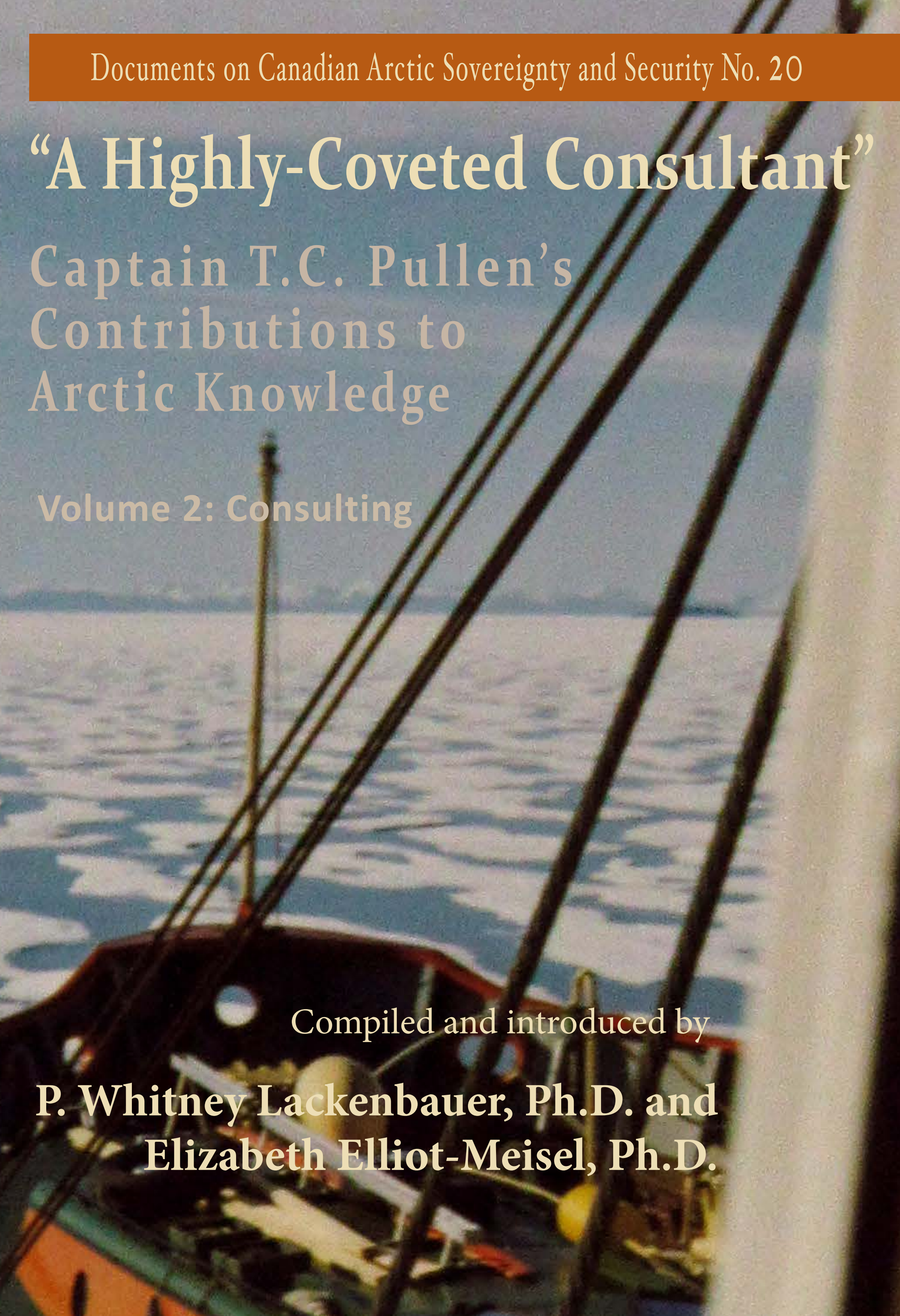
Documents on Canadian Arctic Sovereignty and Security No. 20

"A Highly-Coveted Consultant"

Captain T.C. Pullen's Contributions to Arctic Knowledge

Volume 2: Consulting



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P. Whitney Lackenbauer and Elizabeth Elliot-Meisel
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P. Whitney Lackenbauer, Ph.D.

and

Elizabeth Elliot-Meisel, Ph.D.


1956

[The] Northwest Passage, of course, is the fabled sea route which engrossed the imaginations and attentions of our forebears for centuries. It is a maze of ice-cluttered straits and sounds connecting Baffin Bay in the east to the Beaufort in the west, all involving a voyage of 1,000 miles or so, and is America's Arctic key to the linking of Atlantic and Pacific. Assured delivery of oil and gas from Arctic North America to world markets, both east and west, calls for year-round navigation of the Passage and adjacent waters. In my view prospects for operational success are good though they demand special ships the likes of which fire the imagination. They call also for special people to man them -- people who can rise to the challenge. Finally, of course, the economics must make sense -- and that seems likely to be the major problem.

For those who may be unfamiliar with shipping activities in Arctic North America it should be explained that at this time there is no such thing as routine year-round movement of ships anywhere in the north and there never has been. The annual resupply of remote settlements, the delivery of cargoes required on a recurring basis by exploration companies, and the ongoing scientific activities of the private sector and government agencies (oceanography, hydrography, seismology et al), are all planned and carried out during the summer months. That is the time when nature relents and some ice cover melts and retreats, permitting ships to penetrate selected areas to meet their commitments. These undertakings have been going on for years, the resupply of settlements for many years indeed, and all employ a mix of vessels including tugs, barges, icebreakers, ice-strengthened and unstrengthened ships.

Thomas C. Pullen (1983)

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Introduction: "Pullen of the Arctic"

P. Whitney Lackenbauer and Elizabeth Elliot-Meisel, with contributions by Corah Hodgson

> *[Captain T.C. Pullen, RCN,] had become, and to the last remained, one of the great polar navigators.*
>
> \- Graham Rowley (1992)[1]

Captain Thomas Charles Pullen (1918-90), RCN, OC, CD, D.Sc., FHSC, a fifth-generation naval officer, commanded numerous ships during his career with the Royal Canadian Navy (RCN) from 1936-65. He became a noted authority on and explorer of the Arctic after he took command of the naval icebreaker HMCS *Labrador* in 1956. Retiring after thirty years of active naval service, Pullen served as an advisor and consultant to government and industry on Arctic marine operations for another twenty-four years. An officer of the Order of Canada and the recipient of the Massey Gold Medal of the Royal Canadian Geographical Society for his contributions to Arctic knowledge, "Pullen of the Arctic" (as he became widely known) earned the reputation as North America's foremost expert on Arctic navigation and icebreaking over the course of his life.[2]

This volume is a companion to *"One of the Great Polar Navigators": Captain T.C. Pullen's Personal Records of Arctic Voyages, Part 1: Government Roles* (Documents on Canadian Arctic Sovereignty and Security No. 12), which published key documents on Arctic operations that Pullen wrote in various official capacities over his career. Focusing in particular on his role as the commanding officer of *Labrador* in the 1950s and his observations as the Government of Canada's official representative onboard the icebreaking tanker *Manhattan* in 1969/70, his diaries and reports provide unique insights into key moments in Canadian Arctic history.

Pullen also produced more than fifty reports and papers for clients on Arctic maritime and development issues from the mid-1960s to the late 1980s (see Appendix B), as well as serving as an expert witness in litigation involving the mishandling of ships at sea and testifying before Canadian parliamentary committees on Arctic marine issues. In this volume, we provide a representative sample of his work on subjects ranging from icebreaking conditions to vessel design, from supporting infrastructure needs to cruise tourism. As with the previous volume, our goal is to bring more of Pullen's ideas into public circulation, stimulate informed discussion and debate on the history of maritime operations in the Canadian Arctic, and ensure that "Pullen of the Arctic" gets credit for his contributions to polar navigation, knowledge, and practice.

Much of the biographical sketch that follows is reproduced from volume one, in recognition that some readers may read this book independent of the other one. Given the focus of the present volume, we have reduced the sections on his time commanding *Labrador* and his reflections onboard *Manhattan*, and we have instead expanded the sections on Pullen's consulting activities from 1965-88. We plan to elaborate on all of these topics in a forthcoming biography of Pullen.

Background

Thomas Charles Pullen was born in Oakville, Ontario, on 27 May 1918, into a proud nautical family with a record of naval service dating back to the eighteenth century. His great-great-grandfather, Nicholas Pullen, and sixteen of his shipmates aboard a small vessel trading in the West Indies had been press-ganged into the Royal Navy in 1780. Subsequently, sixteen of Nicholas' descendants became naval officers, including four flag officers, two captains, and two commanders. The Arctic brought the family particular fame, beginning with Tom Pullen's great-uncles Commander (later Vice-Admiral) W.J.S. Pullen, who commanded the depot ship *North Star* on the 1852-54 Belcher expedition to find Franklin, with his younger brother T.C. Pullen (later Captain) as his second-in-command.[3] Thanks to their exploits, when Tom Pullen sailed in the Arctic a century later, "there were four Pullen place-names to remind him of his great-uncles."[4]

After attending Lakefield College School, a private boarding school in the picturesque Kawartha Lakes region of Ontario, from 1929-35, Tom Pullen spent one year at Oakville High School, where the principal prepared him for the Royal Navy officer cadet entrance examination.[5] He entered the RCN as a cadet in 1936, sailed in RMS *Ausonia* to the United Kingdom in August, and took his early training on ships of the Royal Navy.[6] First he was sent to the British training cruiser HMS *Frobisher*, on which he developed his skills in the North Sea, Norwegian Sea, Atlantic Ocean, and West Indies. The next two years he spent in the First Cruiser Squadron of the British Mediterranean Fleet onboard HMS *Shropshire* and *Sussex*, as well as three months of destroyer training with HMS *Hotspur* and *Hostile* of the Second Destroyer Flotilla. His first appointment came onboard *Shropshire* at the rank of Midshipman. He went on to serve on the Nyon patrol off the Iberian Peninsula during the Spanish Civil War, assigned to coastal patrolling and evacuating civilians. "We were running boats from shore out to the ship and on one occasion there was a bombardment from seaward and shells were whistling overhead," he recalled. "It was really a minor overture to World War II." The Royal Navy was training hard for a war that everyone knew was coming, with Pullen observing "a steady procession of all the ships of the Mediterranean Fleet, in and out, doing exercises every day, and night exercises."[7] Pullen then returned to England in 1939 for a subs course, emerging as an acting sub-lieutenant.[8]

When the Second World War broke out on 3 September, Pullen was qualifying as a gunnery officer at Whale Island, Portsmouth. He was soon appointed to the newly commissioned RCN destroyer HMCS *Assiniboine* on 23 October, captained by Commander E.R. Mainguy. "It was a great fun, it was a great learning process," Pullen later recalled. "You had to learn fast in those days because the Navy was expanding and there were not enough experienced and trained officers to go around ... so prospects were bright and it paid to pay attention!"[9] As gunnery officer/watchkeeper on the destroyer, Pullen was involved in the capture of the German merchant ship *Hanover* in the West Indies in March 1940, followed by convoy escort duties running from Halifax to Iceland, which entailed "three days in and three days back."[10] He departed *Assiniboine* on 20 January 1941 so that he could return to Britain for a specialist course in gunnery. After he fell ill with epistaxis (bleeding from the nose) and was hospitalized for a short time, he was tasked with staff duties at HMCS *Niobe* – a "lunatic asylum" (hospital) at Greenock requisitioned by the RCN in 1941 to serve as the headquarters of the senior Canadian naval attaché and advisor in the UK. Pullen was unhappy with the posting. "I bitched and grumbled as much as I could," he recalled, "then asked and requested to go to sea" – as he saw it, "the proper place for a young officer."[11]

His wish granted, Pullen swapped positions with the executive officer (second in command, or first lieutenant) of the destroyer HMCS *Ottawa* in February 1942. It was a trying time for the RCN ships on Mid-Ocean Escort Force operations at the height of the Battle of the Atlantic. Historian Marc Milner describes how:

> 1942 was a very anxious period in the battle against the U-boats in the Atlantic. By the summer of that year the products of Germany's first wartime building program were pouring forth at a rate of nearly twenty U-boats a month ... the number at sea on any given day was increasing, from an average of twenty-two in January to eighty-six in August, reducing

> the potential for successful evasive routing of convoys.... The prospect of the mid-ocean filling up with U-boats among which convoys could only be safely routed by very precise intelligence, was worrisome to say the least.... As early as August it was clear ... that the confrontation in the mid-Atlantic air gap would soon escalate rapidly.... Unfortunately for the Allies, a substantially higher casualty rate in the U-boat fleet was not in the offing in late 1942, and the exchange rate between Allied shipping losses and U-boats destroyed continued to favour the Germans heavily. Through the last months of 1942, U-boats exacted a punishing toll from North Atlantic Shipping.[12]

As the RCN official history later noted, "practically no convoy at sea, especially in mid-ocean, could now help standing into danger" at this stage in the war. "An average of 100 U-boats operated in the Atlantic in September [1942]."[13]

Ottawa sailed from Londonderry on 5 September with Convoy ON 127, escorting thirty-four merchant ships across the North Atlantic. "Up until that time I had bemoaned the fact that we never seemed to have any excitement in all my trans-Atlantic voyages with convoys," Pullen later reminisced. "I was going to live to regret that statement."[14] Several of the merchant ships were sunk by German U-boats before the fateful night of 13 September, when U-91 hit *Ottawa* with two torpedoes (thirty minutes apart) about 500 nautical miles east of St. John's. "Everything happened so swiftly," Pullen remembered. When the captain gave the order to abandon ship, "some over-burdened floats capsized, throwing their occupants into the water and adding to the death toll." It was a tragic scene:

> During those final moments some grim dramas were being played out. The pitiable entreaties emanating from the voice pipe to the bridge from the two young hands trapped in the asdic hut far below became unbearable to those on the bridge, who were totally helpless to do anything for them. What could, what should, one do other than offer words of encouragement that help was coming when such was manifestly out of the question? What happened at the end is hard to contemplate for the imprisoned pair, as that pitch black, watertight, sound-proofed box rolled first 90 degrees to starboard and then 90 degrees onto its back before sliding into the depths and oblivion. It is an ineradicable memory.[15]

The sinking ship took 137 lives with her, and only sixty-five survivors were pulled from the numbing waters of the Atlantic. Pullen was the senior surviving officer. "Pullen was one of the last to leave [the sinking ship]—having tried his sailor's luck by wanting to leave after the captain—and was fortunate to spend only five hours on a raft before being rescued," an obituary later recounted.[16]

The same story also noted that Pullen "had strong reason to survive, as he was on his way home to marry Elizabeth Wheelwright, who was to bear him a son and a daughter." Tom had met Helen Elizabeth (Betty) Wheelwright, who was born and raised in Toronto, in Oakville, Ontario, in the summer of 1936. "We'd only known each other a couple of weeks and off I went [to England]," Pullen later recalled. He wrote her a postcard from Quebec on the voyage overseas, which served as "the trigger ... for a correspondence" that went on "non-stop" for a half century. When he next returned to Oakville in 1938, they "picked up where we left off" before he went off again. On survivor's leave after his harrowing ordeal with ON 127, he followed through on tying the knot. "Ralph Hennessey lent me his cap" and a Toronto tailor produced a uniform for Pullen in a couple of days, he recalled.[17]

After a year's duty ashore as officer-in-charge of the Gunnery School at HMCS *Cornwallis* (the RCN training establishment in Nova Scotia), Pullen returned to sea as the executive officer of the River-class destroyer HMCS *Chaudière* when it was transferred to the RCN in November 1943. The following March, operating as part of the Mid-Ocean Escort Force, she was involved in a thirty-hour battle that ultimately led to the sinking of German submarine U-744 off the Normandy coast. "It was a long hunt," Pullen recounted. "The contact was being gained, lost, regained, and at all times I think there were concerns that we were chasing the wrong sub echo. But, in fact, it was the real thing. It was apparent that she was coming up. You could hear her blowing tanks and she hit the surface, and of course everybody opened fire." A few months later, after workup training in Northern Ireland for "The Blood Bath to Come" (as they jocularly referred to the impending Allied invasion of Europe), Pullen was onboard when *Chaudière* joined Western Approaches Command for invasion support duty and ensured that U-boats did not penetrate the English Channel on the lead-up to D-Day.[18]

In August 1944, at the age of twenty-six, Pullen became one of the youngest destroyer captains in the RCN when he took command of HMCS *Saskatchewan*.[19] "At the end of the war, I was transporting men from Newfoundland to Quebec City for demobilization and I established a record for the fastest runs from Father Point to Quebec City, doing about twenty-six knots," Pullen recalled. "Coming down from Quebec City with the tidal current, we were doing it even faster. It was a tremendous experience." Because of its excessive speed, the ship became popularly known as the "Terror of the St. Lawrence" for the huge wash that it would generate, rolling yachts up on beaches and provoking locals to "run for the woods" when the ship approached.

"I had to undergo a Board of Inquiry, as a result of this excessive speed," he noted, "but I assume that I got off quite lightly [as] nothing ever happened."[20]

After relinquishing command of *Saskatchewan* in the early fall of 1945, Pullen took a gunnery course in the UK with the acting rank of Lieutenant-Commander before returning as the officer in charge of the gunnery course at HMCS *Stadacona* in Nova Scotia and staff gunnery officer on the Atlantic Coast. This was followed by Royal Navy staff courses in 1948, command of the destroyer HMCS *Iroquois* and the frigate *La Hulloise*, and service as the executive officer of the training base HMCS *Cornwallis*. In September 1953, Pullen took command of the Tribal-class destroyer HMCS *Huron* during her second tour of duty as a member of the Commonwealth Task Force in the Korean theatre, and he remained in this appointment until June 1954. For part of this period, he acted as Commander Canadian Destroyers Far East (the senior Canadian naval officer in the Korean theatre) in the acting rank of Captain. In the summer of 1954, he became the Staff Officer (Strategy) to the Director of Naval Plans (Strategy and Operations) at RCN Headquarters in Ottawa before assuming the position of Director of Gunnery Division on the staff of the Assistant Chief of Naval Staff (Warfare) that December. In July 1955, Pullen was officially promoted to a captain in the RCN.[21] This set the stage for him to perpetuate his family's long history of Arctic service when he assumed the command for which he would become best known: that of the Royal Canadian Navy icebreaker HMCS *Labrador* on 13 February 1956.

Commander of HMCS *Labrador*

Although Canada is a coastal state bordered by three oceans, its official motto *a mari usque ad mare* refers only to two. The Canadian navy has traditionally mirrored this national emphasis on the Atlantic and the Pacific. The Royal Navy was at the forefront of the epic search for a Northwest Passage (NWP) in the mid-nineteenth century, which, after great cost and frustration, led to the "discovery" of one-half of the Arctic and three northwest passages.[22] By the end of that century, however, the viability of the route as a passage to "the Orient" was dismissed. Norwegian explorer Roald Amundsen's 1903-06 transit of the Passage was not repeated until Henry Larsen's transits in the Royal Canadian Mounted Police (RCMP) schooner *St. Roch* in 1940 and 1942,[23] and for the first four decades of its existence no Canadian government or admiral dispatched any element of the RCN to Canada's Arctic seas.

At the end of the Second World War, Canada's maritime domain factored heavily into the United States' security considerations. The Canadian government in general, and the military in particular, were at a crossroads. The government had sacrificed men, money, equipment, and political capital to the victorious Allied cause. The military in general stepped "out of the shadows" and made contributions, both at home and abroad, that garnered well-deserved praise.[24] The RCN, in particular, was now a first-rate blue-water navy. When, at war's end, the RCN was downsized dramatically, it had to choose between concentrating its resources in either the Atlantic or the Arctic Ocean. It chose the former.

The North American Arctic, however, was emerging as a front line in the new Cold War. Consistent with concerns over increasing American interest in the region and at a time of regular discussions within Arctic circles in Ottawa about the benefits of "Canadianization,"[25] the RCN decided early in 1948 to begin making plans for the construction of its first Arctic Patrol Vessel. HMCS *Labrador* was launched in December 1951 and commissioned into the RCN in July 1954. Over the next few years, the ship played a major role in facilitating the construction of the Distant Early Warning (DEW) Line, a radar network stretching across the 70th parallel to provide advanced warning of Soviet bombers attacking North America.

Captain Pullen assumed command of *Labrador* on 13 February 1956, and for the next two years he carried on the family tradition of Arctic naval service. "The massive sealift associated with [the DEW Line's] construction, much of it on Canadian territory, was almost entirely an American undertaking and focussed a compelling need for Canada to assert herself and play a significant role," Pullen wrote. "The arrival on the scene of a modern icebreaker, staffed and equipped to exercise command of operations of such size and scope, could not have been better timed." From 1955-57, HMCS *Labrador* performed various roles, ranked by the Naval Staff in order of importance as follows:

(a) "to carry out patrols in northern waters to provide the navy with the knowledge and experience required for the planning and conduct of future naval operations."

(b) "to perform such icebreaking duties as are found to be necessary during the conduct of naval arctic operations."

(c) "to assist in the logistic support of Canadian arctic bases where icebreaking is necessary, and to provide limited logistic support to such bases."

(d) "to carry out such hydrographic and scientific surveys as are from time to time, considered desirable by the navy; and"

(e) "to perform rescue and limited salvage in Canadian arctic areas."[26]

His diaries and reports, reproduced in volume one, provide daily overviews of what he experienced as the captain of *Labrador* at sea.

Despite all of *Labrador*'s successes during its 1957 mission, the RCN decided to opt out of an Arctic role and pay off *Labrador* as a naval ship that following year.[27] Pullen was unabashedly critical of the decision. "No ship has done more for Canada than *Labrador*," he wrote in his diary on 11 October 1957. "No ship is better known to the people in Canada and abroad than *Labrador*, and yet the experts, in their purblind wisdom, have decided that she has nothing to contribute in a war that will never be fought. And so she is got rid of so that a couple of obsolete frigates can be commissioned." Pullen appealed to his brother, Rear Admiral H.F. Pullen, the Flag Officer Atlantic Coast, in hopes that he could reach up the chain of command and convince senior leadership to reverse the decision, but his effort came to naught. *Labrador*'s transfer to the Department of Transport was completed in 1958.[28]

Captain Pullen called his tenure as *Labrador*'s captain "the most challenging and interesting one I ever had," with the ship's "accomplishments ... of significance to Canada and the product of all her dedicated and enthusiastic officers and men."[29] Commander (retired) J.M. Leeming, who had been on board *Labrador* for her first year and a half in service, was more directed in his praise, concluding that the icebreaker's "accomplishments were due entirely to her two commanding officers, Captain Robertson and Pullen. Their professional skill, leadership, and determination to succeed were the keys to *Labrador's* success as that hardy vessel moved through a polar world filled with challenges and dangers."[30] The icebreaker's list of achievements (which Pullen summarized in Figure 1) were impressive by any measure. Naval historian E.C. Russell, paying tribute to *Labrador* in 1964, extolled how:

> HMCS *Labrador* has become a part of the history of the Arctic, her name forever linked with those of *Discovery*, *Fury, Investigator, Gjoa, St. Roch*, and the many great names of the North. Her achievements during her short but illustrious career in the Royal Canadian Navy are too many, varied, and important to be briefly summarized; but it is perhaps no exaggeration to say that during her four years in the RCN she contributed more to man's knowledge of the Canadian Arctic than any ship this century.[31]

Pullen, at the helm for two of those years, deserves much of the credit.

