Sea Ice Pressures observed on the Second "Manhattan" Voyage

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ABSTRACT: Sea-ice pressures encountered by the ice breaker *Louis S. St. Laurent* while escorting the tanker *Manhattan* in the Baffin Bay area in April-May 1970 were observed along with certain wind, ice and ship performance data. Pressure severity was estimated qualitatively. Most pressure episodes occurred during periods of onshore winds; and frequency of occurrence increased with higher wind speeds as did pressure severity. Pressure episodes were of short duration, but the overall inhibiting effect on vessel performance was substantial.

RÉSUMÉ. *Observations sur la pression des glaces de mer pendant le second voyage du* Manhattan. Sur le brise-glace *Louis S. St-Laurent,* escortant le navire-citerne *Manhattan* dans la région de la baie de Baffin en avril-mai 1970, l'auteur a observé les pressions de la glace de mer rencontrées par le navire, de même que certaines données sur le vent, la glace et le rendement du navire. La sévérité de la pression a été estimée qualitativement. La plupart des épisodes de pression se sont produits au cours de périodes pendant lesquelles le vent soufflait de la mer. La fréquence de ces épisodes et la sévérité de la pression croissaient avec la vitesse du vent. Les épisodes de pression étaient de courte durée, mais l'effet de retardement sur le rendement du navire était considérable.

РЕЗЮМЕ. *Наблюдение ледовых сжатий во втором плавании танкера* «MANHATTAN». Наблюдение ледовых сжатий было осуществлено на ледоколе «Louis S. St. Laurent», сопровождавшем в апреле-мае 1970 г. танкер «Manhattan» в Баффиновом заливе. Случаи наибольшего сжатия зарегистрированы в периоды морского бриза. В эти периоды с увеличеним скорости ветра частота случаев сжатия возрастала. Хотя эпизоды сжатия были невелики по длительности, суммарное тормозящее влияние их на ходовые характеристики судна было существенным.

INTRODUCTION

An association between wind and sea ice pressure generation has long been recognized. For example, by the turn of this century the rule of thumb for mariners operating in Baffin Bay was, "Keep away from the land, face the ice and take your chances." (Stefansson 1944). The rule was probably based on lessons learned from such disasters as one which Neatby (1958) relates in his work *In Quest of the Northwest Passage:*

> "In 1830 the pack, urged on with irresistible force by a westerly gale, had crushed a whole convoy of whalers against the shore ice of Melville Bay and ground nineteen ships to matchwood."

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Today, although their main threat to vessel operation is indefinite delay, arctic ice pressures still pose a threat to vessel safety as evidenced by the loss of the barges *Learmonth* and *Johnny Norberg* in Viscount Melville Sound in 1969 and the jamming together of the icebreaker *Louis S. St. Laurent* and the tanker *Manhattan* by ice pressure in northwestern Baffin Bay in 1970.

The objective of the present study is to understand better the occurrence of ice pressures and determine, if possible, their effect on the performance of large modern ships. With such understanding the prediction and, to some extent, the avoidance of ice pressures might become feasible.

OBSERVATION PROGRAM

An examination of the phenomenon in the Gulf of St. Lawrence, showed that ice pressures occur most frequently in periods of onshore winds; and there was some evidence to indicate that, once generated, pressures increase in intensity with proximity to shore (Bradford 1970). The present study was designed to test the relationships indicated by the Gulf of St. Lawrence study.

The Canadian icebreaker *Louis S. St. Laurent*, which accompanied the tanker *Manhattan* on its 1970 winter test program in the Baffin Bay area, was used in this study as an observation platform. The ship's position was recorded at 4-hourly intervals between 08:00 and 20:00 hours each day along with observations of wind speed and direction, ice thickness and concentration, propeller shaft revolutions and estimates of horsepower being developed. Throughout the day, the ice field adjacent to the ship was observed for indications of ice pressure. Whenever conditions permitted, a daily helicopter flight of up to 12 miles was made back along the ship's track as an additional check.

A qualitative rating based on the behaviour of the *Manhattan's* track through the ice was used to estimate ice pressure severity. Pressure was rated as follows:

Pressure Rating	Identification
Light	*Manhattan's* track closes <30% within 1 mile
Medium	*Manhattan's* track closes 30-80% within 1 mile
Heavy	*Manhattan's* track closes 80-99% within 1 mile
Severe	*Manhattan's* track closes completely within 1 mile, ridges forming along track, *St. Laurent* unable to manoeuvre at full power.

Observations were taken on all days, but data collected on days when the ships were carrying out test programs in Pond Inlet were not included in the calculations which follow as the Pond Inlet ice showed no signs of having moved since its formation.

