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Icebreaking Capability of CCGS "Labrador" in Western Barrow Strait, October 23-28, 1973

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ABSTRACT

The icebreaker CCGS "Labrador" journeyed to western Barrow Strait in late October, 1973 to undergo performance trials. While suitable ice conditions for the tests were being sought, vessel progress through 320 miles of pack ice was monitored. Ice conditions were lighter than normal. Ice pressure was frequently observed. The "Labrador" operated mostly in continuous mode. However, enough resistance was encountered to suggest that in normal years, vessels with the "Labrador's" icebreaking capability would be unable to operate in Barrow Strait beyond mid-November.

RÉSUMÉ

Le brise-glace "SGCC Labrador" se rendit au détroit de Barrow pour des épreuves de capacité vers la fin d'octobre 1973; c'était après la saison normale de navigation dans le passage du nord ouest. Le cheminement du "Labrador" fut soigneusement mesuré dans 320 milles de glace pendant cet exercice. La glace était moins épaisse que d'habitude mais il y eut souvent de la pression.

Le "Labrador" put naviguer sans arrêt dans la glace durant la plus grande partie du voyage. Il semble impossible qu'un navire avec la puissance du "Labrador" puisse naviguer normalement dans le détroit de Barrow après le milieu de novembre.

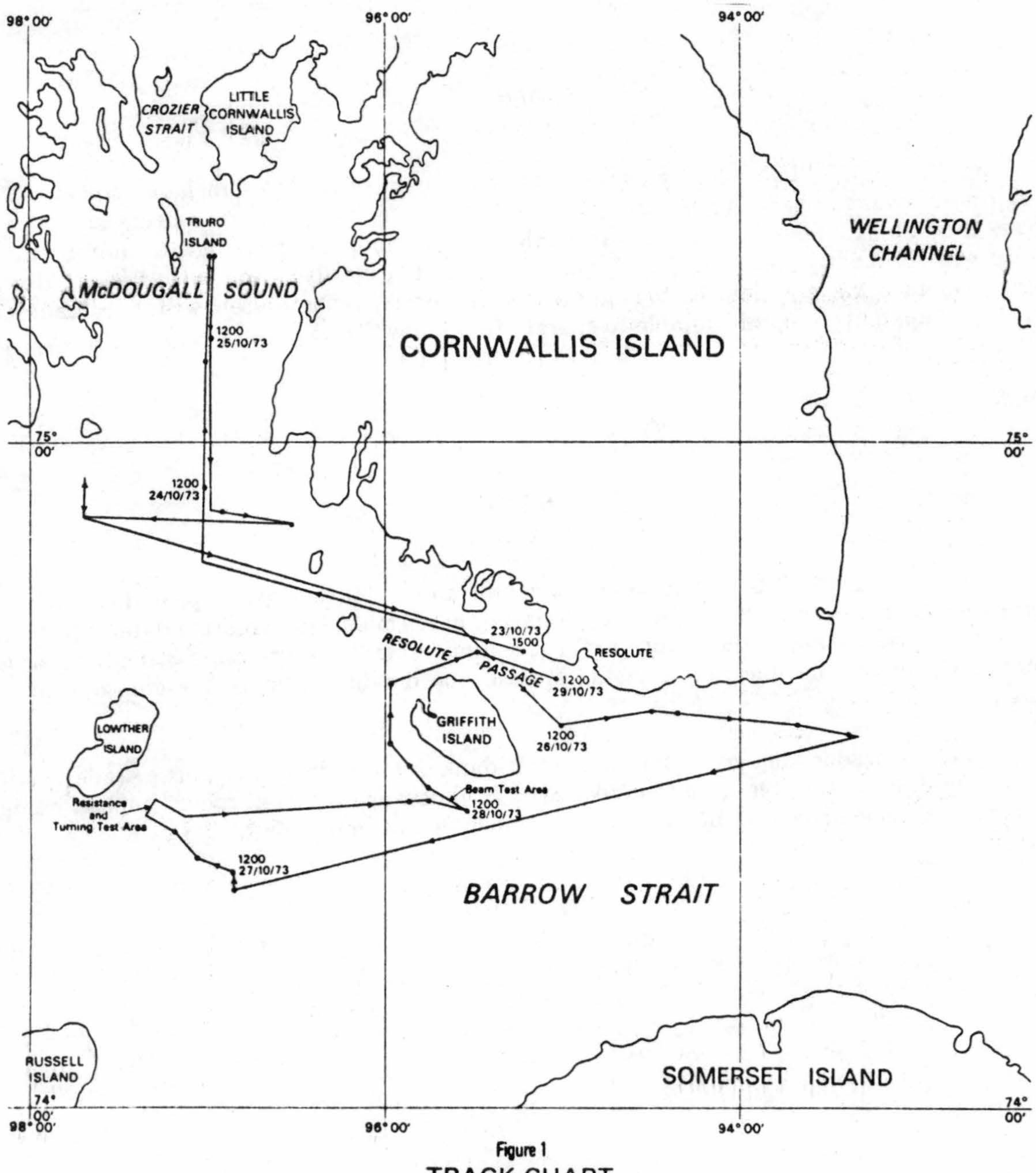


Figure 1

TRACK CHART
(Approximate)
OCTOBER 23-29, 1973

SCALE

0 10 20
NAUTICAL MILES

2. INTRODUCTION

During the last week of October 1973, the Canadian government icebreaker CCGS "Labrador" (3823 tons displacement, 10,000 shaft horsepower) underwent ice resistance and turning trials in Barrow Strait, NWT. The trials, which were conducted by German and Milne, Marine Consultants and Naval Architects, Montreal and which were performed on October 27 are described in a report prepared by G.S. German, Coordinator of the tests (German and Milne, 1974). However, in order to find suitable ice conditions in which to conduct the trials, the "Labrador" steamed approximately 320 miles (515 kilometers) (Fig. 1) in the Barrow Strait - McDougall Sound area; and the author, who was invited by the Ministry of Transport to participate as an observer, was able to monitor the progress of the vessel through the various ice conditions which occurred.