Figure 1

H.M.C.S. LABRADOR- 1956-57
HIGHLIGHTS
--ooOoo--

- First hydrographic survey of narrow, swift flowing, Bellot Strait which separates continental America from the arctic islands. First transit by a deep draft ship and later the locating and naming of hazardous Magpie Rock, on which both M'Clintock's Fox (1858) and Larsen's *St Roch* (1942) nearly came to grief.

- Appointed commander of a U.S. Naval Task Group for the Bellot survey primarily to establish an escape route for ships trapped in the central and western arctic. Also ensured completion of the Northwest Passage by the U.S. Coast Guard ships *Storis, Spar* & *Bramble,* excluding submarines, the first United States ships to do so.

- First east to west transit of Fury & Hecla Strait and the extrication from the pack in the Gulf of Boothia of the US Navy icebreaker *Edisto* which had lost a propeller in heavy ice.

- Penetration and sounding of Wellington and Queens Channels reaching Penny Strait (Pelham Bay). Most northerly such probe to date since Sir Edward Belcher in HM Ships *Assistance* and *Pioneer* in 1852 during the Franklin search.

- The sounding and proving of a much-needed deep water channel for shipping, the Pike-Resor Channel, providing the first safe and direct route to the airport and settlement at the head of Frobisher Bay.

- Continuation of the hydrographic survey of uncharted Foxe Basin, begun in 1955 by Labrador (Capt. O.C.S. Robertson), for the safe navigation of cargo ships to new DEW-Line sites. Surveyed unsounded "Navy" and "Labrador" Channels, developed a direct route between Hall Beach and Rowley Island and first circumnavigated the Spicer Islands.

- The ship and her hydrographers and oceanographers produced 17 new arctic charts and occupied more than 360 oceanographic stations.

- Sounded 35 miles of uncharted water through heavy pack to Brevoort, east Baffin. Surveyed the harbour, erected navigational aids, distributing the resulting charts and sailing directions to ships bearing DEW-Line construction materials and supplies.

- First navigation of Peel Sound since Sir John Franklin in 1846 and Roald Amundsen in 1903, in the process sounding the waters for the first time. First circumnavigation of Somerset Island.
- Carried out the first oceanographic survey of winter ice conditions in the St Lawrence to determine, *inter alia*, the feasibility of year-round shipping operations there, a state of affairs since considered routine.
- Re-assertion of Canadian arctic sovereignty, years before it became an issue exercising Canadians, by taking under her command U.S. Navy and Coast Guard ships formerly operating at will in Canada's arctic waters.

Source: T.C. Pullen, Directorate of History and Heritage (DHH) File

From Naval Officer to Arctic Consultant

After Pullen relinquished command of *Labrador*, he attended the year-long senior staff officer course at the Imperial Defence College (now the Royal College of Defence Studies) at Seaford House, Belgrave Square, in London, England.[32] Subsequently, he returned to HMCS *Niobe*, the asylum-turned-RCN-establishment in London, on 15 December 1958, this time as Executive Officer (XO). His supplemental appointments over the next two years included Chief Staff Officer to the Naval Member Canadian Joint Staff, London, and Canadian Naval Member to the Military Agency for Standardization. Returning to Canada in July 1960, he was appointed Commanding Officer of the naval air station HMCS *Shearwater* before returning to Naval Headquarters in Ottawa to serve on the staff of the Vice Chief Naval Staff and then on the staff of the Assistant Chief Naval Staff Air and Warfare as the Director Naval Ship Requirements. He assumed his last sea-going command on HMCS *Provider*, the RCN's first dedicated auxiliary oiler replenishment ship, when it was commissioned in September 1963. At the end of the following year, he returned to Ottawa and the recently unified Canadian Forces Headquarters as Director Maritime Operations.

Pullen's naval "career ended with the amalgamation of the Canadian Armed Forces in 1964," his obituary in the London *Daily Telegraph* observed. "Like most naval officers he regarded it as totally misguided, and hardly relished the prospect of wearing a bottle-green uniform and being addressed as 'Colonel.'"[33] Although the RCN would continue as a separate service until 1968, the creation of Maritime Command (MARCOM) on 7 June 1965 as part of the reorganization of the services into six functional commands portended the major shift that was occurring. "In the integrated [National Defence

Headquarters]," historian Tony German notes, "the small naval component was all but submerged."[34] Although the changes brought by "unification" were designed to remain at the command level, long-serving personnel like Pullen saw the dismantling of time-honoured naval traditions as an abomination. He had held nearly every appointment available to a naval captain, and with his brother as a rear-admiral "the odds were against appointment of a second Pullen to the same small circle of flag officers."[35] In August 1965 he went on rehabilitation leave, and the following April he took his honourable release from naval service.

"When Captain Pullen retired from the Royal Canadian Navy in 1965, he was 47 years old and anxious to find new and interesting employment," recalled Graham Rowley, then with the Department of Northern Affairs and National Resources. Tom had called Graham in June to see if the latter had any suggestions about consulting opportunities. Rowley, who had an extensive network by virtue of his role as secretary to the federal Advisory Committee on Northern Development, had spoken to Arctic mining engineer and prospector Murray Watts a few days earlier, who had noted the "exceptionally rich iron mines he had recently discovered near Mary River in northern Baffin Island and we discussed the problems that would have to be faced if they were to be exploited." When Rowley asked Pullen if he would be interested in investigating what would be required to transport the ore out of the North, Pullen "replied that this was just the sort of work he would most like to do." Watts jumped at the opportunity to recruit a man of Pullen's knowledge and experience, thus launching the retired naval captain's "new career as an advisor and consultant on arctic marine operations."[36]

With the DEW Line completed, Pullen noted that the emphasis in northern affairs had "shifted from exploration and defence to commerce. The search for minerals, for oil and gas to satisfy a growing demand on a worldwide scale is being pushed hard from Prudhoe Bay, Alaska, to the Fosheim Peninsula in the east."[37] Postwar geological surveys revealed the resource riches of Canada's Arctic, with exploitation contingent on modern transportation to carry marketable products to more populated areas.[38] Pullen's extensive consulting work to industry, listed in his *curriculum vitae* (Appendix B), yielded many key reports and insights into Arctic operations that reinforced his reputation as one of the Western world's foremost authorities on Arctic navigation and icebreaking.[39]

The Arctic Mining Frontier

In the late 1960s, Pullen set to work anticipating the problems in shipping large quantities of ore from Arctic mines, selecting possible dock locations, and determining the limits of the navigation season. One of his first series of projects involved the prospective Baffinland project at Mary River. In July 1962, prospector Murray Watts (head of British Ungava Explorations Ltd.) was exploring central and northern Baffin Island in a Cessna aircraft when he noted massive deposits of high-grade iron ore – large black circles of 65-70% pure iron.[40] There was no question that the concentration at Mary River was world-class, but developing a mine in this austere location would require a massive investment in infrastructure. Securing financial backing would also depend upon a feasible plan for ships to carry the ore through Arctic waters to markets.

In 1965, Baffinland Iron Mines hired Pullen to serve as Government Liaison Agent and Icebreaker Observer during Canadian Coast Guard Ship (CCGS) *John A. Macdonald*'s October voyage. He was tasked with assessing ice conditions in Baffin Bay, determining the time of freeze-up at Milne Inlet and how long the area could be kept open by icebreakers afterwards, and evaluating the general shipping prospects in the area. In **document 1**, he furnished a general overview of ice conditions in Davis Strait and Baffin Bay, Pond Inlet/Eclipse Sound/Navy Board Inlet, Milne Inlet, and Milne Harbour, and recommended a route for shipping while identifying factors that influence shipping in Arctic waters: from wind and fog, to icebreaker escorts and tug services, to ship size, handling, and loading. He also described the characteristics of icebreakers that would be necessary as escorts at the beginning and end of the shipping season. "Size of ships is not a major problem," he concluded. "Indeed the fewer (and therefore the bigger) the better if more efficient use is to be made of the available icebreaker force." Pullen also explained that "from a seaman's point of view an alternative route by way of Foxe Basin has much to commend it, and that heavy ships such as ore carriers should never be taken through the Baffin Bay pack even if icebreaker escort is available. Only when no other route is available should this be attempted."

In 1965, conditions in Baffin Bay (particularly with respect to the extent of the pack) were worse than usual. The following July, Pullen embarked on the Canadian Coast Guard icebreaker *D'Iberville* to survey the route to Baffinland's camp at Mary River before returning south by airplane. In October, he sailed on *John A. Macdonald* from Eclipse Sound to assess the closing phase of the navigation season before returning to Dartmouth, Nova Scotia. His report, reproduced as **document 2**, provided a detailed narrative of ice conditions, which revealed a high degree of interseasonal variability when compared to 1965. "Ice conditions this year were better than average and certainly much better than last year," Pullen reported. During the second half of the season, "there was no Baffin Bay pack such as existed last year to bedevil shipping," and "the opening of Milne Harbour to navigation for ore carriers was governed by heavy ice conditions in Eclipse Sound and not in Baffin Bay." He noted that an ore carrier with icebreaker escort could have reached Milne Harbour by way of Navy Board Inlet as early as 26 July, and an unescorted ore carrier could have reached Milne Harbour by way of Pond Inlet on 1 August. "The length of the 1966 shipping season to and from Milne Inlet and Harbour was 95 days (13-1/2 weeks or 3 months and 2 days) which represents a significant [improvement] over 1965," he observed. With the ship anchored off Pond Inlet on 20 October, Pullen had visited the community and spoke with RCMP Special Constable Lazaroosie Kyak (which Pullen spelled as Kyack),[41] who told him that "1966 was one of the latest freeze-up years in his 23 years of experience in the area. In his opinion the seasons seemed to be getting longer and later each year." Inuit, as the closest observers of changes in their homeland, recognized that the Arctic was warming – but it would take decades for the world to awaken to this reality.

Pullen's reports also reveal cumulative knowledge gleaned from systematic observations. In 1966, he retracted his recommendation from the year before that Foxe Basin and Steensby Inlet might be more feasible than using Milne Inlet and Baffin Bay. "There were, and are, attractive advantages to this, but the use of such an alternative would be dependent upon deep water in Steensby Inlet and suitable terrain between Mary River and tidewater at Steensby Inlet in Foxe Basin," Pullen explained. Having flown from Mary River to Hall Beach, however, he "was appalled at the ruggedness and lake infested nature of the land. For this reason, and this reason only, I [have] withdrawn my suggestion of Foxe Basin as an alternative to Milne Inlet."

In his third annual report to Baffinland Iron Mines, completed after the 1967 Arctic shipping season (**document 3**), Pullen continued to produce essential insights into the feasibility of Eastern Arctic navigation for a large-scale mining operation. Embarking on *John A. Macdonald* under the command of Captain Paul Fournier, Pullen sailed from Montreal on 8 July for Milne Inlet and remained onboard until 4 August, when he disembarked at Pond Inlet. Realities forced Pullen to check his assumptions:

> This year, as the JOHN A MACDONALD was bludgeoning her way through ice in ECLIPSE SOUND more formidable than that encountered there last year at the same time by the D'IBERVILLE, I began to suspect that 1967 would turn out to be a bad ice year for navigation. This view was shared by Special Constable Kyack, R.C.M.P., at POND INLET to whom I spoke on August 4 about ice conditions in the area. He told me the chances were good that the ice might never go from ECLIPSE SOUND in 1967. Eventually, of course, it did. I am sure he is a much better Special Constable than he is a long range ice forecaster! But the Arctic is no place for an impatient person and one should never jump to conclusions. When it was all over, 1967 turned out to be a reasonable navigation year for those imaginary ore carriers after all.

Ultimately, Pullen observed for a second straight year that "the opening of Milne Inlet to navigation by (imaginary) ore carriers would have been governed by ice conditions in Eclipse Sound and not the ice in Baffin Bay." He reiterated his indebtedness to Marine Operations of the Department of Transport, and to the captains and officers of the icebreakers, for enabling his work.

Based on the three years of data that he had collected, Pullen concluded that 1966 could be considered an "above average" year for ice navigation, while 1965 and 1967 represented "average" years for ice navigation to Milne Inlet (ten to eleven weeks' duration).[42] His annual narrative review of ice conditions provided a rich blend of detailed description and expert analysis. An entry from mid-July is indicative:

> At 3 pm on Sunday, July 16, scattered ice (3/10 medium and thick winter ice plus an assortment of heavy polar floes) was encountered 40 miles northwest of DISKO ISLAND (70° 30′ North 56° 28′ West). The ship ignored one such floe, a hefty relic of a pressure ridge 25 feet thick, off which she bounced. The distribution of this sort of ice is what makes for difficulties when escorting shipping. It is sufficiently spread out to appear of little consequence yet the movement of an icebreaker through it sets up eddies which can pull heavy floes into the path of oncoming ships. Low visibility can add to the difficulties of ships being escorted.

In terms of the length of the "unescorted" navigation season (the best ice-free period of navigation when companies might use non-ice-strengthened vessels without icebreaker escort), Pullen noted that "marine underwriters would probably have a great deal to say on this subject." Then, as now, the shipping insurance industry would be the ultimate arbiters of risk thresholds and the economic feasibility of commercial operations.[43]

Figure 2: Navigation Seasons for Shipping Destined for the Proposed Ore Loading Facility in Milne Inlet, with icebreaker escort

Year	Open	Close	Duration (icebreaker-escorted)	Duration (unescorted)
1965	11 Aug.	20 Oct.	70 days (10 weeks)	20 Aug. – 10 Oct. (51 days or 7 weeks + 2 days)
1966	26 Jul.	30 Oct.	97 days (14 weeks less a day)	1 Aug. – 26 Oct. (87 days or 12 weeks + 3 days)
1966	5 Aug.	22 Oct.	78 days (11 weeks plus a day)	20 Aug. – 15 Oct. (56 days or 8 weeks)

While Pullen's reports to Baffinland Iron Mines focused on the navigation of relatively small ships (up to 30,000 tons) with icebreaker support in ice-infested waters, he concluded his 1966 study with thoughts on giant tankers and ore carriers in Arctic waters. "A tanker now in service displacing 150,000 tons deadweight … is hailed as the world's largest ship," he noted. More than 1,000 feet long, 156 feet wide, and with a draught of 53 feet, the ship had a top speed of 17 knots. Largely automated with remote controls for machinery and cargo systems, it had only twenty-nine crew members. With plans for tankers of up to 750,000 tons deadweight, Pullen carefully weighed the benefits and risks of such "giants":

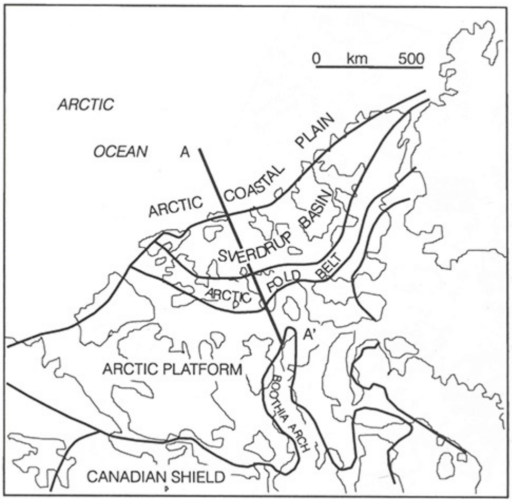
> It is certainly as practicable to build ore carriers of such dimensions as it is oil tankers though in the event of hull damage there would be more risk to the former type. A laden tanker whose plating has been holed, say by ice, simply exchanges oil for water with no appreciable effect on her ability to remain afloat. An ore carrier, however, because of the heavy nature of ore, has a great volume of air in her holds even when fully laden and can endure comparatively little flooding before being in danger of foundering. For ships intended to navigate in ice this possibility would obviously receive special consideration from the naval architects.

Pullen would closely monitor the development of ice-strengthened bulk carriers in the years ahead and continue to offer insights into their implications for development prospects.

The Kitikmeot region of what is now Nunavut had generated excitement about potential mineral resources since the eighteenth century, when Hudson's Bay Company explorer Samuel Hearne and Dene chief Matonabbee returned from their epic 1772 expedition up the Coppermine River to Coronation Gulf. The region contains some of the oldest granitic and volcanic metamorphic rocks in Canada, which can host metallic deposits, such as gold, silver, nickel, or platinum, when exposed across the present landscape of the mainland coast.[44]

In 1968, Pullen reported to Coppermine River Limited on problems associated with the movement of copper concentrates from the Coppermine area (Expediter Cove) to terminal points overseas, as well as issues related to moving fuel and freight into the area (**document 4**). The consummate professional, he made no attempt to overinflate his findings or his conclusions. "What has been attempted here is a superficial examination of some of the factors involved in a project which, taken as a whole, is really most complex and which calls for an all-embracing transportation study," he explained. "Early in my work on this matter it became apparent that information essential for me to submit a meaningful report was just not available or lay outside my field of competence. Until all aspects of the matter can be examined, until the various alternatives can be considered, only then would it become practicable to draw sound conclusions and to present meaningful recommendations."

In this preliminary study, Pullen sought to rule out economically unattractive alternatives and "to settle on a single system (with approximate costs) from the mine to the discharge point overseas." He grappled with a series of overlapping requirements: moving concentrate from Hope Lake to tidewater at Coppermine; stockpiling and storage; requirements for terminals, handling equipment, wharfage, and ship types; the length of the navigation season for the different types of shipping; and how the shipping cycle related to the production cycle. He also noted other complicating variables: marine insurance; ice; hydrography, meteorology, oceanography, and climatology; shipping routes; navigation aids; and ice reconnaissance. "From the work I have done thus far on this subject it would appear that the case for tug and barge operations as the prime means for moving the product has much to commend it and should receive the closest scrutiny," Pullen speculated. He also emphasized that "at this time the only recommendation I would care to make is that what is obviously needed here is a systems approach to the problem covering all aspects of the operation, from the point where the concentrates leave Hope Lake until they are discharged at whatever distant overseas terminal is decided upon." Pullen also shared his expert insights into break-up and freeze-up in the Western Arctic and the concomitant constraints on shipping. "Throughout the year the greater part of the Beaufort Sea is filled with the heavy ice floes and pack ice typical of the Arctic Ocean," he explained. "The mainland coast from Point Barrow eastward to Amundsen Gulf and the west coast of Banks Island lie exposed to this moving pack."



Source: Northern Oil and Gas Directorate, *Petroleum Exploration in Northern Canada: A Guide to Oil and Gas Exploration and Potential* (Ottawa: Indian and Northern Affairs Canada, 1995), 79.

Pullen next cast his consulting attention to the Canadian Arctic Archipelago, where geological information compiled over the previous decade had generated significant interest in prospective petroleum deposits. In the 1950s, the Geological Survey of Canada had first revealed the presence of extensive sedimentary basins with thick successions of Paleozoic and Mesozoic strata in the Arctic islands, potentially favourable for oil and gas.[45] Commercial companies began geological exploration in the High Arctic in 1959, with the formation of Panarctic Oils Ltd. (a consortium that brought together nineteen companies and the Government of Canada) in December 1967 pledging millions of dollars for additional exploration.[46] Early in their exploration program, Panarctic pioneered drilling offshore locations from artificially thickened sea ice, which proved an economic and efficient way of testing offshore structures in the central Sverdrup Basin in water depths of up to 500 metres. A succession of discoveries followed near Lougheed Island, on the southwestern coast of Ellef Ringnes Island, on King Christian Island, and in the waters between them.[47]

Pullen produced a preliminary report for Calgary-based Pacific Petroleums, a Canadian integrated petroleum company,[48] in January 1969 (**document 5**) on the feasibility of supply operations to and from Norwegian Bay in the High Arctic. Given the brief shipping season in the region, Pullen opined that the challenge facing drilling operations was utilizing the region's ice regime to the company's benefit, "exploiting this ice cover" by resupplying and resiting the equipment during the short navigation season and resuming drilling operations in the winter. His preliminary report was thus premised on the need to determine the date when the freeze-up was adequately advanced to commence drilling operations from an ice platform, when the platform would allow safe operations, and the date when the break-up of ice required the suspension of operations.

"Generally speaking, the key to successful Arctic shipping operations is determined by the dates of 'break-up' and 'freeze-up' which are of all-consuming interest to planners and mariners alike," Pullen explained. In the case of Norwegian Bay, however, "there really is no navigation season as such," and in the few areas where "break-up" occurred it was "followed so quickly by 'freeze-up' that the interval between the two for shipping activities is brief indeed compared to more salubrious Arctic areas." In good years, icebreakers would "find conditions relatively easy for their resupply run across the bay en route to Eureka" – the site of a weather station that vessels had resupplied since the late 1940s.[49] "In bad ice years this transit will become a non-stop slugging match. It may even transpire that the breaker will be compelled to turn back and wait for better conditions if the age of the season permits." The company could turn "this state of affairs" to its advantage "by exploiting this ice cover and using the brief navigable interval" to access the bay for resupply and the resiting of equipment mounted in vessels. This required a precise determination of when "freeze-up" permitted drilling operations that used the ice as a platform and when the onset of "break-up" created unsafe conditions and required a temporary suspension of operations.

Pullen identified two surface sea routes by which vessels could access Norwegian Bay. One route via Wellington Channel, Queens Channel, Penny Strait, and Belcher Channel rarely offered "easy passage" and contained multi-year ice. Meanwhile, Department of Transport and US Coast Guard icebreakers were already utilizing a route up the western Greenland coast to Melville Bay, across Baffin Bay to Jones Sound, and via either Cardigan Strait or Hell Gate to Norwegian Bay, for their annual resupply of the Eureka weather station. Pullen suggested that Pacific Petroleums "consider timing any sealift operation into Norwegian Bay to coincide with this mission." Since this route contained easier ice conditions, and was shorter and better charted, it was Pullen's preferred alternative.

Pullen's report also explained that offshore drilling operations in the High Arctic would be feasible during the Arctic winter and suggested that the brief summer navigation period be used to ship material to and from the sites and to relocate floating platforms in the open water. Counterintuitively, he explained, "the longer the ice remains in the bay the better this should be for successful operations." Break-up posed the greatest dangers, subjecting the area to "invasions of pack ice being driven in from adjacent areas," which necessitated specially built structures to withstand the "powerful forces … at work under such circumstances." His summary of ice conditions indicated when these natural processes of break-up and freeze-up would likely occur, complemented by a description of ice behaviour and prospective routes.

Pullen and the *Manhattan* Voyage

During the summer of 1968, Pullen accompanied prospector Murray Watts on a long trip for Coppermine River Ltd. which took them from Coppermine (Kugluktuk) to Eureka, on to Axel Heiberg Island, and then to Point Barrow on the Alaska coast before returning to the Mackenzie Delta. Graham Rowley, who accompanied Pullen on the latter leg of the journey, recalled how:

> On our way back from Point Barrow we had stopped at Prudhoe Bay, then a small drilling camp. I believe it was the day when the discovery of the immense oil and gas field there became common knowledge. The activity at the camp, where we had difficulty finding anyone awake, must have contrasted strongly with that on the world's stock exchanges, where the value of the shares of the companies involved was increasing by hundreds of millions of dollars the same afternoon.[50]

The unprecedented discovery of oil at Prudhoe Bay on Alaska's North Slope in December 1967 led to Pullen's next Arctic assignment. Should the oil be transported from the Arctic to the US east coast by a pipeline or ship? The Trans-Alaska Pipeline System was under development, but Humble Oil, a subsidiary of Standard Oil (now Exxon), chose to explore the feasibility of having commercial tankers deliver the Alaskan crude through the fabled Northwest Passage. The proposed route was round-trip from Halifax, Nova Scotia, to the Chukchi Sea and back again. This was no ordinary transit: as *National Geographic* reporter Bern Keating (who sailed aboard the ship) contended, this was "possibly the largest gamble of any commercial enterprise in history."[51] No regular tanker could make the journey.