ANALYSIS

ICE PRESSURE GENERATION

Pressure was observed in the ice on 19 of the 42 days spent under-way in the ice. A total of 31 pressure episodes were observed. These are mapped on Fig. 1 along with arrows indicating the wind direction observed at the time the pressure was first noted.

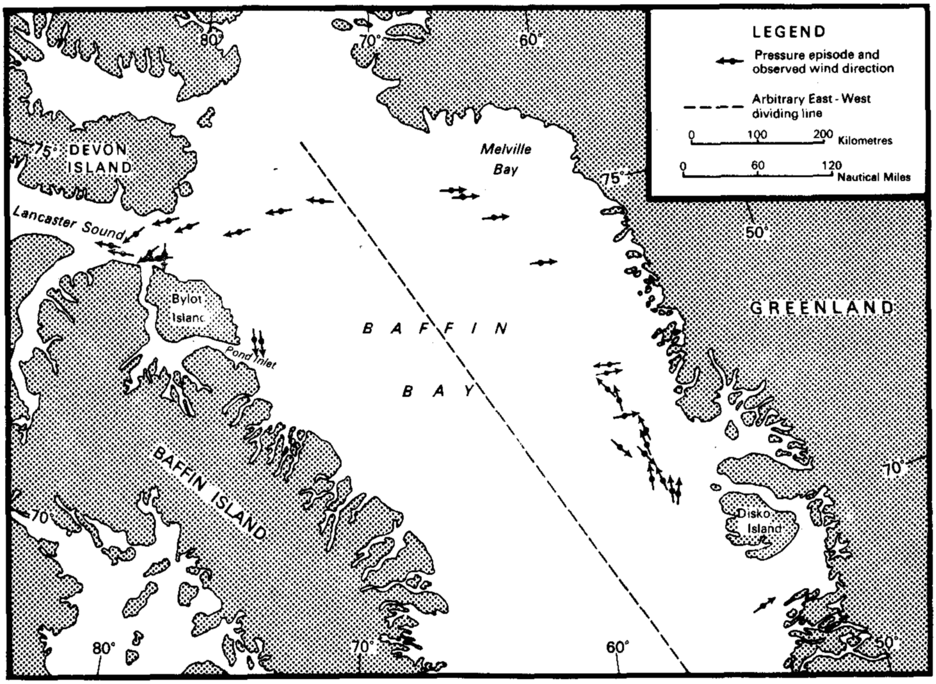

FIG. 1. Observed ice pressure occurrences and wind direction at time of observation.

Computing daily wind speed averages for the 4-hourly observations and comparing these on a percentage basis with days on which ice pressures were observed indicates that the higher the wind speed the greater the chances of ice pressure (Fig. 2).

The graph suggests that the chances of encountering ice pressure seem to be roughly twice as great when winds average 21 to 30 knots as when they average 0 to 10 knots. Because winds averaging >30 knots were only experienced on one day, the graph could not be extended for higher winds; however, the steady increase in frequency with increasing wind speed suggests that the probability of experiencing ice pressures might be even greater in winds averaging over 30 knots.

It was also noted that ice pressure severity seemed to increase with increased wind speed. Whereas heavy or severe pressures were noted on only 4 of 13 pressure days when winds averaged less than 20 knots, they were observed on all 6 pressure days observed when winds averaged over 20 knots.

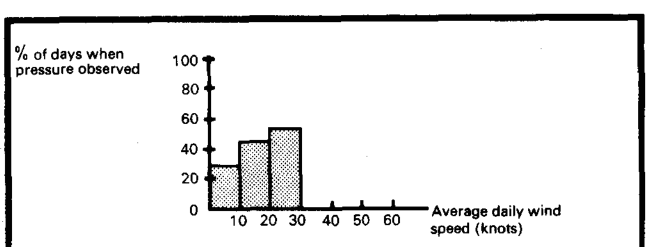

FIG. 2. Percentage frequency for sea ice pressures in increasing wind speeds.

Major wind shifts seemed to generate ice pressure. This is to be expected, of course, because abrupt wind shifts are frequently observed with the passage of deep atmospheric "lows" which would very likely cause convergence of the ice and hence pressure. Eighty per cent of the wind shifts of 80 degrees or more were accompanied by pressure episodes some of which were among the heaviest encountered. The association was doubly interesting in that the pressure was observed usually within an hour of the wind shift. In heavier winds the ice pressure seemed to begin simultaneously with the wind shift.

Ice pressure generation also showed a strong association with winds which were likely to produce an onshore ice drift. Fig. 3 shows ice pressure roses for east and west portions of the Baffin Bay area (see Fig. 1 for the dividing line). The roses are constructed from the wind vectors shown in Fig. 1 with a 40-degree deflection vector added to compensate for *coriolis* effect.