Full-scale ice resistance tests using icebreakers are normally carried out in shore-fast ice of uniform thickness. For the "Labrador" tests, it was hoped that undisturbed shore-fast ice approximately two feet thick (60 cm) could be located. Aircraft ice reconnaissance flights had indicated that such ice appeared to exist in the northern part of McDougall Sound. In actual fact, however, this ice proved to be unsuitable as did another promising-looking ice mass which was situated in Barrow Strait at its intersection with Wellington Channel. Being unable to locate suitable undisturbed fast ice, the scientist-in-charge decided to attempt the tests in a relatively undisturbed formation of pack ice which was located near Lowther Island in western Barrow Strait.

3. ICE CONDITIONS

3.1 General Description

The cruise took place early in the freeze-up period with daytime air temperatures ranging between -12°F and +17°F (-25°C and -8°C). Generally speaking, ice conditions (Fig. 2) in western Barrow Strait area were light with grey-white and grey ice predominating. Most of the area was ice covered. Of 29 observations of ice conditions taken by the author between October 23 and 28, all but six were taken in ice concentrations of 9/10ths - 10/10ths and no concentrations of less than 8/10ths were observed. These concentrations are, of course, estimates based on consultations with the "Labrador's" Ice Observer and on the author's experience gained while participating in previous icebreaker probes.

Ice thickness measurements were obtained on an opportunity basis. When the vessel stopped in the ice, the author was often able to measure directly the thickness of ice upturned against the ship's sides. In this way eleven reasonably accurate measurements were obtained, six in grey-white and five in first-year ice. In addition, as part of the German and Milne trials, ten thickness measurements were obtained with an ice auger and six more by measurement of two experimental ice "beams".

Measurements obtained in grey-white ice (the predominant ice type) averaged 11 inches (27.9 cm). The grey ice was estimated to be approximately 3 inches thick (7.6 cm). Two areas of heavier ice were encountered. Closely-packed accumulations of small first-year floes averaging about 16 inches (40.6 cm) in thickness and cemented together by grey-white ice, blocked McDougall Sound at the latitude of Truro Island. Here, numerous ridges and hummocks complicated the surface topography. The second area was in eastern Barrow Strait at its confluence with Wellington Channel.