S.S. *Manhattan*, the largest ship of its day, was specifically modified to possess icebreaking capabilities for service in the Arctic, where multi-year ice can slice through steel and sink even the largest of ships. In order to convert the tanker in time for a mid-summer test (which was missed nonetheless by two months), it was cut into four parts and simultaneous construction was parcelled out to four different US shipyards.[52] *Manhattan*'s "original bow was cut off and replaced by an ice breaking version," Pullen and A.H.G. Storrs explained, and 10,000 tons of additional steel converted *Manhattan* into "an ice-breaking tanker."[53] Pullen noted that, "until the *Manhattan* appeared on the scene, the largest ship to sail around the top of America had been the [CCGS *John A.*] *Macdonald* displacing 9,000 tons." By contrast, the tanker displaced 155,000 tons, was 1,005 feet long and 150 feet wide, with a draft of 55 feet, making it "truly a remarkable ship and unquestionably the world's finest icebreaker," in Pullen's opinion.[54]

The plan for the test run was to fill six inner tanks with oil, surrounded by thirty-nine tanks filled with sea water.[55] Humble Oil, a privately owned company, "consulted closely with Canadian officials, seeking advice and requesting that a Canadian icebreaker accompany *Manhattan*," Pullen noted. "Canada agreed and gave the voyage full concurrence and support."[56] Importantly for Canada, Humble Oil's request for Canadian cooperation implied acknowledgment that the Northwest Passage cut through Canadian waters. Its instructions for the voyage also stated that if the ship entered Canada's territorial waters, "such an event is regarded as a normal part of the whole operation which has the concurrence and support of the Canadian Government."[57] As part of its support, the Canadian government appointed Pullen as the "on scene" representative of Transport Canada's Director of Marine Operations on board the ship in 1969. In practice, Pullen also acted as the link between the tanker and the Canadian icebreaker, "and as ice adviser to the *Manhattan*'s master."[58] In return for his professional services, the oil industry promised to share data with the Canadian government on ice and ship performance collected during the voyage.[59]

Documents published in the earlier volume on Pullen's official activities present both his day-to-day account of *Manhattan*'s transit and his post-voyage assessments. In a speech to the Empire Club in Toronto, Pullen put the significance of the Arctic Tanker Test into focus:

> Altogether the *Manhattan* became stopped by ice on 25 occasions, requiring assistance from an icebreaker to free her by loosening the accumulated ice around her stern and quarters. But, and I am bound to emphasize, on many occasions the tanker sought the worst ice conditions for test purposes and in the process quite intentionally got herself stuck. These were planned forays, not misadventures, though this may irk those who, for secret reasons of their own, wanted the project to fail. Achievement of [transiting] the Northwest Passage as such was incidental to Humble's purpose. But this more than anything else was what caught the public's imagination. *Manhattan* was, and is, a test vehicle. The object of the exercise was to carry out tests in Arctic ice to achieve a figure of merit for her in various types of ice. The data thus obtained will be extrapolated to provide the characteristics of the ultimate tanker for the

> trade capable of defeating the ice. Whether or not *Manhattan* got into difficulties, by accident or design, was otherwise not meaningful.[60]

Manhattan's east-west transit was completed on 20 September 1969 when she reached Point Barrow, Alaska. There, a single barrel of crude oil was loaded onto the vessel the day before the ship embarked on its return trip to New York. Continuing with her icebreaker-oceanographic tasks during the return transit, *Manhattan* arrived in New York on 12 November; she had completed her "nearly 12,000 miles in 80 days and made history with the process."[61]

Impressed by the performance of *Manhattan* and its crew, as well as the synergy between the behemoth and its Canadian Coast Guard escort *John A. Macdonald* (affectionately known as *Johnny Mac*), Pullen proclaimed the great pride he saw in the "unbeatable team" of the two ships.[62] Dismayed by "the considerable measure of acrimony and uproar" over the *Manhattan* voyage, he asserted that "most critics, although no doubt well meaning and sincere, simply don't know what they're talking about. I have been astonished to hear and read a stream of opinions on this and related Arctic topics from people who know nothing about the subject."[63] He sought to set the record straight, particularly in terms of sovereignty and environmental issues.

Pullen's official "Report to the Canadian Hydrographic Service" and his "Report on the Arctic Tanker Test" for the Department of Transport were reproduced in the previous volume. They document the challenges that *Manhattan* faced in its 1969 voyage, its accomplishments, future prospects, and sober recommendations for future ships that might transport oil through the Northwest Passage. Pullen assessed that the ice conditions during the 1969 voyage, which had occurred in September and October, had been easy and had lacked the desired "sheet of smooth level ice of uniform thickness." Thus, the voyage had not enabled a final decision regarding the potential for year-round operations. As such, a second test voyage was required before the apex of the summer melt. Once again, Pullen produced a detailed report (**document 6**).

Consequently, *Manhattan* departed for Baffin Bay in early May 1970, accompanied by CCGS *Louis S. St. Laurent*, to gather the data required to define the power, hull form, and bow specifications necessary to permit year-round transit of the Passage. From his vantage point aboard *Louis S. St. Laurent*, representing Hudson Bay mining, Pullen noted that *Manhattan*'s 1970 route "was of considerable significance" for Baffinland Iron Mines. Indeed, *Manhattan*'s route up the western Greenland coast, across Baffin Bay to Bylot Island, into Lancaster Sound and to Pond Inlet was the route that ore carriers destined for Milne Inlet would use. The ice encountered in May and June 1970 was significantly harder and more concentrated than the rotting ice through which *Manhattan* had transited in 1969, delaying its progress. Indeed, Pullen indicated that *Louis S. St. Laurent* and *Manhattan* had each proved integral to the other's progress, with the power and size of *Louis S. St. Laurent* being an asset when *Manhattan*'s power alone proved insufficient. The tanker had been unable to push broken ice either underneath itself or on top of the ice beside its bow and could not overcome the ice pressure, with the snow cover creating more friction and "robbing her of power needed to break ice." However, despite *Manhattan*'s difficulties, Pullen indicated that "it does not follow that a very much bigger and more powerful ship would have experienced difficulty," since a giant ore carrier would create tracks through the region that "would remain open throughout the winter" and thereby reduce the icebreaking challenges.

Pullen also reported on the ice thickness and growth at Pond Inlet and Eclipse Sound, as well as wind and temperature data between Pond Inlet and Davis Strait, based upon Humble Oil's ice tests in the region and subsequent ice measurements via helicopter. These observations were of particular interest given the need to transit between Pond Inlet and Eclipse Sound if conducting shipping operations to and from Milne Inlet. Pullen concluded with a photographic summary of the voyage (not included in this volume), depicting the ice conditions and difficulties faced by *Manhattan* and *Louis S. St. Laurent* in 1970 in the region of Pond Inlet and Eclipse Sound, as well as the lessons learned for future operations there.

Pullen had recommended that Humble Oil conduct ice testing in the Pond Inlet region during *Manhattan*'s 1970 voyage, recognizing that such testing would benefit both Humble Oil and Baffinland Iron Mines Limited, which was expressing interest in operating in the region (and had contracted Pullen to conduct research towards that end, which he deferred to incorporate insights gleaned from the *Manhattan* test). **Document 7** reproduces the first volume of Pullen's report to Baffinland Iron Mines Limited, studying the practicability of operating large bulk ore carriers from Milne Inlet to the Port of Rotterdam "on an extended season." Compiled in 1970, his report included environmental observations and ice testing data from *Manhattan*'s second voyage, research that was original and "of prime value" since ships had never attempted to operate in the Pond Inlet and Baffin Bay region so early in the season. Pullen perceived that his report would constitute "a useful planning and operational tool" for Baffinland Iron Mines, providing it "a competitive edge."

Ultimately, Pullen reported that it was possible to operate bulk ore carriers between Milne Inlet and Rotterdam for an extended season. Although non-strengthened ore carriers would be unsuited for the operations, and vessels strengthened to Ice Classes 3, 2, and 1 would be unable to surmount the ice conditions along the route, ore carriers of Lloyd's Ice Class 1* and the Icebreaker Class would be able to sustain operations. Lloyd's Ice Class 1* vessels could operate on a four-month season, from mid-July/early August to mid-November/early December, requiring icebreaker assistance during pressure situations or "unusually heavy ice conditions." Such vessels could thus conduct around four to five round-trip voyages. Based on four voyages per year, Pullen estimated that such vessels could transport an annual tonnage of 1,000,000 to 6,000,000 tons, depending on the deadweight and number of vessels used. The use of Icebreaker Class vessels, with sufficient thrust, horsepower, propulsion, and design, would allow a more extended navigation season. Such vessels could operate "virtually year-round" between Milne Inlet and Rotterdam and enjoy an eight- to twelve-month navigation season, only requiring icebreaker assistance in especially poor ice years. If operating on an eight-month season from mid-June to mid-February, such vessels could conduct nine to ten round-trip voyages and transport 900,000 to 5,400,000 tons. In a twelve-month season, eleven to twelve voyages could be conducted (with eleven being more likely to allow for maintenance, repairs, and dry-docking), enabling the movement of between 1,100,000 and 4,950,000 tons.

For the purposes of Baffinland Iron Mines Limited's proposed operations between Milne Inlet and Rotterdam, Pullen recommended a route from south of Greenland to Davis Strait, across Baffin Bay to Eclipse Sound (via either Pond Inlet or Navy Board Inlet), and thus to Milne Inlet. The optimal route would vary with the ice conditions and time of the year, with Pullen insisting that deviations only be made if aerial ice reconnaissance revealed more favourable conditions along another route. In some years even the most powerful vessel would require icebreaker assistance, with May typically presenting the most severe ice conditions. Otherwise, vessels of any size and deadweight would be able to transit the route. The new terminal being constructed at Europoort-Rotterdam, scheduled for completion in 1973, would accommodate a bulk ore carrier of any beam or length but with a maximum deadweight of 150,000 tons. Though the loading facilities at Milne Inlet were outside the scope of Pullen's study, he predicted that the region would accommodate vessels of the same beam, length, and maximum draft as Europoort-Rotterdam, although measures would be required to clear ice from the loading berth. Tugs could accomplish this, in addition to aiding vessels as they arrived and departed.

Pullen stressed the importance of designing, constructing, and operating vessels appropriate to the Arctic's arduous environment. After documenting the structural requirements for the differing ice classes, Pullen detailed specific technical recommendations for vessels operating in the region. He reviewed features of a professional icebreaking vessel ranging from the propulsion systems to the bow and stern thrusters, from the propellers to the anchoring and steering arrangements, from the generators and heeling systems to the survival equipment, navigational equipment, and safety and habitability features, detailing how such considerations would and should be adapted to ice-capable bulk carriers. Pullen estimated the capital costs of vessels of varying ice classes and sizes, as well as the impact of ice classification on the operational costs of the proposed bulk carriers with respect to such considerations as fuel consumption, maintenance and repair costs, and insurance rates. More specific recommendations as to the type, number, and size of vessels were impossible to provide in the absence of a "detailed economic study," and Pullen cautioned against making "hard and fast" design decisions until the publication of the government's anti-pollution regulations, which were expected to regulate the vessels able to operate in various Arctic zones at different points of the season.

Consequently, Pullen concluded "that it would be technically feasible to provide a year round service from Milne Inlet." Actually doing so, however, would require not only "highly specialized vessels" but also "fully competent crews." Pullen recommended the development of a training program for officers and masters, providing instruction in such topics as navigation equipment and its restrictions in the region, polar meteorology, search and rescue, survival, Canadian law, the impact of ice and other environmental factors on shipping, and the effect of tides, winds, and currents on ice patterns and movement. Even with such training, delays in operations would be inevitable as crews gained experience in ice navigation, as well as in the event of severe ice conditions and mechanical issues.

"A Highly-Coveted Consultant"

As the years passed, and the cycle of "the-more-things-change-the-more-they-stay-the-same" continued, Pullen's tone became increasingly impatient. "Canadians should be pre-eminent" in their Arctic waters, given that "we possess the operational experience and the ship design capability," he asserted in a 1973 article, simultaneously emphasizing that "time is no longer on our side.… We have now no naval arctic capability whatsoever" and "Canada simply must start looking to her maritime responsibilities in the far north." The *Arctic Waters Pollution Prevention Act* (AWPPA), introduced by the federal government in 1971, was an empty law without an enforcement mechanism.[64] He painted a sorry picture of "the unenviable and embarrassing position of calling on the … U.S. Coast Guard icebreakers for assistance" to help a ship in distress in waters that Canada claimed as its own.[65] Canada's "dolorous record in maritime affairs" was an embarrassment, and he prodded the government to take action. "Having defaulted on our general maritime responsibilities … [and continuing] a similar path in respect to the exercise of effective control over our arctic waters," he alleged that Canada seemed "determined to abdicate again our maritime responsibilities."[66] He wanted action, not simple rhetorical displays extolling the importance of "sovereignty."

After the *Manhattan* voyages, Rowley noted, "Pullen found his services as a consultant on marine operations in high demand as companies began to assess the shipping dimensions of large-scale resource development projects. His expertise made him a highly-coveted consultant on icebreaker operations, arctic towing, convoying in ice, arctic hydrography and oceanography." He extended his experience to Alaskan waters by advising the Lost River Mining Corporation on a potential port to handle ore at a site on the Seward Peninsula, joining the US Coast Guard icebreaker *Glacier* for a mid-winter survey of ice conditions in the Bering Sea in 1971. "In subsequent years he undertook the duties of Ice Master in ships engaged in a number of interesting and often pioneering voyages," Rowley noted. These included M/S *Gothic Wasa*, which became the first ship to load lead/zinc ore concentrates at the Nanisivik mine on northern Baffin Island in 1977; conducting a reconnaissance of uncharted waters in Prince Albert Sound onboard CCGS *Sir John Franklin* in 1979 in support of the Polar Gas Project; and assisting CCGS *J.E. Bernier* as it ran track soundings for potential beach landing sites in Minto Inlet and Prince Albert Sound the following summer.[67]

Concurrently, Pullen continued his work consulting for energy companies. When Calgary's Imperial Oil Limited contemplated operating in the central region of the Queen Elizabeth Islands in the early 1970s, it contracted Pullen to provide a marine environmental report on the area. **Document 8** reproduces the introduction to the first volume of his January 1972 report, summarizing the weather and ice conditions, the variations of ice around the islands, the land-fast ice present at particular points of the year, the break-up and consolidation of ice between the islands, the movement of ice throughout the region, the sections of weak ice, and the impact of temperature changes on the ice sheets. Further sections dealt with the varying ice thicknesses and "roughness characteristics" in the area, the glacial ice content, the variable duration and extent of open water, and the availability of further hydrographic information. Pullen also provided a month-by-month summary of the weather conditions in the region.

Pullen cautioned, however, that the region had not benefitted from the same degree of ice observations as had been made in other areas of the Arctic, with the data utilized for the report stemming from observations made over only five years. This was a much shorter period than typical with respect to ice data. The dearth of observations made during freeze-up from late October through late December led Pullen to base his predictions of the ice conditions during that time on "our best marine knowledge and ice expertise." Offering "comprehensive information on ice movement" and related factors, he conceded, was difficult given that observations were made from the air and thus lacked detail on such factors as small-scale movements. Forecasting the seasonal or annual ice conditions was similarly challenging until more accurate predictions could be made of weather patterns in the region and those patterns' relationship with ice formation. Pullen concluded by urging the necessity of more "on-the-ice" research in the region, particularly given the increasing industrial activities occurring there.

Pullen was also tasked with examining the prospects for transiting iron ore from Mary River to Western Canada via the port of Churchill, Manitoba. **Document 9** reproduces his March 1972 report on the port's "Present Inadequacies and How Good Prospects for Its Future Might Be Secured," as well as the text of an address on the topic that he presented in Montreal. Pullen's study was sparked by the development of giant tankers with deadweight capacities of over 250,000 tons. Such vessels offered promise for enhancing Arctic shipping prospects owing to their icebreaking capability, tonnage capacity, and ability to extend the navigation season. They would be of interest and benefit as resource development accelerated in the Canadian Arctic, with Baffinland Iron Mines seeking to transit iron ore from Mary River/Milne Inlet to Europe, as well as other mining interests active around Foxe Basin, the Ungava shore of Hudson Strait, and near Strathcona Sound. The port of Churchill was well situated to facilitate the shipment of ores from the Eastern Arctic to Western Canada. Unfortunately, vessels of adequate icebreaking capacity to surmount the ice along the route to Churchill during the off-season would have drafts of 70 to 80 feet, excluding them from entering the harbour itself (which could only accommodate vessels with loaded drafts of around 30 feet). As Pullen indicated, large vessels “simply cannot use it [the port of Churchill] and never will for the cost of enlarging and deepening the harbour, dredging its approaches and solving the ice problems in both locations, is prohibitive.” Indeed, the harbour also suffered from substantial currents, restricted manoeuvring room, and the accumulation at freeze-up of ice from the Churchill River. This limited the shipping season to Churchill to about three months. Since creating a specific offshore unloading and loading facility would be exorbitantly costly, and the effort and cost required to improve the facilities to handle additional cargo was not “justified,” Churchill was likely to remain “a summertime grain exporting facility.” Even in that role, Pullen indicated in his address, “it has never really lived up to expectations.”

Given Churchill’s inadequacies, and the absence of any other “sub-Arctic port in the east connected by rail to Canada South,” Pullen recommended the construction of a deep-water port further north. The ideal location would be along the western shore of Hudson Bay and would accommodate “the largest ships.” Pullen drew attention to a potential location around Chesterfield Inlet that could accommodate vessels of any type or size, which he referred to in his address as Promise Harbour or Northport. In addition to a human-built harbour to protect the port from pack ice, and a nuclear generating station to circulate warm water to minimize ice issues, Pullen indicated that the new port would require the extension of the railroad from Churchill along the Hudson Bay coast to the site. The proposal was feasible, Pullen argued, because the terrain from Churchill to Chesterfield Inlet appeared suited for a railroad, and because *Manhattan*’s voyages had illustrated the capacity of icebreaking bulk carriers to transit year-round through Hudson Strait and the northern section of Hudson Bay.

The new port would, Pullen argued, ensure a year-round capability to export grain from Western Canada. It would also attract other exports from Western Canada, such as sulphur, potash, pulp and paper products, and coal. It could provide a pipeline terminal for oil and/or gas from the Athabasca tar sands, the Mackenzie Delta, the Alaskan North Slope, and the Eastern Arctic islands, as well as a year-round terminal for minerals destined for Western Canada from mines in the Foxe Basin littoral, Milne Inlet, and other High Arctic developments. The port would furthermore permit year-round access to tide water in the east for both the Northwest Territories and Western Canada, and it could even “serve as a staging point in a whole new pipeline network” were a pipeline to run south to the North American mid-west. The concurrent extension of the railway up the western coast of Hudson Bay would "stimulate growth and development along that littoral," Pullen predicted, with the entire project constituting "a boon to the native population" through its employment opportunities. Although the cost would be high, he insisted that the plan would "open the north" and offer a "new thrust" for northern development, growth, and progress. Pullen urged Canada to do "some homework on this matter of Arctic transportation," and he expressed his hope for "a little leadership" and "a little action" to move forward on a plan that could create "a major industrial" and "inter-modal transportation complex" with both national and international significance.

Casting his gaze further north to Strathcona Sound, Toronto-based Watts, Griffis & McOuat Limited expressed interest in shipping lead and zinc concentrates from that channel situated near the Nanisivik mine to Europe. Pullen submitted a report (**document 10**) to the company in 1973 on the feasibility of this plan, exploring the factors that would dictate marine operations between the sound and Europe and seeking to assess the number, size, and ice capability of the vessels required. Overall, he concluded that operations into the sound would be "perfectly feasible," given that the location was favourably situated to load product as it generally experienced only first-year ice. It was also well located bathymetrically, with the waters between it and Europe being deep, "well charted," and "well travelled." Growlers, fog, and bergy bits around Cape Farewell and in the region of Davis Strait/Baffin Bay would be the primary threat along the route from Rotterdam to Davis Strait and on to Lancaster Sound and Strathcona Sound. No segment of the route placed any restrictions on the size of vessel that could operate, with two prospective loading sites available at Adams Sound and Strathcona Sound. The new Arctic Shipping Pollution Prevention Regulations (ASPPR) would dictate the duration of the navigation season, as would ice conditions, the availability of icebreaker aid, and the types of vessels utilized. Pullen focused on Type "A" vessels, or Lloyd's Ice Class 1* vessels, since they would offer "the most suitable compromise between the lesser ice performance of Types "B" and above and the greater, and therefore more costly, Arctic Class." Even without significant icebreaker assistance and the use of prime movers, Pullen reported that the company's envisaged shipment of 150,000 tons annually of zinc/lead concentrates from Strathcona Sound to Europe was attainable.

These conclusions did not detract from Pullen's longstanding advocacy for Canada to increase its icebreaking capacity. Federal icebreakers had been used in the Canadian Arctic since 1922 to deliver supplies and services to isolated posts and Inuit communities during the short summer season, projecting a form of Canadian state sovereignty into the region. Icebreakers had also allowed the port of Churchill to open for grain shipments in the 1930s, and Pullen himself had demonstrated their value in supplying the DEW Line sites across the Arctic in the late 1950s. Scientific research, resupply operations, and a growing interest in the potential extraction of raw materials in the region had created a heightened demand for icebreakers capable of northern operations over the next decade. With the Canadian Arctic Shipping Pollution Prevention Regulations of 1970 setting out Arctic classifications for icebreakers based upon their ability to break ice in "continuous mode" (the steady movement forward of the icebreaker through the water), the push to procure a heavy vessel to bolster economic opportunities and sovereignty would take these design considerations and standards into account.[68]

On 7 January 1972, Pullen produced a report (**document 11**) outlining the missions, characteristics, and capabilities required of any new Polar Class icebreaker constructed in Canada to ensure its functionality and successful operation in the Arctic. Pullen thus provided "an outline of parameters from which detailed designs and specifications can be developed." In his expert assessment, the foremost mission of Canadian Polar Class icebreakers "is to support shipping including resource exploration support shipping, and anticipated resource (i.e. oil, ore and gas) marine transportation." While operations would, at that time, be concentrated east of the M'Clure and Prince of Wales Straits, it was "desirable" that vessels be capable of operating between eight and ten months through the Northwest Passage. Since liquified natural gas (LNG) and large bulk carriers could surmount ice without assistance, icebreakers were not intended to serve an escort function but rather to "maintain the flow of marine transportation" by aiding the release of beset vessels, assisting damaged vessels to open water or a "port of refuge," and ensuring that ice did not carry beset vessels into perilous situations. Secondarily, such icebreakers would conduct search and rescue and pollution control missions, as well as collecting environmental intelligence along the route. They would also enforce Canadian regulations and offer emergency medical assistance to remote settlements and other ships, "emergency logistic support to remote areas," and a base for marine and hydrographic scientific investigations.