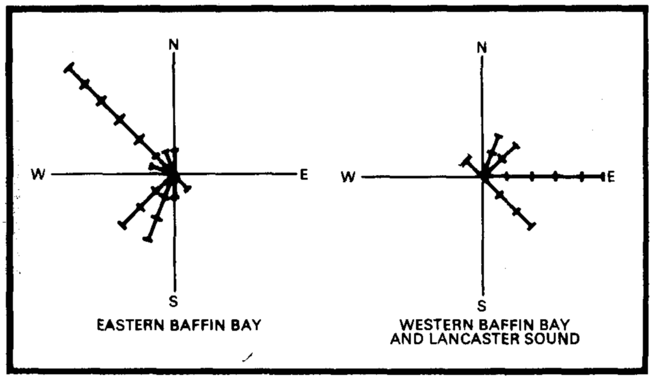

FIG. 3. Ice pressure roses for eastern and western parts of the Baffin Bay area.

Eighty-four per cent of the pressure episodes occurred during winds which, from the standpoint of ice pressure generation, could be classified as "onshore". It is interesting that the one major exception to this onshore pattern — the southeast vector which is shown on the East portion of Fig. 3 — was an episode of light ice pressure. The northwest vector on the West portion of the diagram is attributable to pressure observed near the time of a major wind shift.

The effect of ice thickness was difficult to assess. While the average ice thickness noted when heavy ice pressures were observed was 9 cm. thicker (95 cm.) than the 86-cm. average thickness when medium and light pressures were noted, one of the heaviest episodes occurred when the ice was less than 50 cm. thick. In all episodes of pressure the ice coverage was estimated at 9/10 or greater.

EFFECT ON SHIP PERFORMANCE

While under way in the ice, the ships averaged 37 nautical miles on days when ice pressure was not observed. Thirty-one miles per day on the average were covered when pressure was observed. (Only the distance travelled between 08:00 and 20:00 hours was calculated). One could claim, therefore, that since ice pressures were recorded on only half of the travelling days, the occurrence of ice pressures only increased the elapsed time of the voyage by 8 per cent. However, the calculation does not include 4 days during which the ships did not move

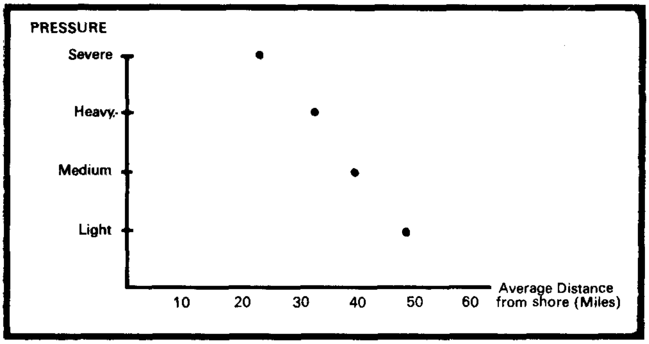

FIG. 4. Average distance from shore of qualitatively-rated ice pressure episodes.

after being jammed together by ice pressure on 25 May. To include this "lost time" would increase the elapsed time by an additional 9 per cent. As the risk of becoming beset for extended periods by ice pressures does exist, perhaps the 17 per cent figure is not unrealistic.

The data indicate increased ice pressure severity with proximity to shore (Fig. 4). For example, the average distance from shore at which light, medium and heavy pressures occurred was 48, 39 and 32 miles respectively. Light pressures caused no noticeable impediment to the ship's progress. Medium and heavy pressures both stopped the *St. Laurent* on several occasions when only intermediate horsepowers were available. Only on three occasions, however, did the vessel become beset in ice pressures while operating within 20 per cent of its maximum horsepower. On those occasions the average distance from shore was 23 miles. These are the episodes which are classified as severe pressures (Fig. 4).

CONCLUSIONS

Sea ice pressures in the Baffin Bay vicinity seem to be closely associated with winds which, with a deflection factor of 30 to 40 degrees added, produce an onshore ice drift. The ice pressures generated increase in frequency and severity with increasing wind speed; and severity of ice pressures seems to increase with proximity to shore. A close association also exists between ice pressure generation and wind shifts greater than 80 degrees.

From the experience of the *Louis S. St. Laurent*, if ships were constructed with the capability of navigating the Baffin pack in late winter, they could expect to encounter ice pressures on roughly 50 per cent of all days spent in transit. The overall effect of the pressure would be to impede progress but probably not by more than 20 per cent. The risk of becoming beset by ice pressure would occur whenever the ships approached within 25 miles of a shoreline in onshore winds of over 20 knots.

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