Here, small floes of first-year ice estimated to be 14 inches (35.5 cm) thick were scattered throughout a matrix of grey-white and grey ice.

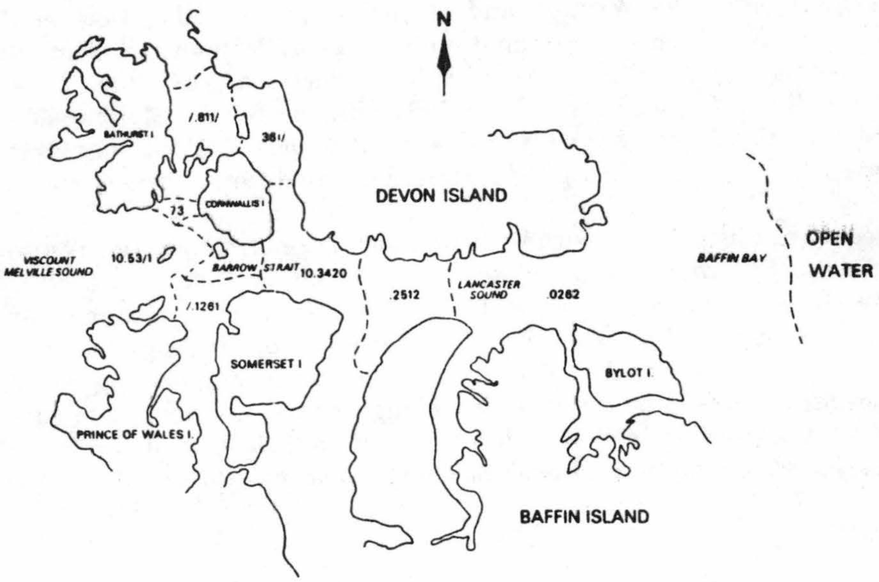


Figure 2
ICE CONDITIONS
AS DESCRIBED BY ICE CENTRAL
OCTOBER 31, 1973
SCALE
0 60 120
NAUTICAL MILES

The site chosen for the ice resistance tests was a large expanse of relatively undisturbed grey-white ice lying south of Lowther Island (Fig. 1). The few ridges which did mar the surface were widely scattered and did not appear to the author to cover much more than 10 - 20 percent of the ice surface. Of twelve thickness measurements obtained before and during the testing all but two ranged between 9.5 and 12 inches (24.1 and 30.5 cm). The two exceptions were 17 inches (43.1 cm) and 47 inches (119.4 cm), the latter being deliberately taken in a ridged formation which was easily breached by the ship. A more complete description of the study area is included in the German and Milne report (German and Milne, 1974).

3.2 Comparison with Recent Years

Table 1 summarizes the ice conditions in late October as reported in Ministry of Transport and Department of Environment ice summaries published since 1962. It appears from the table that conditions in late October, 1973, were lighter than normal. Similar conditions probably occurred in 1962 and possibly in 1966 and 1969; however it is difficult to equate the conditions positively.

Table 1 Comparative ice conditions in Barrow Strait - late October.

Year	Date	Concentration and Type			
1962	Oct 15	60%	4-6/10ths Young	40%	4-6/10ths Slush
1963	Oct 1	50%	7-9/10ths Winter	50%	7-9/10ths Second Year
1964	Oct 22	100%	7-9/10ths Winter		
1965	Oct 22	75%	7-9/10ths Winter	25%	10/10ths Young
1966	Oct 22	90%	7-9/10ths Young	10%	7-9/10ths M. Winter
1967	Oct 22	60%	7-9/10ths M. Winter	40%	10/10ths T. Winter
1968	Oct 22	60%	7-9/10ths Young	40%	7-9/10ths M. Winter
1969	Oct 22	90%	7-9/10ths Young	10%	10/10ths New
1970	Oct 22	90%	7-9/10ths T. Winter	10%	7-9/10ths M. Winter
1971	Oct 22	70%	10/10ths M. Winter	30%	7-9/10ths Gray
1972	Oct 22	60%	10/10ths Young	40%	10/10ths Polar
1973	Oct 22	85%	7-9/10ths Young	15%	10/10ths Winter

3.3 Ice Pressure

Active ridging, rafting and hummocking were observed daily. Two areas where these manifestations of pressure were particularly apparent were the zone of heavier ice south of Wellington Channel and the eventual testing site in the Lowther and Griffith Island vicinity. South of Wellington Channel, on one occasion when the continuous mode was broken, ice was observed to press in behind the vessel. Within two minutes the moving ice had completely closed the ship's track and had rafted an estimated 150 feet (45.4 m) across the unbroken ice surface to the south of the track.