Pullen framed the technical specifications required for an icebreaker to fulfill these functions in ice on a year-round basis. The vessels would need the ability to maintain a minimum of 3 knots "in consolidated pack ice up to 8 feet in thickness" and the capacity to "progress by ramming through consolidated Polar Ice (multi-year ice) of a thickness up to 25 feet." He therefore estimated that the icebreaking capability needed would require a ship of approximately 25,000 tons displacement and 100,000 shaft horsepower (SHP) minimum. Pullen outlined the approximate dimensions of the vessel, as well as the technical requirements to ensure it possessed the endurance needed to conduct its year-round operations, estimating fuel consumption and requisite tank capacity. He offered other technical requirements for features ranging from the bridge design to the propulsion system, from the configuration of the icebreaking bow to the navigations and communications equipment, from over-ice vehicles and landing crafts to the capacity to support the operations of shipborne and shore-based helicopters. An ice and meteorological office/environmental intelligence office would be essential for the icebreaker's mission, contributing to environmental intelligence gathering, as would space to support marine science and hydrographic investigations. Pullen also estimated the variety of personnel required to effectively operate the vessel and outlined requirements respecting such features as accommodations, habitability, amenities, provisions and stores, cargo space, medical services, lighting, fire protection, waste disposal, and free-swimming diving capability.

In 1975, Pullen returned to considering the feasibility of commercial shipping in the Kitikmeot region. In the 1970s, Strathcona Mineral Services Ltd. considered partaking in mineral development in the Coronation Gulf around Kent Peninsula/Bathurst Inlet. Since such development would require a means to transport the product to both international and North American markets, the company solicited Pullen's opinion regarding the practicality of doing so. Given his short-notice contract, Pullen explained that his 18 April 1975 memorandum (**document 12**) dealt "with generalities rather than specifics," and "it errs on the side of prudence for in addition it deals with a region which hitherto has attracted little commercial interest." He explained how Coronation Gulf had been a transit area through which ships had picked their way en route to somewhere else (usually from the west to resupply Cambridge Bay and Spence Bay). He emphasized that, "by arctic standards," bathymetric knowledge of the area was good, particularly along the main shipping channels. "It is skimpy, though, in locations where ships have until now had no reason to venture, e.g. close in to the north shore of the Kent Peninsula," Pullen explained. "But even then there are sufficient data to indicate that the bathymetry would not prevent access by commercial ships to selected locations there."

Late the following year, Pullen cast his attention further westward to assess the practicality of winter drilling operations in the Beaufort Sea (**document 13**), which contains the largest concentration of gas and oil discoveries in the Canadian frontier, with about half onshore and the remainder in relatively shallow water in the Beaufort Sea.[69] Canmar Marine, the marine arm of Dome Petroleum, proposed to carry out winter drilling operations in the inshore area of the Beaufort using the belt of fast ice that formed every year along the coast from the shoreline out to the 10-fathom line. If so, this would allow the companies to make longer use of expensive facilities which otherwise would lie idle beyond the summer season. Pullen's opinion, based on a general outline of what was proposed, indicated that the proposal had "merit." He commented on the practicality of individual facets of the proposed operations, including icebreaker support, drilling locations, and the clearing of ice. He was skeptical about the proposed use of a canopy to direct "the hot waste air from the drilling motors" to prevent ice formation both beneath and within 100 feet of the drill ship, instead recommending bubbling techniques. Overall, Pullen concluded that the proposal constituted "a sound and workable plan" to utilize drill ships more efficiently in the off-season. However, since "there will always be circumstances which arise that have not been thought of and which call for bold, swift and effective measures," those individuals with the authority and knowledge to decide accordingly "would need to be on or near the scene of operations full-time."

Further north in the Sverdrup and Arctic Basins, where a boom in exploratory drilling yielded tremendous promise,[70] pressing questions remained about how proximity to shipping lanes through the Northwest Passage could make the exploitation of discoveries economically feasible. The Polar Gas Project was established in 1972 to determine the best means of moving frontier natural gas from Canada's High Arctic to southern markets. Involving TransCanada PipeLines Limited (acting as Project Manager), Panarctic Oils Limited, Tenneco Oil of Canada Ltd., the Ontario Energy Corporation, and Petro-Canada, the project investigated pipeline routings, present and future reserves in the Canadian Arctic, and methods for installing pipelines in the Arctic channels. Following a meeting in the Polar Gas Project's Toronto offices on 31 March 1977, Pullen reported on plans to ship pipe and general cargo to support development in the High Arctic and to Baker Lake, a hub in what is now the Kivalliq region of Nunavut. His April 1977 study on prospective sealift operations (**document 14**) identified various issues related to landing cargo over the beaches at identified sites, based largely on his "personal knowledge of most of the locations discussed in this report." He assessed the various options, recommending against some sites (Spence Bay/Taloyoak on the east side of Boothia Peninsula, and Allen Bay on Cornwallis Island), emphasizing the benefits of others (Lord Mayor Bay on Boothia, and Radstock Bay for the main cargo transfer activity, with nearby Maxwell Bay being a suitable backup). "Given the fulfilment of certain requirements, all the proposed stockpiling sites are considered accessible," Pullen noted. He also offered a brief review of the Arctic Shipping Pollution Prevention Regulations and how they applied to the various locations. Document 14 also reproduces key memoranda that Pullen wrote with respect to the Polar Gas Project, assessing specific sites, options for large icebreaking bulk carriers, what constituted "moderate" speed in ice, and the ice conditions around the prospective staging sites in the Western Arctic.

Tasked with compiling historical data regarding sea ice conditions in the region, specifically between the Mackenzie Delta, Coronation Gulf, and Prince of Wales Strait, Pullen's 13 September 1978 report included ice charts, surface pressure and temperature charts, and ice comparisons over a fifteen-year period. These provided "a feel for ice conditions during the summer season between Tuktoyaktuk and the Coppermine," with Pullen concluding that these waters were more "encouraging" than Alaskan waters for the Polar Gas Pipeline's proposed operations. He examined the impact of the Western Arctic's ice regime on shipping operations to the staging sites and offered recommendations to manage the movement of cargo in the Western Arctic. Comparing Amundsen Gulf and Alaska, Pullen noted that "the key to shipping" in the Western Arctic was the coastal area from Point Barrow to the Alaska/Yukon border. Indeed, "by the time shipping can be escorted by icebreaker(s) through the Alaskan section and delivered to the Mackenzie Delta, conditions in the latter area will be so far improved that it can either be sent on its way unescorted or, in a slow year, or a bad year for that area, a modicum of icebreaker escort would suffice." Because the ice in the Canadian sector tended to break up and clear earlier than in the Alaskan region, Pullen argued that overwintering vessels would allow them to benefit from the earlier break-up. This would avoid delays due to Alaskan ice conditions and prospective damage to the vessels.

In April 1980, Pullen submitted a detailed memorandum to the Environmental Assessment Review Panel (**document 15**) on the Canadian Arctic Resources Committee's (CARC) submission endorsing the Arctic Pilot Project (APP) – a plan to transport Arctic energy year-round to consumers in North America. Pullen's critical response decried some language and tense choices, generalities, the lack of elaboration or clarity, statements of ignorance, false equivalencies, and inaccurate routing maps. He disagreed with CARC's advocacy for a pipeline primarily directed towards an American market, affirming instead that the APP's proposed routes seemed "reasonable" in his expert opinion. He agreed that these routes had "no reason" to pass near Greenland, that bergy bits and growlers required caution in Arctic navigation, and that radar could be unreliable in foggy conditions. Overall, he concluded that the APP represented a small but flexible energy project offering "exciting benefits in the pioneering of year-round navigation in the arctic and so forth." The project itself, he argued, "stands or falls on the ground of energy need" and energy self-sufficiency, noting that the proceeds from exporting energy could "help to offset the cost of importing energy from overseas."

Canada's role in the APP elicited Pullen's interest. He criticized suggestions that the project should seek internationally constructed ships, noting that doing so would contrast pre-existing policies to "develop a ship-building industry capable of responding to the demand for marine transportation in the Canadian arctic." The LNG vessels would require icebreaker assistance, which Pullen welcomed. After fruitless years of arguing for the development of a Canadian polar icebreaker, Pullen urged the federal government to "bite the bullet, spend the money needed to upgrade a selected east coast yard, and be prepared to build the ships in Canada." He criticized Ottawa's failure to develop any "effective arctic policy" or "effective arctic decision-making capability," its "lacklustre arctic performance," and its lack of "inclination" to construct the Polar icebreakers needed to monitor ice regimes, weather, climatology, and wildlife in the Arctic. Canada also lacked "enough intelligent, trained and qualified southern" officers to handle the APP vessels.

In an appendix, Pullen commented on the marine traffic forecast for the Northwest Passage. He questioned the feasibility of plans to operate a fleet of twenty-four Class 10 icebreaking tankers in the Beaufort Sea by 2000, given Canada's unlikely capacity to construct or crew such vessels. He also criticized and adjusted some of the indicated route options. Together, these factors compelled him to reduce the estimated number of transits from the APP's proposal to 550 by the year 2000. He reinforced the need for an Arctic Class VII Coast Guard icebreaker to examine the prospective impact of operations on the region's ice regime and to conduct the environmental, climatological, and biological investigations required before year-round traffic through the High Arctic could occur. To this end, he recommended that CARC "serve a useful role in pressing for action now" and argued that the Polar Icebreaker

Programme should receive the funds then allocated for the Patrol Frigate Programme.

In March 1983, Pullen's presentation to an industry conference in Gothenburg, Sweden, elaborated on the topic of prospective year-round navigation of the Northwest Passage (**document 16**). Since Roald Amundsen's first transit of the Passage from 1903-06, there had been thirty-four successful passages. The transit still involved myriad dangers and challenges, although the increasing power, size, and strength of vessels continued to reduce some risks. As the development of the Arctic demanded that its resources be transported to international markets, there was an increasing demand for year-round transit. Briefly reviewing the history of the search for the Northwest Passage, Pullen noted that the voyage of *Manhattan* had represented "the first step" towards this outcome.

Pullen highlighted that icebreakers had conducted fourteen of the thirty-five transits of the Passage. Successful operations in the Northwest Passage and the Arctic broadly were directly tied to weight and mass, in addition to thrust and power, since larger ships could both carry more cargo and facilitate icebreaking. As such, transiting the Northwest Passage year-round would require "icebreaking commercial behemoths" – Coast Guard icebreakers could not perform their supervisory functions in the High Arctic while weighted down by the tonnes of materials needed to attain a satisfactory icebreaking capacity. He commented on Dome Canada's current efforts to design "an environmentally safe Arctic tanker" to transport gas and oil from the Beaufort region, the Arctic Pilot Project, and possible LNG shipments from around Ellef Ringnes and King Christian Islands to Europe using three Class 10 vessels. Unfortunately, Pullen observed that "the pace of activity in the Canadian north has been slowing," with each of the three projects experiencing difficulties and delays. Nevertheless, foreign interests seemed "likely" to examine the potential to utilize the Passage in their own resource development endeavours. Once the Alyeska Pipeline reached capacity and marine alternatives were needed to transport Alaskan oil to the eastern seaboard, and as Japan searched for reliable sources of oil, Pullen deemed it possible that foreign icebreakers might begin transiting the Northwest Passage. He ultimately concluded that the "prospects for operational success" in the year-round transit of the Northwest Passage "are good," though doing so would necessitate the development of "special ships and "special people to man them." Economics would also determine the success of such operations, with Pullen noting that falling oil prices could "put a damper on northern development" and subsequently the "prospects for year-round navigation of the Northwest Passage by icebreaking tankers." These considerations remain relevant today.

In May 1983, Pullen's report on Arctic marine transportation issues to the Canadian Arctic Resources Committee (**document 17**) provided an overview of the development of Arctic marine transportation over the preceding three decades. No vessel had ever conducted year-round operations in the Arctic, so Northern resource development demanded the construction of "special ships" with "tremendous size, strength and power" – essentially "icebreaking commercial giants" – to enable the year-round navigation of the Northwest Passage. This possibility raised concerns for Northerners and mariners alike, given impacts on the winter ice regime, on Northerners' ability to use the ice for winter transportation, and on ice break-up patterns in the spring. Such environmental concerns required on-site experiments and investigations and, thus, the development of a Canadian polar icebreaker to conduct them.

Given that Japan and the United States had both demonstrated interest in transporting oil through the NWP, Pullen insisted that "it is essential for Canada to have the ability to deploy there convincing evidence of her sovereign will, against the day when foreign flag ships will attempt its navigation." This required investments in "a suitable icebreaker capability" (Arctic Class VII or higher) for year-round operations; masters and mates with special training, qualifications, and certification; and a northern headquarters to command operations. Although most discussions about Arctic marine transportation emphasized the challenge posed by ice, Pullen argued that Arctic bathymetry posed an "equally challenging problem." The Canadian Hydrographic Service needed more resources to conduct the requisite surveys of Canada's Arctic waters and underwater hazards. Pullen also pointed out the benefits of curtailing the "traditional freedoms of shipmasters" to "go where they will" and seek the easiest route, given the need to avoid "environmentally sensitive areas." As such, he recommended more collaboration between environmentalists/conservationists and mariners. The *Arctic Waters Pollution Prevention Act* and its regulations were "well conceived and realistic" and sufficient to control Arctic shipping, Pullen noted, but only if they were "suitably modified and brought up to date in the light of new information."

Pullen ended by highlighting how Greenlanders had voiced loud concerns about large ships passing "close" to the coast of West Greenland through the year and interfering with traditional over-ice hunting routes. They had also expressed apprehensions about the effect of propeller noises on marine mammals, with Inuit of East Baffin (now part of the Qikiqtani region of

Nunavut) joining in the "chorus of protest." On the issue of propeller noise, Pullen noted that "it will have to be proved that such is the case. It is hard to fathom why this particular concern has surfaced when in other parts of the polar regions a similar outcry has not been made." This concern has grown rather than abated over the past four decades, with the community of Clyde River's opposition to seismic blasting in their waters yielding a favourable verdict at the Supreme Court of Canada in 2017,[71] and the federal minister of Northern Affairs rejecting Baffinland's expansion plan for its Mary River mine in November 2022 because of the potential for "significant adverse ecosystemic effects" on marine mammals and other wildlife.[72]

In 1985, Strathcona Mineral Services of Toronto contracted Pullen to explore the possibilities for shipping product by sea from Bathurst Inlet to Rotterdam, Vancouver, and Yokoyama. His short report (**document 18**) first examined Bathurst Inlet itself, concluding that the bathymetry was "favourable" for use by the 25,000-deadweight-tonne bulk carriers under consideration – but that hydrographic surveys of the waters around the loading facility, wherever it would be located, and in its approaches from Coronation Gulf would be required. He then turned to the ports proposed to receive the shipments (Rotterdam, Vancouver, and Yokoyama), each of which were approximately 4,000 nautical miles from the inlet. He estimated that one vessel should be able to deliver three shipments to either Yokoyama or Vancouver during the summer shipping season, while a ship venturing east to Rotterdam would complete, in average or good ice years, two deliveries during the summer season. Unless benefiting from "very good ice conditions," vessels would require icebreaker escort in Victoria Strait (and probably further north as well), with further hydrographic study required to affirm that the strait would be suitable and safe for the bulk carriers.

Around this time, Pullen's work also led to his active involvement in the introduction of cruise tourism to the North American High Arctic. In 1984, Lindblad Travel, a New York agency, organized and conducted the first tourist cruise through the Northwest Passage in the Canadian Arctic. Captain Pullen participated in planning the expedition and also served as Ice Master and lecturer as the ice-strengthened passenger ship M/S *Lindblad Explorer*[73] transited the Northwest Passage on its voyage from St. John's, Newfoundland, to Yokohama, Japan. With ninety-eight passengers aboard, the cruise ship traversed the Passage in twenty-three days, representing only the thirty-third time a vessel had completed a full passage and the first time that the Northwest Passage was used as a route to Asia. Other companies sought to capitalize on this demonstration of feasibility, but only two crossings succeeded during the next four years.[74] Fitting this pattern, Pullen was onboard the cruise ship M/V *World Discoverer* during its unsuccessful attempt to transit the Passage from east to west in 1986.

"I'm hooked on the Arctic," Pullen admitted to a journalist in 1984. "It's a part of Canada few people know well, and it is a challenge. It does exert a fascination. I'm having so much fun."[75] At the same time, he was the consummate professional. "While he displayed a broad knowledge of the Arctic and a genial personality, Pullen's role called for considerable tact, as he had to give captains the often unwelcome warning that they were pushing their luck in the pack ice," an obituary later noted. "He was obliged, too, to take a strong line with stout American tourists who started behaving like children when they approached icebergs in small boats."[76]

Taking a hard line with misbehaving American tourists, however, did not mean adopting a similar line with the US government. Pullen's writings and speeches reveal a clear-eyed, unsentimental, and pragmatic view of sharing the continent with a superpower. He touted Canada's long history of cooperation with the US Navy and Coast Guard, and he harboured disdain for politicians who sought to whip up Canadian nationalism based on a simplistic anti-Americanism that preyed on popular Canadian ignorance about Arctic issues. Rather than casting the Americans as an existential threat to Canadian sovereignty, Pullen was a tireless critic of Ottawa's unwillingness to invest in capabilities that would allow Canada to exercise control over its Arctic areas.

In Pullen's view, the Canadian government's decision to not accompany the US Coast Guard icebreaker *Polar Sea* through the Northwest Passage in 1985 – a transit that again triggered a tsunami of reactions in Canadian nationalist circles – did not represent an American violation of Canada's Arctic but instead symbolized Canada's inability "to exercise … full sovereignty in and over the waters of the Arctic archipelago.'"[77] In response to the impassioned public response, the Mulroney government announced that Canada was officially implementing straight baselines around the Arctic Archipelago effective 1 January 1986, thus claiming full sovereignty over the Northwest Passage as "historic, internal waters." Concurrently, it outlined an aggressive plan to exercise control over its waters and assert its Arctic sovereignty, including a "Polar 8" icebreaker, new maritime patrol aircraft, a new northern training centre, improved northern airfields, a dozen nuclear-powered submarines, and a fixed sonar detection system at the entrances to the Passage.[78]

Pullen leapt into the debate, offering blunt analysis about what he saw as the real, practical imperatives of sovereignty. In his landmark 1987 article pondering the "price" of Canadian sovereignty, Pullen observed that:

> What in former times were simply matters of concern between governments now routinely become public controversies, with the public more agitated than informed thanks to sensational media coverage. The Arctic is an issue guaranteed to agitate Canada nowadays, and [Canadians] particularly resent encroachments, whether real or perceived—especially in the so-called Northwest Passage. The villain of the piece ought to be the Soviet Union, with its surreptitious use of our straits and sounds [by submarines]; but no, Canadians focus their concerns squarely on the United States.[79]

He urged Canada and the United States, as "friends, neighbors, and allies," to reach an agreement. Ottawa agreed and opened negotiations with the United States – a prudent move that, owing to Prime Minister Brian Mulroney's close relationship with President Ronald Reagan, yielded the 1988 Arctic Cooperation Agreement, which pragmatically solved the delicate issue of icebreaker transits.[80]

The other component of Pullen's solution was practical: he vigorously supported Canada's plans to build a Polar 8 icebreaker, which would be capable of year-round Arctic operations. "One compelling reason for building such a powerful ship is that Canada needs the means to respond swiftly to the emergency that will inevitably arise somewhere in the far reaches of the Arctic," he argued. "If a foreign submarine were in distress, for example, and we had no ship to send to her rescue, Canada's Arctic sovereignty would be exposed as meaningless."[81] Having an icebreaker capable of maintaining headway at 3 knots through hard, level ice up to 8 feet thick would provide Canada with "unequalled flexibility" and "a matchless arctic presence," and allow the country to assert "effective command and control over a wide area" of the Arctic. "This is what sovereignty is about, not, as some seem to imagine, the assumption that the Polar 8 will park in the ice, hoist a large Canadian flag, and conduct non-stop cribbage tournaments," he vented in an obvious critique of Canadian commentators who falsely equated sovereignty with superficial symbolism.[82]

In his final years, Pullen remained an active supporter of Arctic cruise tourism, satiating his passion for the region and for adventure. In 1988, at the age of seventy, he served as Ice Master for the successful Northwest Passage voyage by the ice-strengthened expedition ship M/V *Society Explorer*, which cruised from Dutch Harbour, Alaska, to Narsarsuaq, Greenland, via

Provideniyeh in Eastern Siberia. His private diary from this voyage is reproduced as **document 19**. He considered this west-to-east transit to be his most successful, serving as a fitting capstone on his career. The following year, Pullen joined the cruise ship *World Discoverer* from Iceland to the Eastern Canadian Arctic, and then from Greenland to Churchill, Manitoba. He made plans to transit the Northeast Passage or Northern Sea Route, running north of the Soviet Union, in 1990, in hopes of checking yet another item off his "bucket list" of desired experiences.[83] Unfortunately, ill health prevented him from realizing this final dream.

Honours and Achievements

"Pullen of the Arctic" died of cancer on 3 August 1990 in Ottawa at the age of seventy-two. Recognized as one of the world's foremost authorities on the Arctic, he "did more in Arctic navigation than any individual in North America," according to historian and retired naval commander Tony German.[84] Of all of Pullen's remarkable achievements, he identified several as holding particular significance:

- The double transits in one season of that enormous 155,000-ton icebreaker Manhattan
- The successful tow, from the St Lawrence to the High Arctic, of the 12,000-ton process barge in the face of so many critics who were determined it could not be done
- The completion of four Northwest Passage transits
- Circumnavigation of Baffin Island including the navigation of Fury & Hecla Strait, late in the season, and totally unaided.[85]

Pullen's distinguished contributions earned him specific Canadian accolades, affirming the national importance of his leadership and expertise. On 25 June 1984, Pullen was appointed Officer of the Order of Canada, his citation reading: "Known as 'Pullen of the Arctic,' Captain Thomas Charles Pullen accumulated a prestigious record of Arctic achievements during his career in the RCN. Since his retirement he has gone on to a second career as one of North America's foremost authorities on Arctic navigation and ice breaking."[86] Earlier that year, Pullen had received the Royal Canadian Geographical Society's prestigious Massey Gold Medal "for personal achievements in contributing to the knowledge of the marine environment and ice navigation in ice-infested Canadian waters."[87] Similarly, when Royal Roads Military College conferred Pullen with the degree of Doctor of Science *honoris causa* in 1985, it highlighted that "Captain Pullen is ranked by the

Geographical Society with [Henry] Larsen and [Roald] Amundsen as one of the great pathfinders of Arctic seas.... He is often referred to as the western world's foremost authority on Arctic navigation and icebreaking, and has been involved in marine and industrial projects spanning the North from Greenland waters to the Bering Strait."[88] Soon after his death, Pullen was awarded the Admirals' Medal for his "significant contribution to navigation, exploration, geographical knowledge and the advancement of science in the Arctic." The citation explained that he "was noted for applying his rare expertise and remarkable intellect to problems of Arctic operations and for his tireless efforts in becoming a leading expert in his field through intensive study, which was considered to be of extraordinary and special importance to Canada and to maritime affairs."[89]

It was in his blood – both love of country and a commitment to service: Captain Thomas C. Pullen's distinguished naval career was matched by his ardent support and advocacy for Canada taking its rightful place as an Arctic power. To Pullen, whose naval career began in 1936 and whose life ended as the USSR fell, it was clear that "sovereignty and security are inseparable" and that cooperation with the United States was the way "to find a mutually palatable solution to the issues of Arctic sovereignty and North American security."[90] This point remains relevant in the twenty-first century, as Canada and the United States face opportunities and challenges in a circumpolar world that is being reshaped by climate change, surging international interest, and resurgent strategic competition.

