	-0.5	-1.0
44.3	231.8	-0.09	0.76	0.82	-0.5	-1.0
52.3	239.8	-0.20	0.71	0.76	-0.5	-0.7
60.4	247.9	-0.26	0.70	0.71	-0.5	-0.5
76.2	263.7	-0.26	0.74	0.58	-0.5	-0.5

CENTRE OF GRAVITY: X - Port/Starboard, Port Positive
Y - Fore/Aft, Forward Positive

TABLE 8: Freeboard vs. Ballast Weight

SHAFT RPM

As indicated above, a monitoring system was installed in the Engine Room of the ALEXANDER HENRY to monitor the engine and propeller shaft RPM. In the event the data obtained from the system was not particularly satisfactory, largely because of a scale problem, particularly on the time base, which made the strip chart difficult to read. However, uneven running due to trouble with the starboard fluid coupling was readily apparent and charts for this side were disregarded.

Data recorded on 10 March when the ACIB/ship combination was proceeding at 4-5 knots in 50 cm ice with snow patches indicated clearly smoothness of the port power train. Over the period of the record (nearly 3 hours) the largest Δ detected on the port side was 25 RPM and had a duration of about 20 s.

Data was also recorded on 4 March when the ship alone was ramming in ice varying from 60 to 30 cm with about 12 cm of snow cover. Over the period of this record (nearly an hour) the roughness of the ramming operation is clearly demonstrated, and there are significant Δ s not associated with reversals, which are taken to indicate ice strikes. The highest values of Δ recorded are +107 RPM (forward) for 31 s and -63 RPM (reverse) for 36 s.

TECHNICAL OBSERVATIONS

Liquid Ballast:

To achieve a range of cushion pressures it is necessary to ballast the ACIB between its tare and maximum weights. To date this has been done with concrete blocks weighing about 4,000 kg each. A crane at $100/hour is required to make ballast changes and the blocks occupy deck space which could be used for other purposes. Furthermore, the blocks cannot be jettisoned in emergency situations or for reducing weight in event of skirt damage while operating. The alternative is liquid ballast. The ACIB is provided with three rectangular metal buoyancy tanks having a total displacement of about 150 m^3 (or 120 tonnes of fuel) which is ample to provide space for the required liquid ballast.

Trim ballast is carried at present in two 1,000 gal. (4546 litre) tanks. Water is pumped in and out over the side and the tanks are heated by blowing hot air into canvas shelters which cover them. This is complicated and time consuming. These tanks should be removed and replaced with equivalent underdeck fuel tanks located as far aft as possible. Careful design could reduce the size of the tanks. Trim adjustments would be made by transferring fuel between main and trim ballast tanks, the overall weight remaining constant.

Icing:

Over deck icing is seen as a possible hazard and will be catered for by suppressive measures and covers. Underdeck icing, however, is a hidden problem.

Inspection under the deck after operations revealed very heavy ice build-up on the bottoms of the buoyancy tanks and on structural members. This ice was 15 cm thick in places and its weight was estimated to be at least 25 tonnes.

The build-up may not prove to be a significant problem but it is one about which CCG should be aware so that periodic checks may be made after operating for extended periods in very cold conditions. It may also give rise to a decrease in hover height and to nose down trim change.

Skirt:

The basic design of the skirt system is good and the wear encountered to date has been minimal. The material is satisfactory and repairs can be carried out locally provided adequate curing time is allowed. Permanent repairs in situ cannot be made at low temperatures using available techniques.

- **Notch Segments.** The notch segments were virtually rebuilt for the 1982/83 season and careful attention was paid to the geometry. As a result they inflated and operated extremely well. Some damage occurred because both the THUNDER CAPE and ALEXANDER HENRY were notched right into the bumper which took them beyond the wear apron. Other damage was due mainly to deterioration of the material.

- **Straight and Curved Segments.** These segments were all refurbished to 1981/82 configuration with sole plates and trailing flaps. There was no trouble whatever with the primary segments and the new attachment fittings eliminated problems previously experienced. The performance of the aft straight segments was satisfactory, only slight damage occurring to the trailing flaps and sole plates. On the curved and forward straight segments, however, there was a great deal of damage to trailing flaps and sole plates, all of which occurred in forward motion when the flaps and sole plates are not performing any useful function.

  After some consideration of the requirement for flaps and sole plates on the curved and forward straight segments, the prudent decision to make repairs was made. Flaps were tucked in and bonded on all segments. This was not successful due to poor bonding. However, it is now considered that a fully closed sole with good drainage is the right way to go. Sole plates should be bonded inside on forward segments and outside on aft segments. The side corner segments probably do not require sole plates.

- **Spray Apron.** After increasing the top gap to overcome an icing problem, the spray apron was effective and trouble free. It is expected that spray suppression can be further improved by adding a flap over the top gap and/or by adding flap covered vents on the apron face.