In the test site areas, pressure twice interfered with activities. The test programme called for ice thickness measurements to be obtained along the vessel track. The plan was for a two-man team (one being the author) operating from the ship's helicopter, to bore measuring holes at roughly regular intervals along each leg of the test pattern. On the 11th hole, the auger became jammed by ice rafting under the floe being drilled. The auger could not be extracted. Less than 100 feet (30.3 m) away from the helicopter, the ice began to buckle and a ridge began to build. The drill site was, therefore, quickly evacuated. From the helicopter, evidence of large-scale movements of ice could be seen. The "Labrador's" track for the first leg of the trial was 85 percent closed and partially ridged. The second leg was largely unrecognizable with long fingers rafted at least 100 feet (30.3 m) beyond where the "Labrador" had passed less than one-half hour previously. This latter leg was roughly parallel to the south shore of Lowther Island and was the one where thickness measurements were being taken when pressure seized the auger. The third leg was still relatively undisturbed. The wind, was from the south.

The following day (October 28) lookouts on the "Labrador" observed cracking in the ice immediately ahead of the ship while measurements of ice beams were being taken. Once again the site was quickly evacuated and, for the next two hours, evidence of almost continuous pressure was observed.

The frequent occurrence of pressure can probably be chiefly attributed to tidal streams and variations in wind direction. The Arctic Pilot warns that tidal streams of up to 3 knots can be expected in the Barrow Strait area. On an earlier occasion, the author, while aboard the CCGS "John A. MacDonald" anchored in Resolute Passage in the summer of 1971, noticed that rapidly drifting ice dragged the vessel in opposite directions with each change of the tide, sometimes directly into the wind. Almost identical observations of ice drift attributed to tidal exchange were observed from an icebreaker anchored off Resolute in August, 1951 (Winchester, 1954). Movement of ice in Barrow Strait is, therefore, to be expected. But in the present case the movement was probably complicated by other movements induced by winds. From October 24 to 26, winds tended to be from the north diminishing in speed from about 15 mph to 5 mph (6.6 mps to 2.2 mps) under rising barometric pressure. On the 27th, the barometer fell steadily and winds changed to south blowing at 22 mph (9.8 mps). On the following day, winds were from the east to southeast at about 19 mph (8.4 mps). These frequent wind shifts may have driven ice into the study area from other parts of Barrow Strait and Viscount Melville Sound causing compression of the ice masses entrained in the tidal streams.

4. VESSEL PERFORMANCE

Between October 24 and 28, the "Labrador" used all six engines when underway in ice. Total shaft horsepower produced ranged roughly between 5,500 and 8,500 and averaged over 7,000 (except during the tests some parts of which called for very low horsepower). On October 25, torquemeters attached to both shafts indicated that at 124 rpm about 4200 horsepower per shaft was being developed (124 rpm being close to the maximum developed over the 5 day period). Thus, the ship was operating at close to 85 percent of its rated efficiency.

With this amount of power available, the "Labrador" was able to move with relative ease through the grey-white and grey ice which covered most of western Barrow Strait. Seldom did the vessel have to resort to backing and charging to maintain headway; and, depending upon the ratio of grey-white to grey ice and on the degree of rafting, the ship was able to operate in the 8 - 16 knot range, 16 knots being approximately its maximum speed.

The heavier ice found in McDougall Channel, however, proved to be more of a problem. Working at half power, the ship made three isolated attempts to proceed, but progress appeared to be only of the order of 1 to 2 shiplengths per charge. As the ice conditions did not lend themselves to the type of testing planned, no persistent effort to navigate in this ice was exerted.