In his writings, Pullen encouraged Canadian decision-makers to look to the future and anticipate changes – not sit passively and expect that past apathetic or reactive behaviour, with few follow-through investments in substantive Arctic maritime capabilities, can suffice. "A lot of key decisions affecting Arctic development must be made in the coming months and years," Pullen anticipated in 1970. "Let's hope that in Canada 'dog in the manger' attitudes on matters such as sovereignty will give way to a bolder spirit which those who went before bequeathed us. And anyway, in my view, the dog doesn't even own the manger. Not all of it."[91] More than a half century later, Canadian commentators and Arctic experts continue to push Ottawa for a sustained commitment to the kinds of research and investment that Pullen promoted in his reports, writings, and lectures.

Notes

[1] Graham Rowley, "Captain T.C. Pullen, RCN: Polar Navigator," *Northern Mariner* 2/2 (April 1992): 47.
[2] W.O. Kupsch, "Thomas C. Pullen," *The Musk-ox* 38 (1991): 69; David Maclellan, "Pullen of the Arctic," *Canadian Geographic* 104/2 (1984): 26.
[3] Maclellan, "Pullen of the Arctic," 27.
[4] Captain Tom Pullen obit, *Daily Telegraph* [London].
[5] James Goodwin, *"Our Gallant Doctor" – Enigma and Tragedy: Surgeon Lieutenant George Hendry and HMCS* Ottawa*, 1942* (St Catharines: Dundurn, 2007), 96.
[6] Directorate of Public Relations (National Defence) Armed Forces News, 22 November 1954, Directorate of History and Heritage (DHH) 2004/55, file 3 – Press clippings & news releases.
[7] Report of Interview with Captain Thomas Charles Pullen in Ottawa, DHH 2004/55, folder 2, pp. 12, 15-16.
[8] See "Captain T.C. Pullen: Naval Service," notes on DHH 2004/55, file 1, and Report of Interview.
[9] DHH, Pullen interview with Cdr (ret'd) Tony German, 26 January 1985; also quoted in Goodwin, *"Our Gallant Doctor" – Enigma and Tragedy*, 97.
[10] Report of Interview, pp. 33-42.
[11] Report of Interview, pp. 45-46; "Captain T.C. Pullen: Naval Service," notes on DHH 2004/55, file 1; Directorate of Public Relations (National Defence) Armed Forces News, 22 November 1954, DHH 2004/55, file 3 – Press clippings & news releases.
[12] Marc Milner, *North Atlantic Run: The Royal Canadian Navy and the Battle for the Convoys* (Toronto: University of Toronto Press, 1985), 158.
[13] W.A.B. Douglas et al., *No Higher Purpose: The Official Operational History of the Royal Canadian Navy in the Second World War, 1939-1943, Volume II, Part 1* (St. Catherines: Vanwell, 2002), 508.
[14] Report of Interview, p. 47.
[15] T.C. Pullen, "Convoy O.N. 127 & the Loss of HMCS *Ottawa*, 13 September 1942: A Personal Reminiscence," *Northern Mariner* 2/2 (April 1992): 15.
[16] Captain Tom Pullen obit, *Daily Telegraph* [London]. On the sinking of HMCS *Ottawa*, see also Douglas et al., *No Higher Purpose*, 518-24.
[17] Report of Interview, pp. 4, 53. Pullen noted that once his survivor's leave was over, Tom and Betty found themselves apart once again – a frequent dynamic in their life together.
[18] Report of Interview, pp. 56-58, 60-61; For Posterity's Sake, "HMCS Chaudiere H99," http://www.forposterityssake.ca/Navy/HMCS_CHAUDIERE_H99.htm; Keith Butterley and Ken Macpherson, *River Class Destroyers of the Royal Canadian Navy*, 2nd ed. (St. Catharines: Vanwell, 2008).
[19] Captain Tom Pullen obit, *Daily Telegraph* [London].

[20] Report of Interview, pp. 61-62.
[21] Directorate of Public Relations (National Defence) Armed Forces News, 22 November 1954, DHH 2004/55, file 3 – Press clippings & news releases. On RCN operations during the Korean War, see Thor Thorgrimsson and E.C. Russell, *Canadian Naval Operations in Korean Waters, 1950-1955* (Ottawa: Naval Historical Section, Canadian Forces Headquarters, 1965).
[22] For an excellent scholarly overview, see Hugh N. Wallace, *The Navy, the Company, and Richard King: British Exploration in the Canadian Arctic, 1829-1860* (Montreal and Kingston: McGill-Queen's University Press, 1980).
[23] RCMP officer Bill White suggests that Larsen's achievement was preceded by other Canadian ships. White alleges that "the so-called Northwest Passage was a busy bloody highway by this time with trading posts all along it and supply ships like the *Chimo* and the *Aklavik* going this way and that way every year. Not too many crossed through from west to east, but I know the *Aklavik* did it in 1938 and Henry [Larsen] knew it too." Patrick White, *Mountie in Mukluks: The Arctic Adventures of Bill White* (Madeira Park, BC: Harbour Publishing, 2004), 227-28. See also P. Whitney Lackenbauer and Shelagh D. Grant, eds., *"The Adventurous Voyage":* St. Roch *and the Northwest Passage, 1940-42 and 1944,* Arctic Operational History Series No. 7 (Antigonish: Mulroney Institute of Government, 2019), and Peter Kikkert and P. Whitney Lackenbauer, "'On Hallowed Ground': *St. Roch*, Sovereignty, and the 1944 Northwest Passage Transit," *Northern Mariner* 29/3 (Fall 2019): 213-32.
[24] W.A.B. Douglas and Brereton Greenhous, *Out of the Shadows: Canada in the Second World War* (St. Catharines: Dundurn, 1995).
[25] On this theme, see Shelagh D. Grant, *Sovereignty or Security? Government Policy in the Canadian North, 1936-1950* (Vancouver: UBC Press, 1988); Peter Kikkert, "Pragmatism and Cooperation: Canadian-American Defence Activities in the Arctic, 1945-1951" (unpublished M.A. thesis, University of Waterloo, 2009); Peter Kikkert and P. Whitney Lackenbauer, "Setting an Arctic Course: Task Force 80 and Canadian Control in the Arctic, 1948," *Northern Mariner* 21/4 (October 2011): 327-58; and P. Whitney Lackenbauer and Daniel Heidt, eds., *The Advisory Committee on Northern Development: Context and Meeting Minutes, 1948-71,* Documents on Canadian Arctic Sovereignty and Security (DCASS) No. 4, revised edition (Calgary and Waterloo: Centre for Military and Strategic Studies/Centre on Foreign Policy and Federalism, 2019).
[26] Quoted in Thomas C. Pullen, "The Navy, Science and the Arctic," article manuscript, Hudson's Bay Company (HBC) Archives H2-141.3-1.
[27] See also Kenneth C. Eyre, "Custos Borealis: The Military in the Canadian North" (unpublished Ph.D. thesis, University of London – King's College, 1981), 187-96, and J.M. Leeming, "HMCS *Labrador* and the Canadian Arctic," in *RCN in Retrospect, 1910-1968*, ed. James A. Boutilier (Vancouver: UBC Press, 1982), 286-307.

[28] Minister of National Defence George Pearkes, on the occasion of paying off *Labrador*, applauded "the splendid record established by the ship under the White Ensign." She had been the only naval icebreaker in the Commonwealth but "now, with her transfer, trained and experienced personnel will be made available to help man our fighting ships, whose operation is our primary task." Priority message, Minister of National Defence to *Labrador*, 21 November 1957, DHH 81/520-8000.
[29] "H.M.C.S. *Labrador*," HBC Archives E346/8/1.
[30] Leeming, "HMCS *Labrador* and the Canadian Arctic," 307.
[31] E.C. Russell, 1964, quoted in Maclellan, "Pullen of the Arctic," 31. Pullen also used this quote to conclude his article on "The Navy, Science and the Arctic."
[32] See United Kingdom, Ministry of Defence, "A History of RCDS," archived on 11 December 2009, http://webarchive.nationalarchives.gov.uk/20091211061225/http://www.da.mod.uk/colleges/rcds/About_Us/A%20History%20of%20RCDS.
[33] Captain Tom Pullen obit, *Daily Telegraph* [London]. The obituary notes that "although he never personally vented his feelings to the Liberal minister of national defence Paul Hellyer, his mother, who met the minister on an aircraft without realizing who he was, made her son's opinions extremely clear."
[34] Tony German, *The Sea is at Our Gates: The History of the Canadian Navy* (Toronto: McClelland and Stewart, 1990), 284.
[35] Maclellan, "Pullen of the Arctic," 31.
[36] Rowley, "Captain T.C. Pullen, RCN: Polar Navigator," 38.
[37] Thomas C. Pullen, "Canada and Future Shipping Operations in the Arctic," *Canadian Defence Quarterly* 3/2 (1973): 10.
[38] See, for example, W.W. Nassichuk, "Forty Years of Northern Non-Renewable Natural Resource Development," *Arctic* 40/4 (1987): 275.
[39] We hope that excerpts from these reports, coupled with the regular diary that he kept on each voyage, will be the subject of a companion DCASS volume at a later date.
[40] Isuma TV, "Who is Baffinland," http://www.isuma.tv/ashleigh-gaul/who-is-baffinland.
[41] R.S. Pilot, "Lazaroosie Kyak (1919-1976)," *Arctic* 37/1 (1984): 78.
[42] "Other commitments prevented me from personally witnessing the final freeze-up and the close of navigation for 1967," Pullen noted, but Captain Dufour on *D'Iberville* supplied him "with sufficient data for this report to be completed."
[43] See, for example, Aurélie Sarrabezoles, Frédéric Lasserre, and Zebret Hagouagn'rin, "Arctic Shipping Insurance: Towards a Harmonisation of Practices and Costs?," *Polar Record* 52/4 (2016): 393-98; Huiru Liu, "Arctic Marine Insurance: Towards a New Risk Coverage Regime," *Journal of Maritime Law & Commerce* 47/1 (2016): 77-100; and Proshanto K. Mukherjee and Huiru Liu, "Legal Regime of Marine Insurance in Arctic Shipping: Safety and Environmental Implications," in *Sustainable Shipping in a Changing Arctic*, eds. Lawrence P. Hildebrand, Lawson W. Brigham, and Tafsir M. Johansson (Cham: Springer, 2018), 191-225.

[44] See, for example, P.G. Sly, L. Little, R. Freeman, and J. McCullum, "Updated State of Knowledge Report of the West Kitikmeot and Slave Geological Province (30 May 2001), https://www.enr.gov.nt.ca/sites/enr/files/wkss_state_of_knowledge_2001.pdf.
[45] Y.O. Fortier, A.H. McNair, and R. Thorsteinsson, "Geology and petroleum possibilities in Canadian Arctic Islands," *Bulletin of the American Association of Petroleum Geologists* 38/10 (1954): 2075-109; R. Thorsteinsson, "Cornwallis and Little Cornwallis islands, District of Franklin, Northwest Territories," *Geological Survey of Canada Memorandum* (1958): 294.
[46] Nassichuk, "Forty Years," 281.
[47] Northern Oil and Gas Directorate, *Petroleum Exploration in Northern Canada: A Guide to Oil and Gas Exploration and Potential* (Ottawa: Indian and Northern Affairs Canada, 1995), 79.
[48] In 1978/79, the Crown corporation Petro-Canada purchased Pacific for $1.5 billion in the most expensive corporate takeover in Canadian history to that time. Earle Gray, *Wildcatters: The Story of Pacific Petroleums and Westcoast Transmission* (Toronto: McClelland and Stewart, 1982).
[49] See Daniel Heidt and P. Whitney Lackenbauer, *The Joint Arctic Weather Stations: Science and Sovereignty in the High Arctic, 1946-1972* (Calgary: University of Calgary Press, 2022).
[50] "Captain T.C. Pullen, R.C.N.," draft biographical sketch by Graham Rowley, DHH 99/36, box 35, file 10.
[51] Bern Keating, *The Northwest Passage: From the* Mathew *to the* Manhattan*, 1497 to 1969* (Chicago: Rand McNally and Company, 1970), 140.
[52] Captain T.C. Pullen, "S.S. Manhattan's Northwest Passage Voyage—Observations by Canada's Representative," 12 February 1970, *The Empire Club of Canada Speeches 1969-1970* (Toronto: The Empire Club Foundation, 1970), 260-72. Available online at http://speeches.empireclub.org/61281/data.
[53] A.H.G. Storrs and T.C. Pullen, "S.S. *Manhattan* in Arctic Waters," *Canadian Geographic Journal* 80/5 (1970): 171.
[54] Pullen, "S.S. Manhattan's Northwest Passage Voyage." The spelling of the *Johnny Mac* differs among sources: Coen spells it *MacDonald*, while Pullen, Keating, and the Canadian Coast Guard spell it *Macdonald*.
[55] Thomas C. Pullen, "What Price Canadian Sovereignty?," *U.S. Naval Institute Proceedings* 113 (September 1987): 71.
[56] Pullen, "What Price Canadian Sovereignty?," 71. See also "Memorandum: *Letter of Instruction to Captain T.C. Pullen* from Admiral A.H.G. Storrs, Director of Maritime Operations, Department of Transport to Captain T.C. Pullen, 11 July 1969," Pullen Papers, Hudson's Bay Company Archives, Winnipeg, Manitoba, reprinted in this volume.
[57] Letter of Instruction to Pullen from Storrs, 11 July 1969.
[58] Letter of Instruction to Pullen from Storrs, 11 July 1969.
[59] Pullen, "What Price Canadian Sovereignty?," 71.

[60] Pullen, "S.S. Manhattan's Northwest Passage Voyage."
[61] Pullen, "S.S. Manhattan's Northwest Passage Voyage." Technically, according to Professor Lawson Brigham, *Manhattan* did not transit the whole Passage, as the ship's western-most point was the Beaufort Sea, not the Pacific Ocean. See Ross Coen, *Breaking Ice for Arctic Oil: The Epic Voyage of the SS* Manhattan *through the Northwest Passage* (Fairbanks: University of Alaska Press, 2012), viii. Such technicality is rarely noted, and Coen's statement that "Amundsen Gulf, whose waters marked the end of the Northwest Passage," is more common (*Breaking Ice for Arctic Oil*, 127). Humble Oil spoke of Amundsen Gulf as the terminus of a complete voyage. See Humble Oil and Refining Company Media Relations, 10 November 1969. Pullen's own works spoke of "completing the passage in both directions in a single season with the icebreakers *John A. Macdonald* and *Northwind*" and listed it among all other full transits in his "Report to The Canadian Hydrographic Service Marine Sciences Branch, Department of Energy, Mines and Resources," in March 1970 (reprinted in this volume).
[62] Pullen, "S.S. Manhattan's Northwest Passage Voyage."
[63] Pullen, "S.S. Manhattan's Northwest Passage Voyage."
[64] Pullen, "Canada and Future Shipping Operations," 9, 13.
[65] T.C. Pullen, "In the Wake of the Manhattan," *Canadian Shipping and Marine Engineering* (1970): 16.
[66] Pullen, "Canada and Future Shipping Operations," 8, 13.
[67] Rowley, "Captain T.C. Pullen, RCN: Polar Navigator," 44; Department of Fisheries and Oceans, *Report of the Institute of Ocean Sciences 1980* (Sidney, BC: Institute of Ocean Sciences, Patricia Bay, 1981), 14; T.C. Pullen, "A 3000-mile Arctic Towing Odyssey," *Canadian Geographic* 51/6 (1981-82): 16-23.
[68] Rob Huebert, "Steel, Ice and Decision-Making: The Voyage of the Polar Sea and its Aftermath: The Making of Canadian Northern Foreign Policy" (unpublished Ph.D. dissertation, Dalhousie University, 1993); Kim Richard Nossal, "Polar Icebreakers: The Politics of Inertia," in *Politics of the Northwest Passage*, ed. Franklyn Griffiths (Montreal and Kingston: McGill-Queen's University Press, 1987), 220-22.
[69] Northern Oil and Gas Directorate, *Petroleum Exploration in Northern Canada*, 4.
[70] Thirty-seven wells were drilled in the peak year of 1973, but activity declined precipitously to only four wells in 1980. Companies worked new exploration licences across the basin in the early 1980s before declining mid-decade, with the last exploratory well spudded in 1986. The basin has seen little to no exploration activity since that time. Northern Oil and Gas Directorate, *Petroleum Exploration in Northern Canada*, 85.
[71] Clyde River (Hamlet) v. Petroleum Geo-Services Inc., 2017 SCC 40 (CanLII), [2017] 1 SCR 1069, https://canlii.ca/t/h51gv.
[72] Amy Tucker, "Baffinland CEO disappointed by rejection of company's expansion project," CBC News, 17 November 2022,

https://www.cbc.ca/news/canada/north/baffinland-iron-mines-reaction-phase-2-rejected-1.6655864.

[73] The *Lindblad Explorer*, built in 1969 and known as "the little red ship," was the first vessel specifically designed and built for cruise tourism in the polar regions. She earned "an esteemed reputation in the niche polar travel sector" before becoming the first cruise ship to sink in polar waters when off the coast of the Antarctic Peninsula in 2007. All onboard were safely evacuated. See E.J. Stewart and D. Draper, "The Sinking of the MS *Explorer*: Implications for Cruise Tourism in Arctic Canada," *Arctic* 61/2 (2008): 224.

[74] J. Marsh and S. Staple, "Cruise Tourism in the Canadian Arctic and its Implications," in *Polar Tourism: Tourism and the Arctic and Antarctic Regions*, eds. Colin Michael Hall and Margaret E. Johnston (Chichester: John Wiley and Sons, 1995), 63-72. See also C.S. Jones, "Arctic Ship Tourism: An Industry in Adolescence," *The Northern Raven* 13/1 (1999): 28-31.

[75] Maclellan, "Pullen of the Arctic," 26.

[76] Captain Tom Pullen obit, *Daily Telegraph* [London].

[77] Pullen, "That Polar Ice-breaker," quoting Joe Clark's House of Commons statement on 10 September 1985. The *Polar Sea* voyage, undertaken for reasonable operational reasons relating to the resupply of the American base at Thule, Greenland, launched another Canadian "crisis" over the Northwest Passage. The Americans refused to seek official permission from Canada prior to making the transit, recognizing that this would prejudice their own legal position.

[78] See Rob Huebert, "A Northern Foreign Policy: The Politics of Ad Hocery," in *Diplomatic Departures: The Conservative Era in Canadian Foreign Policy, 1984-93*, eds. Nelson Michaud and Kim Richard Nossal (Vancouver: UBC Press, 2001), 84-99.

[79] Pullen, "What Price Canadian Sovereignty?," 66.

[80] By "agreeing to disagree" on the legal status of the Passage, the two countries ultimately reached "a pragmatic solution based on our special bilateral relationship, our common interest in cooperating on Arctic matters, and the nature of the area" that did not prejudice either country's legal position nor set a precedent for other areas of the world. David L. Larson, "United States Interests in the Arctic Region," *Ocean Development and International Law* 21/2 (1990): 183.

[81] Pullen, "What Price Canadian Sovereignty?," 71-72.

[82] T.C. Pullen, "Why we need the Polar 8," *Canadian Geographic* 57/2 (1987): 85-86.

[83] Rowley, "Captain T.C. Pullen, RCN: Polar Navigator," 46.

[84] Mohammed Adam and Alana Kainz, "Pullen of the Arctic," *Ottawa Citizen*, August 1990, C1.

[85] Pullen resumé, July 1999, DHH 2004/55, folder 1.

[86] Governor General of Canada, "Order of Canada: Thomas C. Pullen," http://archive.gg.ca/honours/search-recherche/honours-desc.asp?lang=e&TypeID=orc&id=1376 (link no longer active).

[87] Massey Medal awarded in 1984 by the Royal Canadian Geographical Society, "Massey Medal," http://www.rcgs.org/awards/massey_medal/previous_winners.asp (link no longer active).
[88] Thomas Charles Pullen, OC, CD, RCN (Retd) citation, reprinted in *The Northern Mariner* 2/2 (April 1992): 28.
[89] Royal Canadian Navy, "Admirals' Medal Recipients," http://www.navy-marine.forces.gc.ca/en/about/in-depth-admirals-medal-recipients.page (link no longer active). Established in 1985, in conjunction with the seventy-fifth anniversary of the Naval Service of Canada, the Admirals' Medal is bestowed upon individual Canadians in recognition of their outstanding achievements in the advancement of maritime affairs in Canada.
[90] Pullen, "What Price Canadian Sovereignty?," 66.
[91] Pullen, "S.S. Manhattan's Northwest Passage Voyage," 260-72.

Acknowledgements

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List of Acronyms

ASPPR	Arctic Shipping Pollution Prevention Regulations
CARC	Canadian Arctic Resources Committee
CCGS	Canadian Coast Guard Ship
deg.	degree
DEW	Distant Early Warning
ETA	estimated time of arrival
F.	Fahrenheit
HMCS	Her/His Majesty's Canadian Ship
hr.	hour
knots	nautical mile per hour
lbs	pounds
LNG	liquified natural gas
min.	minute
M/V	motor vessel
nm	nautical mile
NWP	Northwest Passage
P.O.	Petty officer
POL	petroleum, oil, lubricants
RATT	Radio automatic teletype
RCMP	Royal Canadian Mounted Police
RCN	Royal Canadian Navy
SHP	shaft horsepower
SS	Steamship
T	thrust
US	United States
USCGC	United States Coast Guard Cutter
USSR	Union of Soviet Socialist Republics
W.C.	washroom
W.L.	waterline length

The Documents

CCGS *John A. Macdonald* alongside an iceberg in Milne Harbour, 26 October 1966. "The shot gives some idea of the hard blue nature of glacial ice."

Doc. 1: T.C. Pullen, Report to Baffinland Iron Mines: Concerning Ice Conditions in, and the ability of ships to use, waters leading from MILNE INLET to BAFFIN BAY, 1965.

HBC Archives H2-141-1-2 (E 346/1/4)

- 1965 -

REPORT

TO

BAFFINLAND IRON MINES

Concerning Ice Conditions
in, and the ability of ships
to use, waters leading from
MILNE INLET to BAFFIN BAY

BY

Captain T.C. Pullen

REPORT TO BAFFINLAND IRON MINES CONCERNING ICE CONDITIONS IN, AND THE ABILITY OF SHIPS TO USE, THE WATERS LEADING FROM MILNE INLET TO BAFFIN BAY

1965

1. INTRODUCTION

In accordance with our agreement, whereby I undertook to act as Government Liaison Agent and Icebreaker Observer during the month of October 1965, the following report is submitted.

2. I joined the Canadian Coastguard Ship JOHN A. MACDONALD on 2 October while that ship was lying in Churchill Harbour. It was my opinion, subsequently justified, that by so doing it would enable me to assess ice conditions in Baffin Bay from the outset and also establish good relations with the Master and his Officers.

3. My task was to determine the time of freeze-up at Milne Inlet, after the freeze-up to determine how long the area could be kept open by icebreakers, and finally to consider the whole matter of shipping using the area. I hope the attached report will serve to answer these questions.