- **Wear Apron.** This was generally satisfactory but needs to be extended to the full depth of the notch (see Notch Segments).

CONCLUSIONS

1) SERVICEABILITY. Although a number of problems were encountered, notably with skirt segment sole plates, the hydraulic system and the fan clutches, it is considered that effective solutions can be applied to all the unsatisfactory conditions which have been encountered.

In point of fact, there was no time during the operational trials when the ACIB could not have been made available when required. Provided that the ACIB is handled with care when going astern, it may well be that the sole plates on the forward segments are not essential.

The Project Team is confident that a craft can be provided for the 1983/84 season which should be much easier to operate and virtually trouble-free. In any case, it must be appreciated that, if the ACIB/ship combination can break ice at ten times the rate of the ship alone, it is only required to operate for one tenth of the time. This implies much greater flexibility in the choice of conditions, and that nine days out of ten can be given to maintenance, if necessary, without jeopardizing the program. Continuous availability is not a necessity.

2) ICEBREAKING. That the ACIB will break ice satisfactorily was very clearly demonstrated and, although 66 cm was about the maximum thickness encountered during the trials, there is no reason to doubt that ice up to 1 m in thickness can be broken.

Additionally, it was shown that considerable economies can be achieved because of the rate at which ice is broken and the reduction in propulsion power. Use of the ACIB with the ALEXANDER HENRY eliminated any necessity for ramming, and ice contacts with the propellers were much less frequent and severe, thus reducing hull damage and strain on the propulsion system, additional major economies.

However, the greatest opportunity for saving lies in the potential to operate the ACIB with a smaller and more economical vessel, such as a tug. Operation with the tug THUNDER CAPE was most impressive and a clear indicator of the possibilities. The charter cost was $500.00 per hour on an as required basis.

It is quite possible that another season of operation will demonstrate that the ACIB/small vessel combination is capable of performing efficient ice management without any backup, and that trials in other areas are desirable. Too much emphasis should not be placed on reliability at this stage of assessing the ACIB, because the improved performance offsets a considerable amount of down-time, and the potential cost of repairs will be more than offset by eliminating the necessity to have a conventional icebreaker operating for a very much longer period.

3) SUMMARY.

- The icebreaking capability of the ACIB was clearly demonstrated.
- The potential economies of air cushion icebreaking for the port of Thunder Bay were shown to be substantial.
- No problems were encountered during the trials which cannot be reduced or eliminated.
- Satisfactory operational performance can be expected from the ACIB during the 1983/84 season.

The opinions expressed in this paper are those of the authors, and do not necessarily reflect the views of the Department of Transport.

DEVELOPMENT OF HOVERCRAFT 140

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ABSTRACT

This paper discusses the basic design philosophy, method of manufacture and market potential of Hovercraft 140.

AIR CUSHION LANDING GEAR ELASTIC TRUNK PROGRESS

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ABSTRACT

The application of Air Cushion Landing Gear to a light (4,000 lb) aircraft is discussed. The reasons for selecting a light aircraft and also basing the ACLG on a new aircraft design are given, together with an alternative current retrofit possibility. The rationale for and benefits from ACLG use are stated.

The ACLG depends on the use of a special elastic membrane forming the retractable air cushion trunk. Initial technological development of this material system was accomplished in the USAF/CANADA XC-8A program. This has been continued during the two years through the BACT LACTA phase I program supported by the Canadian Government DITC. Substantial improvements have been made.

Detail of the present LACTA trunk design approach and construction methods are illustrated. The test rig construction and functions are described, together with initial test experience.

It is concluded that the advantages claimed have not been diminished by the test experience, but considerable further work is required to reach a production system.

INITIAL EXPERIENCE WITH A THREE PLENUM CELL AIR CUSHION EQUIPMENT TRANSPORTER

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ABSTRACT

This paper describes the design and test of an Air Cushion Equipment Transporter (ACET).

The United States Air Force, in it's ongoing programs to counter the threat of runway denial to fighter aircraft due to intervening battle damage terrain between runway and aircraft disposal points, identified a potential solution in the application of an Air Cushion Equipment Transporter (ACET) capable of transporting a fully operational aircraft over rough terrain. Bell Aerospace Textron having previously undertaken extensive study in the application of air cushion technology to Alternate Aircraft Takeoff System (AATS) had gained valuable experience in both vehicle design concepts and cushion research which was directly applicable to the design of an ACET vehicle. To capitalize on this work, Bell Aerospace Canada Textron under contract to the Canadian Commercial Corporation in a jointly funded program between the Department of Industry, Trade and Commerce and the Flight Dynamics Laboratory of the USAF Wright Aeronautical Laboratories undertook to design and test under realistic conditions, a vehicle capable of transporting a fully operational fighter aircraft.