The only other area where performance was noticeably affected was off the mouth of Wellington Channel where, in a mixture of first-year, grey-white and grey ice, the "Labrador's" speed was reduced to 6 knots. Over a period of 50 minutes, ice halted the vessel three times: each time where grey-white ice had rafted and refrozen. Sometimes the ship appeared to be labouring, perhaps because of the pressure described in the previous section.

Figure 3 is a graph of progress as it relates to ice conditions. The vertical axis represents ice conditions as expressed in terms of an ice index which is arrived at simply by multiplying observed ice thickness (measured or estimated) by observed ice coverage. The horizontal axis represents the number of nautical miles travelled in one hour. In cases where the ship operated for only part of an hour, the distance covered was projected to cover one full hour. The ice index was developed by the author in an earlier report to the Ministry of Transport describing extended navigation feasibility probes in the Lake Melville-Goose Bay area (Bradford, 1972).

The graph seems to indicate that the "Labrador", working at up to 85 percent efficiency, can make consistently good progress, i.e. 8 knots or more, in high concentrations of pack ice up to about 8 inches (20.3 cm) in thickness. Similar concentrations of ice between 8 and 12 inches (20.3 and 30.4 cm) thick apparently slow the ship to between 4 and 8 knots, whereas an ice index of 150 [for example, 10/10ths concentration of ice 15 inches (38 cm) thick or 9/10ths concentration of ice 17 inches (43 cm) thick] would probably approach the upper limit for continuous mode operation. It must be kept in mind that these approximations refer to the pack ice environment which includes ridges, hummocks and intermittent periods of pressure all of which either alone or in combination might produce performance results lower than normally expected for a 10,000 hp icebreaker.

A greater scatter was expected in Figure 3 because of the frequent occurrence of ice pressure. An explanation for the relative lack of scatter is that, as stated previously, the "Labrador" was normally able to operate easily in continuous mode. For this reason it was probably able to maintain a velocity sufficiently high to offset the rate of closure of the converging ice thus preventing unbroken ice from pressing against the vessel's sides. Pressure, therefore, was probably not a significant determinant of progress. However, the implications of the frequent pressure for merchant vessel escort are obvious.

It is interesting to compare the "Labrador's" performance with that of two other powerful Canadian icebreakers the CCGS "John A. MacDonald" (15,000 shp) and the CCGS "Louis S. St-Laurent" (25,000 shp). Performance data for these vessels were obtained by the author on the above-mentioned feasibility probes of January and April, 1972. Plots of the performance data are shown in Figure 4. The relative performance of the three vessels is summarized in Table 2.

Table 2 Approximate progress in one hour.

Ice Index*	"Labrador" (nautical miles)	"MacDonald" (nautical miles)	"St-Laurent" (nautical miles)
0 - 80	8 - 15	12 - 16	14 - 16
80 - 120	4 - 8	9 - 12	12 - 14
120 - 150	2 - 4	7 - 9	11 - 12
150 - 180	<2	<7	<11

***Ice Index = Thickness (inches) x concentration (tenths)**

It must be emphasized that the values in the table are only approximations based on a limited number of observations. They indicate certain relative differences in performance which may or may not be real. If valid, however, this type of information could be used to assist in icebreaker deployment because it roughly equates vessel performance under actual operating conditions to an ice index which can be easily calculated from standard ice charts. However, more observations are needed to substantiate the performance curves.

5. DISCUSSION

Thickness measurements of shore-fast ice in Resolute Bay are taken on a routine basis by Atmospheric Environment Service personnel. On October 26, 1973, the measurement was 16.0 inches