4. From her departure from CHURCHILL on 2nd. October until her arrival in DARTMOUTH, Nova Scotia, on 29th October, the JOHN A. MACDONALD steamed 6350 miles; she spent 21 days north of the Arctic Circle. During my time onboard I was given every consideration and had the run of the ship. The Master and his Officers were most helpful for which I am very grateful.

5. The report is laid out as follows:

- a - This Introduction
- b - Summary of Conclusions
- c - Definitions
- d - General Review of Ice Conditions in Canadian Arctic Waters:
  - (i) Davis Strait & Baffin Bay
  - (ii) Pond Inlet/Eclipse Sound/Navy Board Inlet
  - (iii) Milne Inlet
  - (iv) Milne Harbour
- e - Review of Ice Conditions in 1965 from Milne Harbour to Baffin Bay:
  - (i) Milne Harbour
  - (ii) Milne Inlet/Eclipse Sound/Pond & Navy Board Inlets
  - (iii) Baffin Bay

f - Recommended Route for Shipping
g - Air Reconnaissance
h - Factors Influencing Shipping in Arctic Waters from Milne Inlet to Baffin Bay:
  (i) Wind
  (ii) Fog
  (iii) Icebergs
  (iv) Darkness
  (v) Snow
  (vi) Navigation
  (vii) Sea Ice
  (viii) Icebreaker Escort
  (ix) Gales
  (x) Tug Services
  (xi) Bubblers
  (xii) Handling of Ships
  (xiii) Size of Ships
  (xiv) Loading of Ships
i - Characteristics of Icebreakers
j - Command and Control
k - Foxe Basin - A Possible Alternative

6. Each copy has two pull-out maps to assist the reader in locating the various places and areas mentioned.

7. A number of photographs are included, colour and black and white, which shows better than words what conditions were like.

8. Ice charts have not been included as it is understood a complete series covering the 1965 shipping season have already been prepared and copies are being made available to the Company.

[Signed: T.C. Pullen]
T.C. Pullen

Ottawa, Ontario. 8 November 1965

9. SUMMARY OF CONCLUSIONS - BASED ON EXPERIENCE IN 1965

(a) The opening of Milne Harbour for shipping was governed by ice conditions in the Inlets.

(b) The closing of Milne Harbour to shipping was governed by ice conditions in Baffin Bay.

(c) Delay to shipping during the season was caused by wind-driven ice blocking the Inlets.

(d) Based on hearsay the first ship could have arrived in Milne Harbour for loading on 11 August. There are those who maintain this date could have been bettered.

(e) Conditions in Baffin Bay were such that the last ship should have sailed from Milne Harbour not later than 20 October.

(f) For 1965 the shipping season was therefore from 11 August to 20 October, a period of 70 days, or 10 weeks.

(g) Icebreaker escort would have been necessary at the beginning and the end of the shipping season.

(h) The recommended route is by way of the open water on the Greenland side of Baffin Bay, north about the Baffin Bay Pack, thence direct to Milne Inlet by way of Pond Inlet or Navy Board Inlet whichever offers the better conditions as determined by ice reconnaissance flights and local knowledge.

(i) Heavy ships such as ore carriers should never be taken through the Baffin Bay pack even if icebreaker escort is available. Only when no other route is available should this be attempted.

(j) There may be occasions when a route will be available up the west side of Baffin Bay but the danger of the Baffin Bay pack moving in against the coast makes selection of this route risky.

(k) At no time would Milne Harbour and approaches have been inaccessible to an ore carrier during the freeze-up i. e. 25 September to 20 October. In the later stages an icebreaker would have been required.

(l) Conditions this year in Baffin Bay, particularly with respect to the extent of the pack, were worse than usual.

(m) Steaming distances through ice this year would have been approximately 800 miles.

(n) Size of ships is not a major problem. Indeed the fewer (and therefore the bigger) the better if more efficient use is to be made of the available icebreaker force.

(o) The provision of a tug at Milne Harbour should be considered to assist in berthing ships, clearing ice from the face of the jetty and keeping ice in the harbour stirred up.

(p) The fitting of bow-thrusters to ore carriers would facilitate berthing and manoevring in Milne Harbour whether or not a tug is available. They would also increase the ability of these unwieldy vessels to manoevre through and around ice in areas such as Baffin Bay.

(q) Consideration should be given to the equipping of ore carriers to carry, operate and control helicopters to provide up to the minute local ice data.

(r) From a seaman's point of view an alternative route by way of Foxe Basin has much to commend it.

(s) The matter of 'command and control' would have to be resolved. The safe and timely arrival of ore carriers at their loading and unloading ports will not just happen. Someone will have to co-ordinate plans and make decisions.

10. DEFINITIONS

Listed here are definitions of the terms used in the report to describe the ice conditions which may be unfamiliar to the reader.

BELT - Long area of Pack/Drift ice from a few miles to more than 60 miles in width.

BERGY BIT - A medium-size piece of ice, generally less than 17 feet above sea-level and about the size of a small cottage, mainly originating from glacier ice, but occasionally a massive piece of 'sea ice'.

BRASH ICE - Accumulation of small fragments not more than 7 feet across. It is the wreckage of other forms of ice.

FAST ICE - 'Sea Ice' which remains fast - generally in the position where it originally formed, and which may attain considerable thickness. It is found along coasts where it is attached to the shore, or over shoals where it may be held in position by islands, grounded icebergs or grounded polar ice.

FRAZIL - Frazil or Ice Crystals - Fine spicules or plates of ice, suspended in water. One of the early stages in the freezing of salt water.

GLACIAL ICE - Any ice floating in the sea e. g. iceberg, bergy bit or growler, which originates from a land glacier.

GROWLER - A piece of ice smaller than a bergy bit, frequently appearing greenish in colour and barely showing above water. May originate from either sea ice or glacial ice.

ICEBERG - Large mass of floating or stranded ice, more than 17 feet above sea-level, which has broken away from a glacier or from an ice shelf formation.

ICE BLINK - A typical whitish glare on low clouds above an accumulation of distant ice. It is especially glowing when observed on the horizon.

ICE EDGE - The boundary at any given time between the open sea and sea ice of any kind whether floating or fast.

ICE FLOE - A single piece of sea ice, other than fast ice, large or small and described as 'light' or 'heavy' according to thickness.

ICE RIND - A thin, elastic, shining crust of ice, formed by the freezing of slush on a quiet sea surface. Thickness less than 2 inches. It is easily broken by wind or swell and makes a tinkling noise when passed through by ship.

LEAD - A navigable passage through pack/drift ice.

NEW ICE - A general term which includes ice crystals, frazil crystals, slush, pancake ice and ice rind.

PACK ICE/DRIFT ICE - Term used in a wide sense to include any area of 'sea ice', other than 'fast ice', no matter what form it takes or how disposed.

PANCAKE ICE - Pieces of newly formed ice, usually approximately circular, 1 to 10 feet across, and with raised rims, due to pieces striking against each other as the result of wind and swell.

POLAR ICE - Extremely heavy 'sea ice' up to 10 feet or more in thickness; of more than one winter's growth. Heavily hummocked and very hard. Particularly dangerous to ships when disguised by a covering of snow.

PRESSURE ICE - A general term for ice which has been squeezed together and in places forced upwards.

RAFTING - The over-riding of one floe on another, the mildest form of pressure.

RIDGING - Ridge or wall of hummocked ice where floes have been pressed against each other.

ROTTEN ICE - Ice which has become honey-combed in the course of melting and which is in an advanced state of disintegration.

SEA ICE - Any form of ice (new/young/winter/polar) which has originated from the freezing of sea water.

SLUSH - An accumulation of ice crystals which remain separate or only slightly frozen together. It forms a thin layer and gives the sea surface a greyish or leaden-tinted colour. With light winds no ripples appear.

WATER SKY - Dark patches and strips on low clouds over a water area surrounded by ice or behind its edge. It is due sometimes to an open water area beyond the range of visibility.

WINTER ICE - More or less unbroken level ice of not more than one winter's growth, originating from 'young ice'. Thickness from 6 inches to 7 feet. Winter ice is described as 'medium' when it is 6 inches to 12 inches in thickness, and as 'thick' when it exceeds 12 inches.

YOUNG ICE - Newly formed 'level ice' generally in the transition stage of development from 'ice rind', or 'pancake ice' to 'winter ice'; thickness from 2 to 6 inches.

11. SUMMARY OF ICE AGES AND THICKNESSES

NEW ICE - Up to 2 inches thick - includes SLUSH, PANCAKE and ICE RIND

YOUNG ICE - Up from 2 to 6 inches in thickness

WINTER ICE - MEDIUM WINTER - 6 to 12 inches thick
THICK WINTER - over 12 inches thick

Winter Ice is ONE year's growth

POLAR ICE - YOUNG POLAR - Up to 8 feet thick
ARCTIC PACK - Over 8 feet thick

More than One Winter's Growth

12. GENERAL REVIEW OF ICE CONDITIONS IN CANADIAN ARCTIC WATERS

To have an understanding of arctic navigation it is essential to have some knowledge of the conditions which confront the arctic navigator, conditions not encountered elsewhere and which demand specialised knowledge, experience and equipment.

13. Surface navigation in Canadian Arctic waters is not feasible during the winter months because of the formidable ice cover in all channels and inlets. In some areas this ice may be present in the form of a solidly cemented sheet, in others, it may exist as broad fields of heavy floes, constantly in motion under the influence of wind and tide, but so densely packed as to offer no passage even to icebreakers.

14. The state of the ice during summer may vary considerably from one season to another. The most favourable conditions occur where the one year ice cover of such areas as Hudson Bay and Hudson Strait, or the locally formed pack of Davis Strait and Baffin Bay, may usually be counted on to clear in the course of the summer.

15. Favourable conditions do not occur in all the Arctic channels simultaneously as much of the ice clears by moving out of its winter area rather than by melting 'in situ'. In general, this movement is toward the south and east, and as one area clears the neighbouring channels become choked by its outgoing floes.

16. Thus for example, the ice from Hudson Bay and Foxe Basin may block Hudson Strait long after its own local ice has disappeared. Conversely, in areas such as Baffin Bay, seasons with practically ice-free waters may result when the ice in Kane Basin fails to break up and the heavy pack from the Lincoln Sea, and icebergs from the Petermann and Humboldt glaciers, are thus prevented from passing south.

17. The main drift of ice from the Archipelago is carried south by the Canadian Current in Baffin Bay and Davis Strait. Such south-moving currents lie along the western side of their channels and their load of ice thus packs heavily against those shores.

18. Ice conditions in channels such as Hudson Strait and Lancaster and Jones Sounds which lie roughly at right angles to the flow of the Canadian Current, are complicated by the quantities of heavy ice and bergs that may be drawn through their entrances on the counter-current along their northern shores. This ice is carried some considerable distance westward before crossing over to the south shore and joining the out-going ice stream back to the main southbound current. The entrances of such channels may thus be blocked for a period by west-flowing ice along the north shore and out-flowing ice along the south shore.

19. The start of the short Arctic shipping season depends on the break-up of ice. Break-up of the ice depends not only on the temperature and the amount of sunlight but, to an even greater degree, on the strength and direction of the wind. As wind and weather vary considerably over such a large area, the date of break-up and the speed and extent of ice clearance may show considerable variation not only from year to year but from one locality to another. The ice, once broken, will drift in the current in calm weather but it is so extremely sensitive to wind force that strong contrary winds may succeed either in holding it stationary or even in driving it against the current.

20. Strong south winds, for example, in the area of Davis Strait, may hold the ice of Baffin Bay back northward of Cape Dyer. West and northwest winds may accelerate the flow of ice southeastwards and, if persistent throughout the summer, may bring such quantities from the neighbouring channels that a relatively high percentage of ice may remain in Baffin Bay and Davis Strait throughout the whole navigation season. Only the icebergs remain unaffected. With most of their bulk submerged and therefore protected from the wind, they continue to move mainly with the currents.

21. <u>Davis Strait and Baffin Bay</u>

The general movement of the ice in Davis Strait and Baffin Bay is controlled mainly by the north and south-flowing currents along their shores, and its distribution at any given time is largely dependent on the strength and direction of the prevailing winds. With the exception of icebergs not more than two thirds of the ice in these sea areas is of local origin, and its concentration throughout the summer season is, therefore, greatly affected by the quantities which enter from Smith, Jones and Lancaster Sounds.

22. Along the Greenland coasts, the warm north-flowing waters of the West Greenland Current keep the more southerly stretches free of ice during most of the winter, and a narrowing belt of open water usually continues up the coast to a little north of Upernavik until about Christmas.

23. On the Western side, the cold waters of the south-flowing Canadian Current permit the formation of ice cover along the entire shoreline. All the fiords become covered by an ice sheet and along Baffin Island the land-fast ice borders the coast as far south as Cape Dyer, extending seaward about 10 miles off Bylot Island. Beyond the fast ice the heavy pack moves with the great eddy circulation of Baffin Bay, northward along the West Greenland coast beyond the Disko area, around Melville Bay to the entrance of Smith Sound, and from there southward along the coasts of the Canadian Archipelago.

24. Although in winter in Baffin Bay, particularly on the western side, has generally a 10/10 ice cover, it is not a solid sheet but rather a cemented drifting pack in which the floes may at any time be subjected to violent re-arrangement by the gales.

25. The northern inlets begin to freeze over about the end of September, and in Baffin Bay itself ice begins to make in October. The heavy ice is mainly of local origin, rafted by frequent gales during and after freeze-up, and containing here and there, icebergs and fragments of older ice. In the western part of the bay it drifts south at the rate of about 4 miles a day even in winter.

26. During June and July heavy fields of close-packed ice move down the Baffin Island coast in a solid belt which, under the influence of westerly and northwesterly winds, has been known to extend roughly 125 miles to the eastward from Cape Dyer. In seasons when Kane and Hall Basins break-up, the resultant outflow of polar ice through Smith Sound may give a second summer ice-maximum about August and, in some years, may help to maintain considerable quantities of ice in Baffin Bay throughout the entire summer.

27. The heaviest concentration of pack appears to lie as a tapering north-south belt just west of the central axis of Baffin Bay. As summer progresses, this zone gradually shrinks, but in its southern limits, extending along the Home Bay coast to beyond Cape Dyer, heavy ice may persist in some years until late August.

28. August and September are usually the most ice-free months. In some years the only ice to be seen during these months may be the stream of bergs moving south to the Labrador Sea.

29. Icebergs are an outstanding feature in Baffin Bay and Davis Strait, many of them drifting southwards into the North Atlantic. Although some of these bergs originate from the great glaciers flowing into Kane and Hall Basins, or from the Ellesmere, Devon and Baffin Island Glaciers, the majority come from the area of Melville Bay on the Greenland side of the Bay. Those originating in the Disko area of Greenland frequently appear to be carried westward into Davis Strait by an arm of the West Greenland Current and are caught up relatively soon in the southward flow along the Baffin Island Coast. Those from areas north of Disko are first carried north by the current, to make the circuit around Melville Bay before joining the stately southbound procession along the western side of Baffin Bay.

30. In years when the fast ice in Melville Bay fails to move out, the bergs in that area remain imprisoned. This results in a light iceberg concentration throughout Baffin Bay, at least until the next spring. Conversely, when this fast ice does break-up, the iceberg menace for the next couple of years is heightened.

31. <u>Pond Inlet</u> - <u>Eclipse Sound</u> - <u>Navy Board Inlet</u>

The east-flowing current in Lancaster Sound which, as already reported in para 18 above, carries ice out into Baffin Bay also flows into Navy Board Inlet and is one source of ice, both winter and polar, which contributes to the mass of ice to be found in the general area of Eclipse Sound. The occasional iceberg, carried into Lancaster Sound by the west setting element of the Canadian Current, crosses over and moves east and then south into the Inlet and from there into Eclipse Sound where they usually run aground.

32. Again, the south setting Canadian Current carrying ice south along the east coast of Bylot Island will feed ice into Pond Inlet.

33. Wind, depending upon its direction, will also influence the movement of ice, both into Pond Inlet when it has an easterly component in it, and into Navy Board Inlet when it has a northerly component.

34. Finally there is the locally formed ice, mostly winter floes, which originates in Eclipse Sound and neighbouring inlets. Under the influence of wind and current this ice circulates within the Sound but the area is normally ice-free (less than 1/10) from the second or third week in August to the end of September. Loose ice and bergs may be driven by the winds and currents into the area at any time during the shipping season.

CCGS *John A. Macdonald* in Eclipse Sound, 1965.

35. <u>Milne Inlet</u>

Conditions in Milne Inlet generally reflect those conditions which exist in Eclipse Sound but made worse should there be a northerly wind during and after the break-up. In this event ice is piled into both the Inlet and the Harbour making navigation difficult. There is not much available in the way of meteorological data for this area as yet though it is known that at Pond Inlet (where the settlement is located) the prevailing wind is reported to be east to northeast. It occasionally blows from the west and in winter the prevailing wind is south.

36. Milne Harbour

Milne Harbour freezes over in late September or early October and this ice remains landfast until the break-up the following July or August. This winter ice causes no difficulty once it has been broken up, either by the normal process of rotting and removal by a south wind, or by being assisted in its destruction by icebreakers.

37. As already explained should there be a period of wind with a northerly component in it, Milne Inlet will become choked with ice and this in turn will delay the clearing from Milne Harbour of its winter ice.

38. REVIEW OF ICE CONDITIONS IN 1965 FROM MILNE HARBOUR TO BAFFIN BAY

It is generally agreed that conditions were worse than usual this year in Baffin Bay. The northern limit of the Baffin Bay pack was established at Latitude 75° North, some 150 miles or so further north than is usual.

39. Milne Harbour

The first complete cover of the harbour occurred on 25 September. This new ice grew undisturbed until 4 October at which time it was 5 inches thick and growing at the rate of 1/2 an inch a day. When the JOHN A. MACDONALD arrived late 11 October the ice was 7 to 8 inches thick.

40. The ship departed 13 October but before leaving she steamed about the harbour smashing up the ice. When assessing ice conditions, from the bridge of an icebreaker, there is a tendency to under-estimate its strength and thickness. With this in mind, and making due allowance for the difference between icebreakers and ore carriers, I am of the opinion that even at this time a ship of the latter type could have manoevred, with some difficult[y], alone in Milne Harbour.

41. It should be remembered that were a tug available in Milne Harbour to assist in berthing ships and clearing ice from the face of the jetty she would also have been employed keeping the harbour ice broken and stirred up from the very moment new ice started to form on 25 September.

42. By 16 October it was reported by radio, from the Camp at Milne Harbour to the ship lying at the time in Eclipse Sound, that the temperature was 12° below zero in Milne and that the harbour ice was 11-1/2 inches thick.

43. On 17 October, while the ship remained in Eclipse Sound, a helicopter flew from the ship into the Camp Site and determined that the ice was a foot thick and that the tracks made by the ship on the 13th, while still clearly visible, were frozen solid. Even at this stage it would have been feasible for an ore carrier of any size to have entered harbour, with icebreaker assistance, to load.

44. It may be of interest to note the spread in temperatures between the Camp at Milne Harbour and the ship lying just 30 miles away in Eclipse Sound: the former, under the influence of a continental climate and with cold air flowing down into the valleys, reported 12° below zero while the ship, under the more moderate influence of a maritime climate, recorded 10° above zero - a difference of 22°.

45. Long before Milne Harbour became frozen to the point where it would have become impassable - and I question whether this could ever happen to an icebreaker - it became obvious that the key to the shipping season, certainly this year and probably in future years too, lay outside in Baffin Bay. Conditions there would become impassable to all shipping, including icebreakers, before the winter ice in the inlets posed a problem.

46. <u>Milne Inlet/Eclipse Sound/Pond Inlet/Navy Board Inlet</u>

When the JOHN A. MACDONALD entered Pond Inlet 11 October there was 5/10 young ice, about 2 inches thick, and for the rest it was open water and easy going. Later that same day and in the same area conditions had deteriorated somewhat because the young ice extended to 7/10 cover and its thickness had increased to 4 inches with considerable rafting. Frazil, ice rind and pancake ice were also encountered.

47. In Eclipse Sound, where earlier in the day there had been much open water, there was by evening a noticeable increase in new ice.

48. Moving down Milne Inlet that same day the ship met only young ice until the harbour itself was reached and, as already indicated, the ice there was much more solid having attained a thickness of 8 inches.

49. From the foregoing it was clear that ice in these areas posed no difficulties to shipping generally. But this situation did not last for long for when the ship returned to the same area on 16 October Eclipse Sound was almost completely frozen and the young ice was nearly 6 inches thick and again, under the influence of wind and current, there had been considerable rafting which doubles its thickness. Later in the season this makes for heavy going when the ice has thickened and hardened.

50. On 17 October, after lying parked in the ice overnight, it was discovered that the ship had drifted, by reason of the local current, a distance of 7 miles. At this time too a certain amount of open water was visible where before there had been ice. During the day the JOHN A. MACDONALD moved westward across Eclipse Sound and stopped off the entrance to Milne Inlet. In this area on the 11th there had been a mixture of new ice and areas of open water; now the ice was 11 inches thick - an indication of the rate at which the freeze-up was proceeding.

51. Also on 17th there was another ice reconnaissance flight in the icebreaker's helicopter and on this occasion it flew up Navy Board Inlet until the waters of Lancaster Sound were in sight. There was little ice to be seen in the inlet and, except for some pack ice along the north shore of Bylot Island, Lancaster Sound appeared to be clear. Certainly on this date Navy Board Inlet would have been the preferred route to Milne Inlet.

52. On 18 October, with the ship still sitting in the ice off Milne Inlet, an accurate measurement was made of the ice and it was reported to be 16 inches thick.

53. There is little doubt that ice conditions in these areas would have posed no problem to ore carriers with icebreaker support; ice conditions would have been manageable until 20 October.

54. <u>Baffin Bay</u>

From what had been experienced to date it was apparent that the governing factor in deciding where and when the 1965 shipping season would end was undoubtedly the Baffin Bay pack. It was therefore necessary to establish the latest date it would be possible to keep open a channel through which ships could pass to skirt the pack to reach open water to the south. Accordingly the

JOHN A. MACDONALD departed Pond Inlet late on 13 October and steered a course parallel to the pack in a northerly direction. At 8 p.m. that day, in position 73° 10' North 75° 46' West, the weather was partly cloudy and clear, the temperature 22° F. and there was 4/10 young and winter ice amid a large number of southbound icebergs. This position, which is just off the entrance to Pond Inlet, is subject to rapid changes of ice due to the aforementioned Canadian Current.

55. The next day, 14 October, there was 9/10 young ice in addition to numerous icebergs and growlers. The ship having reached Latitude 75° North course was altered to the East through 10/10 young pancake ice. Off to the south could be seen the ice edge of the Baffin Bay pack. By mid-day it was apparent that there was no difficulty here for an ore carrier.

56. For the night 14/15 October the ship lay stopped in the ice and the next morning she had drifted a distance of 8 miles to the Southeast, proof of the never-ending movement of the water and ice in Baffin Bay. By daylight the air temperature was 19° F. and the ice was thickening and getting crisper. Snow reduced visibility and cancelled reconnaissance flights by the helicopter. During the day course was reversed for a return to Eclipse Sound. A suggestion that it might be of interest to return by way of Navy Board Inlet to check on that alternative route failed to receive approval and our course lay to the south and Pond Inlet.

57. The next occasion when the ship put out into Baffin Bay was 18 October at dusk when, once more off the approaches to Pond Inlet, it was noted how much the situation had changed. It was necessary to pick our way through a belt of floes held in place by young ice. Some of these floes were of heavy polar ice and it was the JOHN A. MACDONALD which bounced. The floes barely moved when struck.