Figure 3

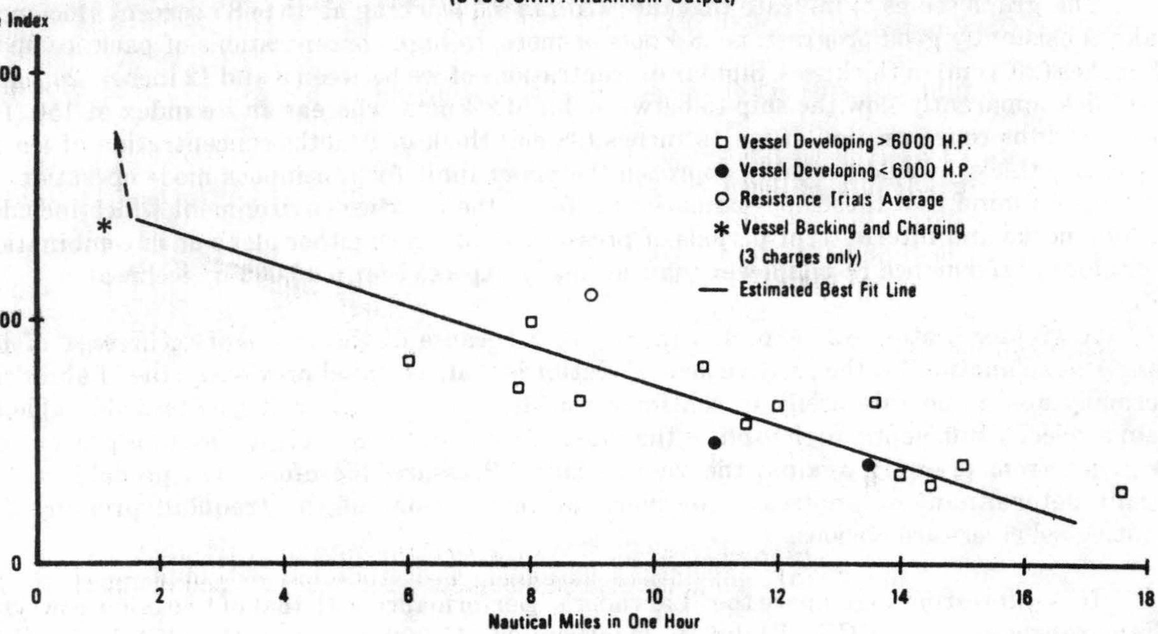
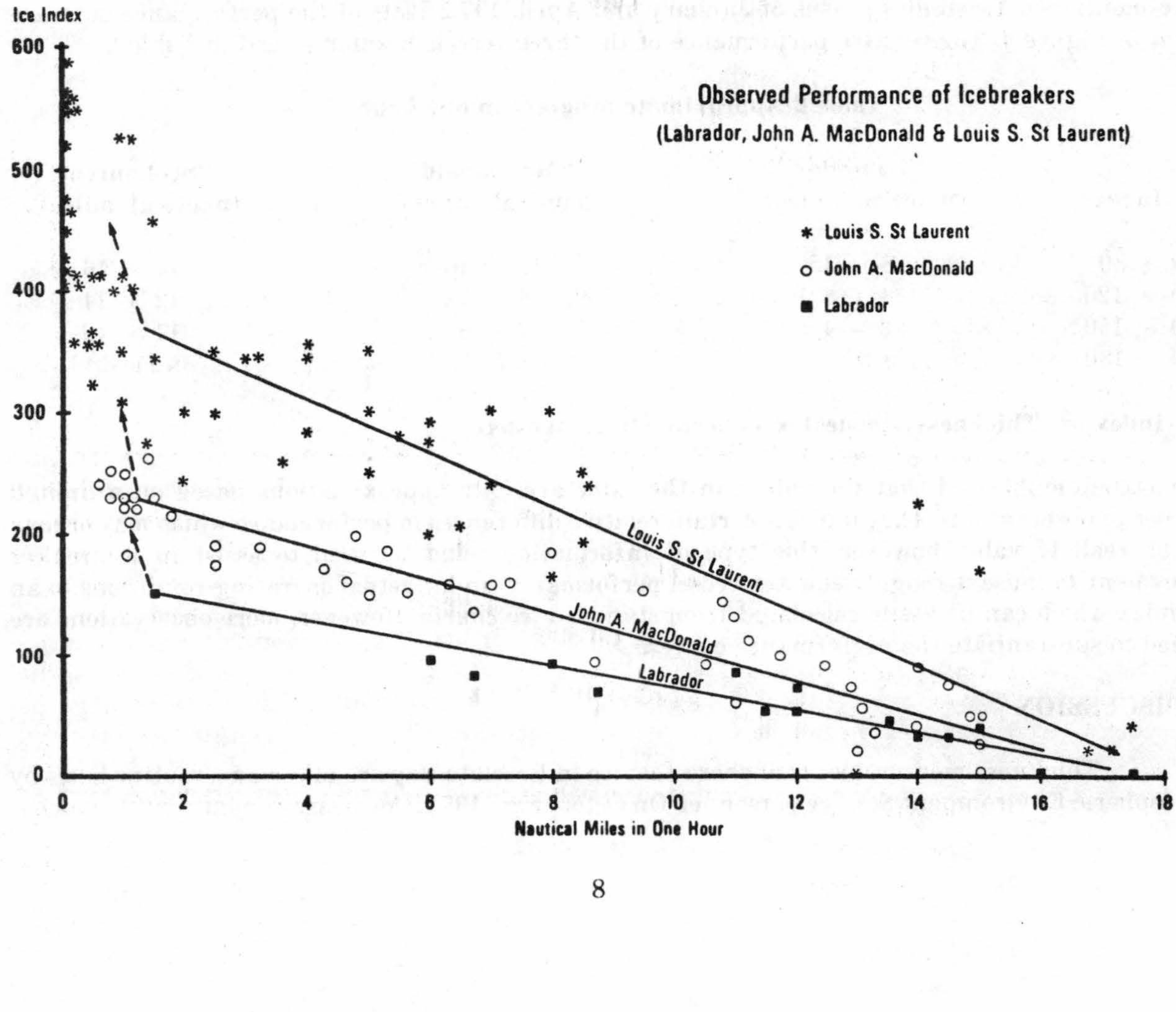


Figure 4



(40.6 cm). Corresponding figures for the last week in October from 1956 are provided in Table 3 as are the recorded thicknesses approximately one month later.

Table 3 Ice thickness measurements, Resolute Bay, NWT.*

Year	Date	Thickness (inches)	(cm)	Date	Thickness (inches)	(cm)
1973	Oct 26	16.0	40.6	Nov 30	21.0	53.3
1972	Oct 27	15.0	38.1	Nov 24	26.0	66.0
1971	Oct 29	24.0	60.9	Nov 26	31.0	78.7
1970	Oct 30	16.0	40.6	Nov 29	26.5	67.3
1969	Oct 24	20.0	50.8	Nov 28	34.0	86.3
1968	Oct 25	17.0	43.1	Nov 29	25.5	64.7
1967	Oct 27	18.0	45.7	Nov 24	32.0	81.2
1966	Oct 28	19.0	48.2	Nov 25	33.0	83.8
1965	Oct 29	13.5	34.2	Nov 26	32.0	81.2
1964	Oct 30	17.0	43.1	Nov 27	28.0	71.1
1963	Oct 25	15.0	38.1	Nov 29	26.0	66.0
1962	Oct 29	17.0	43.1	Nov 24	37.0	93.9
1961	Oct 29	18.0	45.7	Nov 24	29.0	73.6
1960	Oct 28	19.0	48.2	Nov 24	30.0	76.2
1959	Oct 30	18.0	45.7	Nov 30	28.0	71.1
1958	Oct 26	13.0	33.0	Nov 27	32.0	81.2
1957	Oct 27	16.0	40.6	Nov 24	27.0	68.5
1956	Oct 27	22.0	55.9	Nov 27	33.0	83.8

***Source: Ice Central, Atmospheric Environment Service**

Between 1956 and 1973, the sea ice thickness in Resolute Bay during the final week of October averaged 17.4 inches (44.1 cm) and thicknesses ranged between 13.0 inches (33.0 cm) and 24.0 inches (60.9 cm). The Barrow Strait ice thicknesses measured from the "Labrador" in the last week of October 1973 averaged 11.0 inches (27.9 cm). Thus, on the basis of one single comparison, the drifting ice appeared to be approximately 30 percent thinner on the average than the shore-fast ice.