58. In darkness and driving snow the help given by searchlights and radar is inadequate: in such circumstances it is dangerous for a ship to continue, even an icebreaker. An icebreaker escorted ore carrier would have stopped until daylight rather than risk damage. This heavy ice had no doubt been carried south from Jones and Smith Sounds to the north.

59. By daylight, 19 October, it was confirmed that the heavy ice was negotiable and course was again shaped to the north for another end-run

around the Baffin Bay pack. At this time the sea was completely covered, 10/10 young ice, 5 inches thick plus some winter ice about 8 inches thick and pancake ice, all of which had frozen together making for slow progress. Still passable, though, to escorted shipping.

60. By this time the ice was thick enough so that when it was broken by the passage of the ship, instead of the shattered pieces sliding atop one another, they butted edge to edge. It is this sort of behaviour which, as ice really thickens from inches into feet, slows and eventually halts traffic.

61. By the afternoon of 19 October the winter ice north of the Baffin Bay pack measured 12 inches. There had been snow and all was cloaked by its cover making it difficult to identify the heavy hard polar floes from the softer winter ice. It was at this time I made up my mind that, insofar as it is possible to select a particular moment when shipping would have to stop, 20 October would have been the latest date on which an escorted ore carrier could have been assured of reaching open water in Southern Baffin Bay from Milne Inlet departing the latter place on that date. With the conditions then prevailing it is certain that a ship arriving from the south making for Milne Inlet would have had to be turned back before entering the ice.

62. However, in an attempt to be quite certain that matters had progressed to the stage where shipping really would have had to stop, the JOHN A. MACDONALD once more retraced her steps to the West and South toward Pond Inlet. At 5 a.m., 22 October, the ship began to strike heavy ice and by 6. 30 a.m. it became, according to her captain, more than he was prepared to tackle. At this time it was still dark, we were but 60 miles from the entrance to Pond Inlet, and it might have served our purposes better if instead of retreating we had stopped until daylight for an attempt at helicopter flights to check the ice and the possibility of a thrust instead in the direction of Navy Board Inlet. This was not to be. The entry in the ship's log for 6. 30 a.m. read: "Stopped by 10/10 thick winter ice with rafting and under pressure in position 73° 49' North 75° 07' West. Course reversed to 010°".

63. For the last time the ship headed north then east and finally south around the Baffin Bay pack. The winter ice was thickening and there was no point in remaining in the area any longer. Conditions in Baffin Bay undoubtedly governed the duration of the 1965 shipping season. This pattern

may be repeated in other years but no reliance should be put on this; certainly conditions in the Bay were bad in 1965.

64. RECOMMENDED ROUTE FOR SHIPPING

Thin-skinned ships, and ore carriers are included in this category regardless of their size, have little choice as to route but are compelled to seek open water all the way to Milne Harbour and return. No ship should try conclusions with the Baffin Bay pack unless there is no alternative and time is too short to wait for better conditions. The recommended route follows the open water off the West Greenland coast northward to the vicinity of Melville Bay to skirt the northern extremity of the pack thence westerly to attain Pond Inlet. There may be occasions when it would be easier going to enter Eclipse Sound by way of Navy Board Inlet and Lancaster Sound but this would depend on prevailing conditions at the time.

65. There may be occasions when the pack would lie clear of the west side of Baffin Bay which would permit a ship to move down the east shore of Baffin Island in open water leads all the way but such occasions would be rare.

66. In 1965, as already stated, the northern limit of the Baffin Bay pack reached so far north that ore carriers would have had to steer north from Pond Inlet a distance of about 150 miles before being able to make any easting. With the onset of winter, lengthening period of darkness, and the other hazards of arctic navigation, this would confront masters of the last ships out with quite a challenge.

67. There are no other routes.

68. AIR RECONNAISSANCE

Air reconnaissance of ice conditions in the track of shipping is of great value but it must be carried out frequently by people skilled in ice interpretation and with experience, it must be carried out using aircraft with ample endurance, with the latest equipment and the ability to operate in marginal conditions.

69. If air reconnaissance of ice conditions falls short of the foregoing requirements then it will not achieve its purpose. Masters of ships will lose confidence in the information they are given and will be reluctant to use it.

70. Long range ice reconnaissance is provided by fixed wing aircraft based ashore and which fly routine sorties of a particular area and/or flights of a specific area at the request of shipping. The data thus derived is used by ships to select the best route to follow to reach a destination with minimum interference from ice even if it is the long way round. Ice information can be valid for only a short time as conditions can quickly change because of wind and current. It happens too that low cloud, fog, snow or darkness will, on occasion, permit an ice reconnaissance aircraft to supply only a partial assessment of ice conditions. If there has been a snowfall the ice will be covered making it impossible to differentiate between a few inches of young ice and many feet of polar ice. The tendency here on the part of airborne ice observers is to give a pessimistic assessment as it is impossible to gauge thickness from the air.

71. Short range ice reconnaissance is provided by helicopters based in the ships themselves and which fly local flights of 20 miles or so passing the results direct to the ships; some masters of ships fly to see for themselves the ice situation. Most icebreakers are provided with helicopters and it would seem worthwhile to consider equipping ore carriers to carry, operate and control such machines during that part of the season when they might be operating alone.

72. In 1965, during my time onboard the JOHN A. MACDONALD, much use was made of the ship's helicopters and ice observer to give the Master an assessment of conditions lying ahead of his vessel. If this is useful to an icebreaker how much more would it be to the Master of a large and unwieldy thin-skinned vessel.

73. During October little use was made of the long range ice reconnaissance facilities available at Frobisher Bay. This was partly because of unsuitable flying conditions but also, or so it seemed, from a reluctance to use the facilities available. This may have been a lack of confidence in the information provided or it may have been for another reason.

74. To give the ice observers practise in their trade and also to provide the ship with an opportunity to compare reported conditions of ice with conditions

as actually experienced, use of these facilities would have benefitted all concerned.

75. If ore carriers are to be successfully taken through Arctic waters then this will be better achieved if there are reliable and accurate ice reports.

76. <u>FACTORS WHICH INFLUENCE SHIPPING IN ARCTIC WATERS FROM MILNE INLET TO SOUTHERN BAFFIN BAY</u>

(a) <u>Wind.</u> The direction of the wind, at certain times during the shipping season and certainly at the beginning, can exert a dominant influence on how quickly the waterways will become clear for shipping and once clear how long they will remain that way. A change of wind direction can, in a matter of hours, choke access to an inlet and upset shipping schedules. Icebreakers can assist here but the strength and direction of the wind can delay the start of the shipping season and during it can make for unpredictable delays.

(b) <u>Fog.</u> This occurs during what should be the best period for shipping, during July and August. It occurs over open water in Baffin Bay and a generous allowance would have to be made in any shipping schedule to cater for delays caused by it. No heavy ship could run the risk of ice damage by pressing on in low visibility in such waters.

(c) <u>Icebergs.</u> Baffin Bay sees more icebergs than anywhere else. It is possible to count them by the dozen from the deck of a ship. Off Pond Inlet on 18 October there were 72 bergs in sight. In Melville Bay they can be counted in their thousands. In addition, and really more dangerous, there are growlers and bergy bits. Without labouring the point further there is a danger from 'glacial' ice.

(d) <u>Darkness.</u> By October there are fewer hours of daylight for ice reconnaissance flights and ice navigation. With heavy and hard ice about thin-skinned ships would be advised to heave-to until daylight. The risk of damage from unseen ice or ice which was sighted too late to be avoided would be too much.

(e) <u>Snow.</u> Snow cuts visibility and is another factor in arctic navigation which can bedevil schedules. While fog is encountered at the beginning of the season, snow and darkness combine at the end to make difficulties.

(f) Navigation. Navigation is not a problem in Baffin Bay. From Pond Inlet to Milne Harbour the land is very high and steep giving excellent radar response; the channels are deep and present no dangers even to ships of the deepest draft. A ship could make her way from Pond to Milne Harbour in the thickest fog.

(g) Handling of Ships. The use of bow thrusters would enable ships to manoevre and berth unaided should a tug not be available. Ships could also manoevre more agilely through ice and thrusters might make the difference between a safe passage through ice and expensive damage. In deep draft vessels installation could be well below ice level. Winter ice does not exceed 7 feet in thickness so that, even when ballasted, ice should not threaten the bow thruster installation. In ice the attitude of the master is often the key to success. The timid man is almost invariably the one who damages his ship by not keeping closed up to the escorting icebreaker and by not handling his ship in a decisive and bold manner.

(h) Loading of Ships. The speedy loading of ships would be essential with no waste of time between turn around. This should be one aspect of the operation over which man has complete control. Every spare hour during the shipping season should be available for the passage to and from Milne Inlet.

(i) Icebreaker Escort. Essential both at the beginning and end of the season. There is too the matter of strain and apprehension to which Masters of ore carriers would be subjected. The very presence of powerful icebreakers should help to make the prospect of ice navigation less daunting. But their presence is no guarantee that ships will not be damaged. Icebreakers may have to stand-by during the season in addition to escorting ships actively at the beginning and end.

(j) Gales. By September gales become more frequent. The danger here is that in rough water growlers cannot be detected by radar nor, if it is dark, can they be seen yet weighing as they do several hundred tons they constitute a hazard.

(k) Tug Services. The provision of a tug in Milne Harbour to assist ships in berthing would seem to be a requirement. In addition it, or they, could be employed keeping ice away from the face of the jetty and in breaking up young ice as soon as it started to form in the harbour.

(l) Bubblers. As installed at Thule bubblers are understood to have been a success in prolonging availability of jetties there. If conditions in Milne were suitable then not only would it be easier to deal with ice in the vicinity of the jetty but a better haven might be available for the tug herself during the winter lay-up.

77. CHARACTERISTICS OF ICEBREAKERS

Lest anyone get the impression that icebreakers are super-ships and can deal with any type of ice, a few remarks on the subject might be of help to the uninitiated.

78. A good icebreaker is a successful combination of power, strength, manoevrability and endurance. Add to these qualities the skill and experience of the man in command. How much can an icebreaker break? This is a question icebreaker captains are continually being asked. If they say 3 feet or 20 feet, either is correct, for icebreaking ability depends not so much on the thickness of ice as upon other factors. A snow cover will cushion and dissipate the icebreaking effect. Solid or 10/10 solid ice slows the icebreaker because it continually resists the ship's advance, besides allowing no opportunity for escape of ice displaced by the hull of the icebreaker herself. 10/10 slush can hold the ship back more than 6-foot thick ice of 3/10 concentration. If ice has water space into which it can be shoved, very thick ice can be broken.

79. To elaborate further, young ice is more plastic than old ice. Antarctic ice is like a bed of feathers, compared to old Arctic ice. Even the temperature has its effect, the hardness of ice increasing with decreasing temperatures. At 32° F, ice has a hardness of 2 on Moh's scale; this increases to 4 at 50° below zero, and 6 at 80° below. The hardness of mild steel plate is about 5-1/2, and of glass about 6 on the same scale. To answer the question truthfully about how much ice an icebreaker can break, one should say, "It all depends". The answer must always be qualified.

80. The skill of an icebreaker captain is partly his ability to know when ice conditions are reaching the stage where his ship cannot cope. There must always be an alternative course of action otherwise he and his ship are liable to become a permanent part of the Arctic scenery.

81. <u>COMMAND AND CONTROL</u>

The shipping aspect will involve those concerned inescapably in what could be referred to as 'Command & Control'. The scheduling of ships into and out of Milne Inlet, the deployment of icebreakers for escort purposes, decisions as to sailing dates and routes to be followed, the use to be made of information provided by ice reconnaissance aircraft, the authority of the icebreaker captains vis-à-vis the ore carrier masters, all these plus others are matters which cannot be ignored and left unresolved.

82. It is essential there be mutual confidence and trust between the ships being escorted, the ships escorting, and the aircraft providing ice data. In fog, darkness, snow and amid ice of all shapes and sizes there is no time for argument as to who is to do what and when. The inevitable result would at best be delay, at worst damage and disaster.

83. Ignorance, timidity, indecision, refusal to co-operate, refusal to make use of ALL the facilities and aids available, these are the sorts of things which would make for difficulties.

84. It would seem that icebreaker captains will have to be given certain authority and they will have to be prepared to exercise command, not only of their own ships, but to exercise command of the entire 'escort operation' for that is what it will be. Communications too will have to be efficient, adequate and reliable.

85. This is a complex subject; I mention it only to ensure that it is not forgotten.

86. <u>FOXE BASIN - A POSSIBLE ALTERNATIVE</u>

From a seaman's point of view the use of Steensby Inlet in northern Foxe Basin has advantages over Baffin Bay and Milne Inlet. Provided there is deep water in Steensby so that it could be used as a loading point, and provided a deep water channel exists from there south through Foxe Basin, there is much to be said for this route.

87. By using it the heavy Baffin Bay pack could be avoided altogether, as could much of the iceberg traffic. The shipping season would be longer and could be extended more than it could in northern Baffin Bay. The ice problem would, in general, be a matter of coping with winter ice whereas to reach Milne Inlet the ice encountered is, apart from glacial ice, both polar and winter.

88. There is a commitment for Government icebreakers to be available in Hudson Strait at the beginning and at the close of the navigation season. With a limited number of such vessels more efficient use could be made of that number if all shipping were to be routed through Hudson Strait.

89. The distance to Steensby is shorter, and much more so when the round-about route necessary to evade the Baffin pack en route to Milne is considered.

90. The risk from glacial ice would be reduced by this alternative route. The number of icebergs between the latitude of Hudson Strait and Pond Inlet is remarkable.

91. It is appreciated that the matter of terrain from the mine site to Steensby and the situation at Steensby itself may be completely unsatisfactory.

92. The matter of this alternative appealed to me more while northbound in JOHN A. MACDONALD as it was my opinion that conditions would be more difficult in Baffin Bay than they eventually turned out to be. Nonetheless the Foxe Basin route has much to commend it. It would be of interest to know more about the freeze-up there and also the depths in the approaches to Steensby Inlet and in the Inlet itself.

Doc. 2: T.C. Pullen, Report to Baffinland Iron Mines: Concerning Shipping Conditions to MILNE INLET, 1966.

HBC Archives H2-141-1-2 (E 346/1/5)

1966

R E P O R T

TO

BAFFINLAND IRON MINES

Concerning Shipping
Conditions to MILNE
INLET

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1. Submitted herewith is this report to BAFFINLAND IRON MINES concerning the critical opening and closing phases of navigation to Milne Inlet during the 1966 Arctic Shipping Season.

2. For the opening phase of navigation I embarked in the Canadian Coastguard Icebreaker D'IBERVILLE (Captain W. Dufour - Master) and sailed from Montreal on July 11th. From Montreal to Milne Inlet D'IBERVILLE steamed 3170 miles, crossing the Arctic Circle northbound on July 18th. I remained onboard until July 31st, when I transferred to the Company's camp at Mary River. From there I flew south, the first part of my survey being finished.

3. For the closing phase of navigation I embarked in the Canadian Coastguard Icebreaker JOHN A MACDONALD (Captain P.M. Fournier - Master) on October 13th in Eclipse Sound. I remained onboard, assessing freeze-up conditions, returning in the ship to Dartmouth, Nova Scotia, on November 5th.

4. Captain Dufour and Captain Fournier were both most helpful in making it possible for me to get the information I needed. I was particularly grateful to them for the extensive use of helicopters which made my task easier.

5. This Report is laid out as follows:-

PART I.	Highlights of the 1966 Arctic Shipping Season as it affected navigation to Milne Inlet.
PART II.	Review of Conditions in 1966:-
	(a) The Opening of Navigation.
	(b) The Close of Navigation.
PART III.	1965 and 1966 Seasons Compared.
PART IV.	Photographic Survey of 1966.
PART V.	General Remarks:-
	(1) The Foxe Basin alternative.
	(2) Icebergs in Milne Inlet.
	(3) Availability of the Chartered Beaver aircraft.
	(4) The Phillip's Creek Bridge Washout.

6. <u>Two pull-out maps</u> -- one of the Bylot Island area and one of the Baffin Bay/Davis Strait area -- <u>are included at the back of the Report</u>. The letters thereon correspond with the lettered photographs in PART IV to show where the pictures were taken.

7. My Report to the Company last year included background material on Arctic ice conditions, in the hope that it would be of help to the uninitiated. This material hasn't been repeated this year in the belief that readers of this 1966 Report will also have access to [its] predecessor.

8. However details of the different types and ages of ice have been included, with the two maps, as an aide-memoire at the end of this Report.

9. Except for my reference to Foxe Basin, in PART V in this Report, all my remarks and conclusions contained in last year's Report to the Company still stand.

[Signed: T.C. Pullen]
T.C. Pullen
Captain R.C.N. (Ret'd)

Ottawa, Ontario. 1 December 1966

PART I

HIGHLIGHTS OF THE 1966 SEASON

1. Ice conditions this year were better than average and certainly much better than last year.

2. For the latter half of this season there was no Baffin Bay pack such as existed last year to bedevil shipping.

3. The opening of Milne Harbour to navigation for ore carriers was governed by heavy ice conditions in Eclipse Sound and not in Baffin Bay.

4. The closing of Milne Harbour to navigation for ore carriers was governed by ice conditions in Baffin Bay as was the case last year.

5. The first ore carrier, with icebreaker escort, could have reached Milne Harbour by way of Navy Board Inlet for loading on July 26th.

6. The first unescorted ore carrier could have reached Milne Harbour by way of Pond Inlet on August 1st.

7. The last unescorted ore carrier should have sailed from Milne Harbour on October 26th though even this date could have been bettered.

8. The last escorted ore carrier should have sailed from Milne Harbour on October 28th though October 30th would still have been possible.

9. The length of the 1966 shipping season to and from Milne Inlet and Harbour was 95 days (13-1/2 weeks or 3 months and 2 days) which represents a significant [improvement] over 1965.

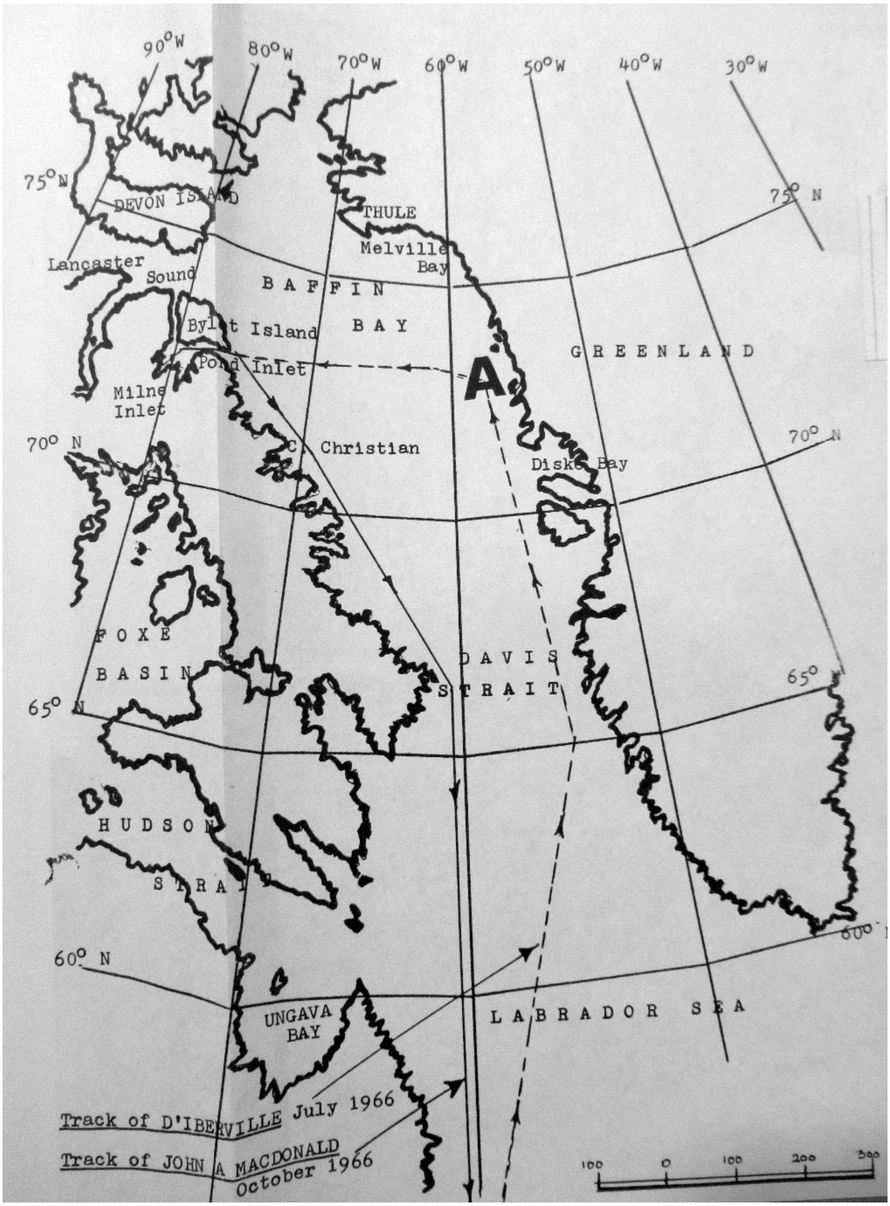
10. Steaming distances through ice this year were:-

(a) At the Opening of Navigation.

100 miles in Baffin Bay plus 80 miles in Eclipse Sound and Milne Inlet as far as Stephens Island -- a total of 180 miles.

(b) At the Close of Navigation.

From the harbour in Milne Inlet to Baffin Bay a total of 200 miles. All of this ice, however, was a mixture of new ice, young ice plus a modicum of medium winter ice. None of it a significant barrier to shipping.


90°W
80°W
70°W
60°W
50°W
40°W
30°W
75°N
75° N
DEVON ISLAND
THULE
Melville Bay
Lancaster Sound
BAFFIN
BAY
Bylot Island
Pond Inlet
A
GREENLAND
Milne Inlet
70° N
70° N
C. Christian
Diske Bay
FOXE
BASIN
DAVIS
STRAIT
65° N
65°
HUDSON
STRAIT
60° N
60°
UNGAVA BAY
LABRADOR SEA
Track of D'IBERVILLE July 1966
Track of JOHN A MACDONALD October 1966
100
0
100
200
300

PART II

Review of Conditions in 1966

(a) The Opening of Navigation.

1. D'IBERVILLE pursued the customary route north up the Greenland shore of Baffin Bay to avoid pack-ice along the Baffin coast to the westward. At 5.30 a.m. on July 19th., the latitude of Pond Inlet, she altered course to the northwest in low visibility. Ice conditions steadily deteriorated until by 9.15 a.m. it was 9/10ths though mostly quite soft. By 10.30 a.m. in low visibility she became stuck in a heavy floe. At this time a report, from the Department of Transport long range ice reconnaissance aircraft, told us that ice conditions would not hinder the ship much longer and that visibility would improve.

2. By 2.30 a.m. on July 20th., open water was reached and these welcome conditions prevailed for the balance of the passage across the Bay. D'IBERVILLE had only 100 miles of Baffin Bay ice to negotiate, 30 miles of which comprised heavy ice and even that, for the most part, was soft and rotten. But notwithstanding such good ice conditions, escort for ore carriers would have been necessary at this time of the year and along this route.