For discussion purposes only, let us assume that during the freeze-up regime the drift ice is 30 percent thinner on average than the shore-fast ice. At the end of November between 1956 and 1973, the average ice thickness in Resolute Bay (Table 3) was 29.5 inches (74.9 cm). Applying the 30 percent differential, one could then assume that the thickness of Barrow Strait drift ice would average approximately 21 inches (52.5 cm). Therefore, based on its 1973 performance (Fig. 3), the "Labrador", in average end-of-November ice conditions, would probably have to operate exclusively in the backing and charging mode at a probable speed of less than 2 knots. This is assuming 10/10ths ice cover averaging 21 inches (52.5 cm) for an ice index of 210. Schedule H of the Arctic Waters Pollution Prevention Act (Statutes of Canada, 1970) implies that a vessel with roughly the "Labrador's" Arctic capability could be expected to operate in the Barrow Strait area until the end of December.

Performance figures for the "MacDonald" (Figure 4) indicate that by the end of November (ice index 210) the vessel would be operating at the uppermost limit of its continuous mode with speed reduced to less than 4 knots. This thickness figure may err towards the conservative side considering that Lindsay (1968) indicated about 33 inches (83.8 cm) as being a representative thickness for 15 selected Arctic channels at the end of November. Using Lindsay's estimate, and still applying the 30 percent thickness reduction, the ice index would be 231 [23.1 inches (58.6 cm) x 10/10ths concentration] putting the "MacDonald" into the backing and charging mode. Thus it would appear that end-of-November ice conditions even in average years would tax the "MacDonald's" icebreaking capability. We note again that under Schedule H of the Arctic Waters Pollution Prevention Act ships with Arctic capability roughly equivalent to those of the "MacDonald" could be expected to operate in Barrow Strait until mid-February.

6. CONCLUSION

The voyage raises some interesting questions. It was the latest recorded visit of a motor-driven vessel to the Resolute Bay area. The ice appeared to be well within the "Labrador's" operational capability even though shaft horsepower output was 15 - 20 percent below the rated maximum. Seldom was continuous mode broken. But the ice conditions were less severe than normal and, bearing in mind that the continuous mode was occasionally broken, one wonders how well the vessel would have performed in a normal or severe year. This raises the further question of how well the ship would have performed at the end of December which under the Arctic Waters Pollution Prevention Act marks the close of the navigation season for the western Barrow Strait area for ships with roughly the "Labrador's" Arctic capability. It might, therefore, be useful to consider the possibility of scheduling an exploratory probe into the same area, perhaps in mid-November, in order to obtain information on the general feasibility of extending the navigation season and also to examine, by means of an operational test, the efficacy of the closing dates for navigation under Schedule H of the Arctic Waters Pollution Prevention Act.

7. ADDENDUM

Since preparing this report, a copy of the German and Milne description of the tests has been received. Performance values for those parts of the tests where high power was used are summarized in Table 4.

Table 4 High power performance during resistance trials.

	Elapsed Time	Distance Run	Average Speed	Average Shaft Horsepower
Course 1A	240 sec	4200 ft (1280 m)	10.4 kt	8,227
Course 1B		All output below 6000 hp		
Course 2	306 sec	4500 ft (1371 m)	8.7 kt	8,441
Course 3	180 sec	2260 ft (689 m)	7.5 kt	8,140

Comparison of the test performance with the general performance over the 5 day period reveals an interesting difference. While operating at high power during the test, the "Labrador" ran a total distance of 10,960 feet (3341 m) in an elapsed time of 726 seconds for an average speed of 8.8 knots. This was achieved with an average of 8,270 shaft horsepower and in spite of the fact that each run was commenced from a standing start. Therefore one could expect an average speed considerably in excess of 8.8 knots if an uninterrupted 8,270 shaft horsepower had been delivered throughout the test. The average ice thickness in the test area was 11 inches (27.9 cm) and the ice index was 110.

The general performance over the October 24 - 28 period shows the "Labrador" operating in an ice index of 110 at a speed of roughly 6 knots (see Figure 3). Thus the general performance figure is only two-thirds of the test figure. The most probable explanation of the difference is that the test figure approximates an ideal situation in that it is based on a preferred site having relatively uniform ice thickness characteristics, whereas the general performance figure is based upon a broader spectrum of ice and operating conditions. However, the 2.8 knot difference is probably statistically significant considering that the average variance about the estimated best fit line on Figure 3 is only 0.8 knots. More data are needed in order to verify this very preliminary conclusion.

8. ACKNOWLEDGEMENTS

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