3. Had the ship probed further north, along the Greenland coast, before attempting to make 'westing' towards Pond Inlet, she might have been rewarded with a passage through open water the whole distance. But fog, to be expected at this time of the year, prevented the ice reconnaissance aircraft from delineating the ice boundary for the benefit of D'IBERVILLE.

4. That evening (July 20th) the ship arrived off the entrance of Pond Inlet and picked her way around an assortment of heavy floes but generally found the going quite easy.

5. I flew a helicopter ice reconnaissance up the Inlet where 10/10ths thick winter ice was sighted. This ice was considered to be two feet thick, with puddling and melting well advanced, and no problem to an icebreaker. At Beloeil Island, mid-way up the Inlet, fog forced us to return to the approaching D'IBERVILLE.


CCGS *D'Iberville* in ice, 1966.

The ship continued throughout the night of July 20/21st (in daylight of course because of the latitude) while the ice became thicker and progressively more difficult. These conditions were encountered beyond the furthest point of our earlier helicopter ice reconnaissance. The ship advanced a paltry 13 miles between 1 a.m. and 8 a.m. on the 21st. Eclipse Sound, when the fog finally cleared, confronted us with an unbroken sheet of thick winter ice varying in thickness from four to six feet. Puddling and rotting, under the influence of non-stop sunshine, was proceeding apace.

6. D'IBERVILLE would ram this ice, shoulder and shudder her way a distance about equal to her length - 100 yards - and slowly come to a stand-still. With engines reversed she'd back off some 300 yards and charge again. This process was repeated over and over. For those onboard the sensation is analogous to a truck, without benefit of tires, being driven vigorously up and down a mammoth flight of concrete steps. This ship has a profligate appetite for fuel -- during this performance she lapped it up at a rate of 180 tons a day!

7. Instead of continuing this uneconomical struggle between ship and ice, it might have been more fruitful if D'IBERVILLE had retreated and

circumnavigated Bylot Island to attempt an entry by way of Navy Board Inlet. It was known at this time that Lancaster Sound was wide open; it was suspected that Navy Board too was open, or at least easier when compared to the struggle the ship was committed to in Pond Inlet and eastern Eclipse Sound. Lack of ice reconnaissance data from the long range aircraft was partly to account for this not having been attempted, a view in which the Master concurred.

8. That same day, July 21st, there was another helicopter ice reconnaissance over Eclipse Sound and it was obvious this whole area, about 1000 square miles of it, was one unbroken sheet of thick winter ice. We did spot one large tidal crack, trending in a westerly direction, into which the ship was directed. Down this she romped at 12 knots, bouncing from side to side, for 5 miles or so until it petered out, and once again the slugging match through 10/10ths ice had to be resumed.

9. By July 22nd the ship had battered a path across Eclipse Sound and was carving her way down Milne Inlet. At this stage ice conditions began to improve and, when abreast Stephens Island, she slid into open water. From there on there was no more ice all the way to Milne Harbour. The reason for this, of course, is the heavy fresh water run-off in all the inlets plus the higher melting temperature of fresh water.

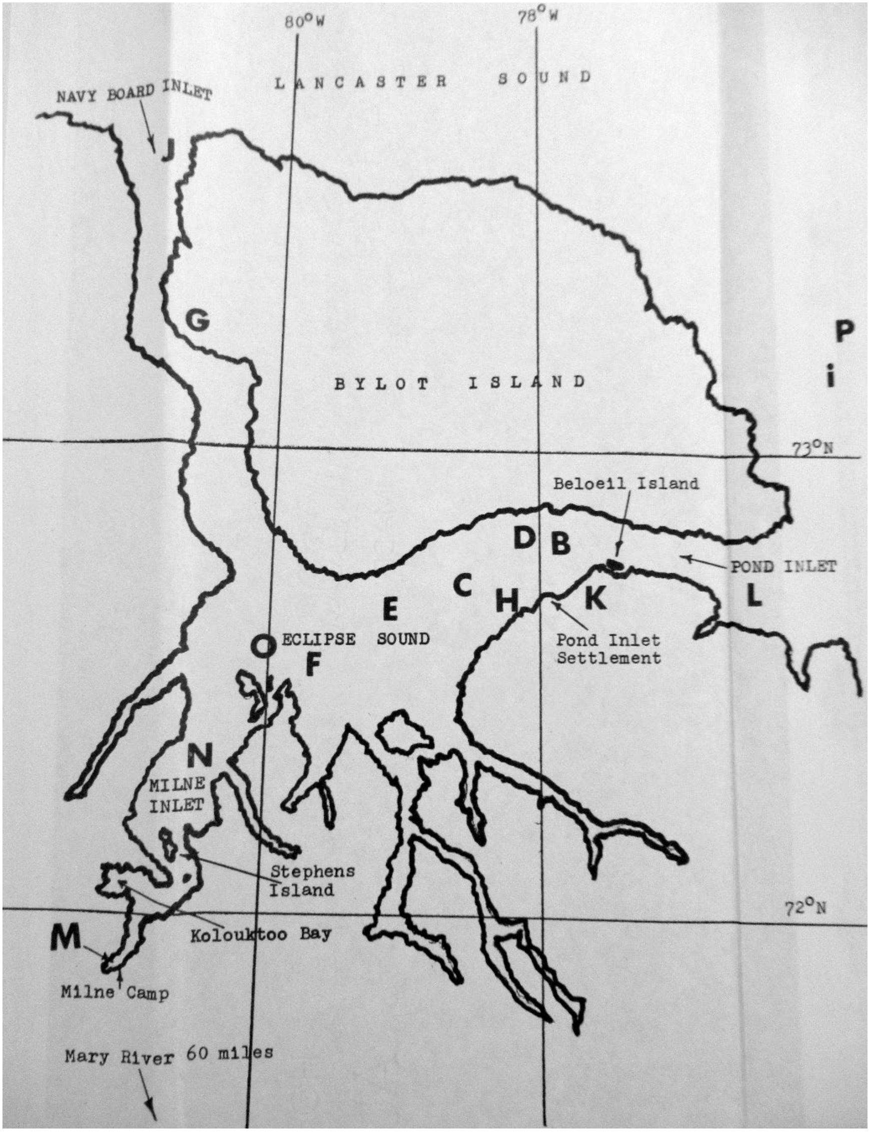
10. It is of interest to record that divers from the JOHN A MACDONALD, when she was in Milne Harbour in August, reported the depth of fresh or brackish water on top of the salt water as 13 feet -- so the fresh water run-off is substantial.

11. On arrival I learned from the people ashore in the camp that the chartered Beaver from TRANSAIR, in which it had been planned to fly ice reconnaissance patrols during the critical break-up period, was away in Churchill having [its] wheels exchanged for floats. At that time I could only hope it would return in time to be of some use before the ice had completely cleared.

12. D'IBERVILLE remained at anchor unloading cargo until 4 a.m. on July 26th when she got under way to check on ice conditions in Eclipse Sound. This was a chore better suited to the still-awaited Beaver aircraft. Open water prevailed as far as Stephens Island. From there northwards to Eclipse Sound there was thick winter ice but it was in an advanced state of rottenness and

melting fast. There was one tight stretch where Milne Inlet joins Eclipse Sound but after that it was relatively easy.

13. I flew in the helicopter up Navy Board Inlet at 7000 feet until I could see the whole of the Inlet, Lancaster Sound beyond and, indeed, as far away as Devon Island on [its] far side 70 miles away. Navy Board and Lancaster Sound were wide open except for two belts of easily negotiable ice in the Inlet. There



was no point in the ship continuing towards Navy Board so she altered away and shaped course towards Pond Inlet.

14. Another helicopter ice reconnaissance, this time towards Pond Inlet, indicated a remarkable improvement in conditions since our struggle in that area a few days earlier -- vivid manifestation of how fast nature works at clearing ice by drift, ablation and melting.

15. As a result of our observations on July 26th I concluded that:-

(a) The start of navigation for escorted ore carriers was July 26th.

(b) Navy Board Inlet was the route to follow to reach Milne Inlet.

(c) The route by way of Pond Inlet on July 26th was still unsuitable for escorted ore carriers.

(d) It would have facilitated matters considerably if an icebreaker had broken up the ice at the entrance to Milne Inlet, referred to in paragraph 13 above, before undertaking the escort of an ore carrier. This was a belt of ice some 30 miles in extent.

16. After this successful day the ship retraced her steps down Milne Inlet to anchor in Kolouktoo Bay for the benefit of the hydrographic survey work being undertaken in that area.

17. At last, on July 30th, the long-awaited Beaver aircraft returned and in it I transferred to the camp at Mary River. Plans to fly an ice reconnaissance the next day were frustrated by mist and rain. Conditions improved on August 1st and so, after two flights to ferry treads for the D-6 tractor from Milne to Mary River, we took off and flew in the direction of Eclipse Sound.

18. There had been quite a change since our last visit to Eclipse on July 26th. The melting and removal of ice had proceeded swiftly and there was open water all the way to Pond Inlet from Baffin Bay and along the south shore of Bylot Island. Conditions were so good an ore carrier could have made Milne Inlet on this day unescorted.

19. There was an accumulation of broken winter ice, rotten and melting, on the western side of Eclipse Sound where Navy Board Inlet debouches into

the Sound, so that on this date Pond Inlet was the better route. A few days more and the whole area would have cleared and ships could have chosen either route.

20. My survey having been completed I returned to the south.

. . . . . .

Review of Conditions in 1966

(b) The Close of Navigation.

1. It was 10° below zero at Resolute Bay on the morning of Thursday, October 13th. Barrow Strait, Wellington Channel and the western portion of Lancaster Sound were frozen. With such low temperatures, and with such visible evidence of approaching winter before me, it seemed that freeze-up in Milne Inlet and Baffin Bay could not be long delayed.

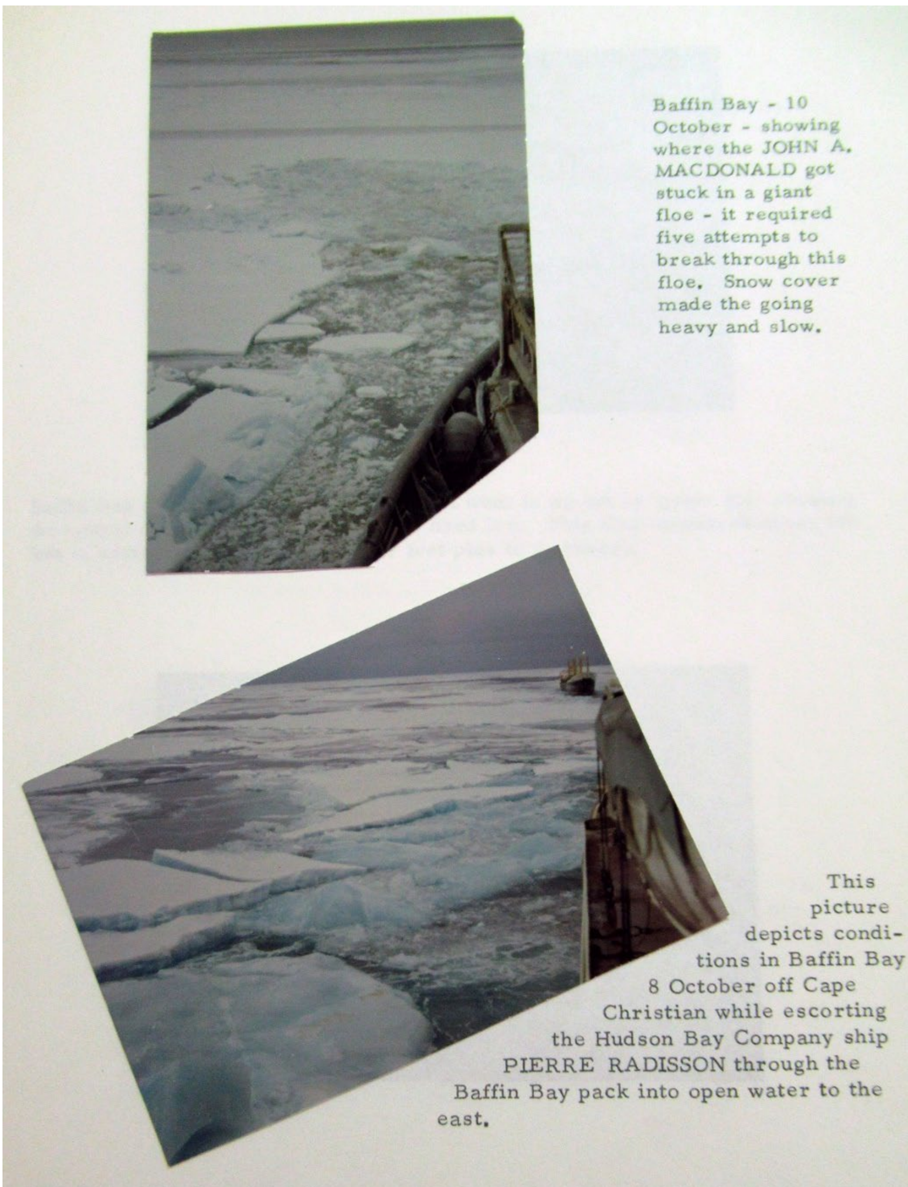
2. Four hours later, when the single-engined Otter bearing me from Resolute to Pond Inlet descended through heavy overcast and broke into the clear, I could see all of Eclipse Sound and nowhere was there ice to be seen. The only object in sight was the JOHN A MACDONALD ploughing across the Sound to recover her helicopter, with me onboard, after which she altered course and steered for Milne Inlet.

3. It wasn't until the ship reached the entrance to Milne Harbour, past Kolouktoo Bay, that we came upon ice. But it was a piddling two inches, just thick enough to hold the ship and make it unnecessary to anchor. This was at 9 p.m. Last year, when we arrived on October 12th, the ice here had been eight inches thick and growing fast.

4. It was agreed the ship should remain for the weekend. No purpose would be served steaming about aimlessly with freeze-up everywhere progressing so slowly. On Saturday, October 15th, the ice measured three inches and a helicopter flight to Kolouktoo Bay reported open water to the north as far as we could see.

5. By Monday, October 17th, the ice measured five inches and the temperature of the air was +5° F. It had been a cold weekend and freeze-up was proceeding -- at least in the harbour.

6. When the ship was in Milne Harbour in August her divers reported a layer of fresh water, lying on top of the salt water, which measured between



Baffin Bay - 10 October - showing where the JOHN A. MACDONALD got stuck in a giant floe - it required five attempts to break through this floe. Snow cover made the going heavy and slow.

This picture depicts conditions in Baffin Bay 8 October off Cape Christian while escorting the Hudson Bay Company ship PIERRE RADISSON through the Baffin Bay pack into open water to the east.

eight and thirteen feet in depth, remarkable proof of the extent of fresh water run-off in this area, and one reason why freeze-up occurs so quickly in the fall and break-up so early in the spring.

7. On Monday, October 17th, the JOHN A MACDONALD cruised up Milne Inlet to discover new ice forming where four days before there had been open water. But in Eclipse Sound there was no ice. The air temperature that morning in Milne Harbour had been +5° F, but in Eclipse Sound it was +20° F.

8. In Pond Inlet itself there was some young and new ice, mostly loose pancake, lying in belts across the entrance. It had been thoroughly churned up by a wind that had been blowing at 30 knots from the north-east all day.

9. Tuesday, October 18th, the ship steamed up the east coast of Bylot Island and, while thus engaged, I flew an ice reconnaissance flight to the east and north-east in an attempt to judge ice conditions out in Baffin Bay.

10. Belts of loose young ice were visible in the distance 30 miles or so away to the eastward. To the north the ice concentration appeared more extensive. Many icebergs could be seen, most of them 'cathedral' type 'bergs 200 to 300 feet high.

11. When the ship reached Lancaster Sound we met more and heavier ice, especially off the entrance to Navy Board Inlet where we parked, for the night of October 18/19, in a convenient large floe.

12. Under way again at 8 a.m., October 19th, the JOHN A MACDONALD had to shoulder her way through and around some heavy floes, made sticky by recent snow falls. Visibility deteriorated off the entrance to Navy Board Inlet, frustrating planned helicopter flights.

13. Open water and improving visibility were encountered in the southern half of the Inlet. When we reached Eclipse Sound at 5 p.m. there was no ice in sight. It had been a satisfaction to see conditions in Lancaster Sound and Navy Board Inlet. Our circumnavigation of Bylot Island proved that no ore carrier could have used that route <u>at that time</u> to reach Baffin Bay. Pond Inlet was the preferred exit. At 6.45 p.m., October 19th., the ship anchored off Pond Inlet settlement.

14. A flight in the helicopter the next morning revealed continuing good conditions in Baffin Bay. At the same time the remarkable influence of current off the entrance to Pond Inlet was apparent, judging from [its] effect on the ice -- this is shown effectively in Photograph 'L' in PART IV. On this date an ore carrier would not have required icebreaker escort. Exactly one year earlier Baffin Bay was frozen and this was the latest date for an ore carrier to get out before final freeze-up.

15. During the time the ship lay off the settlement I spoke with Special Constable Kyack [*sic*: should be Kyak] who told me 1966 was one of the latest freeze-up years in his 23 years of experience in the area. In his opinion the seasons seemed to be getting longer and later each year. The local inhabitants were impatiently waiting for ice to form to permit ski-equipped aircraft to come in.

16. The ship weighed anchor and proceeded out through Pond Inlet to Baffin Bay at 8.30 a.m. October 22nd. The air temperature was +23° F., the sea temperature 29° F., and everywhere the water had that black oily appearance when it's on the verge of freezing. In Baffin Bay there was much more ice about, pancake and young ice in large floes and belts, but soft and no problem to our imaginary ore carrier. 10 miles off the entrance the ship hove to to measure the current. This was only partially successful because of strong winds.

17. On Sunday October 23rd., while drifting about in Baffin Bay, I estimated conditions at that time to be 5 to 6/10ths loose pancake, young ice and new ice. There was also plenty of open water visible. With the relatively warm temperatures we had been experiencing -- what else could one expect? At 8 a.m. that morning the air temperature was +26° F. Conditions being so good the ship once again retraced her steps to anchor off Pond Inlet settlement in the afternoon.

18. A week having elapsed since conditions were inspected in Milne Harbour, the JOHN A MACDONALD weighed anchor at 9 a.m. Monday, October 24th, and crossed Eclipse Sound heading in that direction. Ice had certainly begun to form in the Sound but it was still no problem to shipping. New ice was also forming in Milne Inlet. In the harbour itself, where the ship parked, the ice had grown considerably in thickness. The air temperature that night was +13° F.

19. The entire crew maintained a close check on temperatures. To a man they earnestly hoped for low readings for only then would they find themselves homeward bound. For my part my wish was quite the opposite. Such a conflict of interest was not calculated to make me very popular.

20. During our previous stay in the harbour I inspected the camp site and found everything well secured for winter. There were numerous animal tracks about and one large wolf appeared one day on the ice beside the ship to stare down the crew before limping off across the bay.

21. On Wednesday, October 26th, the Master manoeuvred his ship alongside the local iceberg that had invaded the harbour thus getting a good estimate of [its] size. Opinion was divided whether it was aground or not -- the Master reckoned it wasn't.

22. Gloom prevailed on October 26th when the crew discovered the air temperature at 4 a.m. had been +32° F. To me this day marked the first day of the fourth month of the 1966 shipping season -- surely a record. The prevailing wind had been from the northeast for many days which had a tempering effect on the weather in our area and certainly held back the freeze-up. Weather systems to the south were the cause of this sustained flow of milder air.

23. With six engines (nine engines represent full power) the ship left her icy berth and headed north up the Inlet at 9 a.m. on October 27th. Ice in the harbour varied in thickness -- near the iceberg it measured only five inches.

24. In the vicinity of Stephens Island we encountered a growing amount of new and young ice -- three inches thick -- together with some medium winter ice six to ten inches thick. To our surprise the western half of Eclipse Sound was 10/10ths young pancake. It had been packed against the shore by the strong easterly wind that had been blowing for so long. But the eastern half of the Sound remained unfrozen.

25. We made our way out into Baffin Bay parking off the entrance at 8 p.m. for the night to measure our drift.

26. On Friday, October 28th., there was 9/10ths young and medium winter ice, measuring ten inches, with some snow cover. The temperature at noon was +13° F. On this day a message came from Ottawa to the effect that,

if ice conditions did not compel an earlier departure, the ship should start for Halifax p.m. Sunday October 30th. It seemed Headquarters had lost patience with the freeze-up -- or the lack of it. By this time the wind was strong from the northwest and temperatures were noticeably chillier.

27. Having parked for the night of October 28/29 the JOHN A MACDONALD returned for a final look at Eclipse Sound and Milne Inlet. In the eastern portion of the former there was still a lot of open water. Off the approaches to the latter a final helicopter ice reconnaissance was flown down the Inlet as far as Kolouktoo Bay. Everywhere there was young ice - 10/10ths for three miles or so immediately north of Stephens Island, but in Kolouktoo Bay there was still some open water. No doubt about it -- freeze-up here was at last well under way though this ice would have been nothing to an icebreaker escorting an ore carrier.

28. We retreated across Eclipse Sound and anchored off Pond Inlet settlement to await a final mail delivery from Resolute Bay. When this had been collected we went into Baffin Bay to park in 10/10ths young and medium winter ice. During the night the ship drifted four and a half miles south along the coast.

29. On Sunday, October 30th., a final helicopter flight went up the east coast of Bylot Island (see photo ‘P’ - Part IV) where conditions were still navigable. We swung out over the bay and then returned to the ship. A great many icebergs could be seen moving down, under the influence of the south-setting current, along the [Bylot] and Baffin coasts.

30. By 10.30 a.m. the same day the ship got under way with nine engines and was homeward-bound. This year there was no Baffin Bay pack. It was simply a matter of following a direct course paralleling the coast towards Cape Christian. The ice at this stage was 9/10ths young and medium winter about six inches thick though in numerous places it was much thinner than that.

31. At 16 knots the great swell created by the passage of the ship through the ice shattered and broke it outwards 500 feet or more.

32. The Master sent a message to his Headquarters reporting ice in Milne Inlet as 9/10ths young and medium winter, Eclipse Sound 7/10ths young and medium winter, Pond Inlet and Eastern Approaches thereto 10/10ths young

and medium winter with rafting, and that the last date (in his judgment) for escorted shipping was October 27th. In my opinion October 28th was a better choice -- indeed a ship would have had no difficulty on October 30th which is the date I have used in calculating the season.

33. At 4.45 p.m., October 30th., the ship ran out of the ice in position 72° 01' North 71° 05' West -- approximately mid-way between Pond Inlet and Cape Christian and some 100 miles from the former. This was indeed a far cry from what we experienced here last year when we were compelled to steam 150 miles north of Pond Inlet to get around the Baffin Bay pack.

34. Off Cape Dyer we ran into a fresh to strong south-easterly gale with winds to 45 knots and 20 foot seas. The ship made good if uncomfortable progress through this, wallowing and pitching as only an icebreaker can in heavy going.

35. We arrived in Dartmouth, Nova Scotia, at 10.00 a.m. on Saturday November 5th and my survey for 1966 was completed.

. . . .

PART III

1965 and 1966 Compared

1. The 1965 navigation season for ore carriers into Milne Inlet started August 11th. In 1966 [it] started July 26th -- earlier by 16 days.

2. The 1965 season ended October 20th. The 1966 season ended October 30th -- later by 10 days.

3. The duration of the 1965 season was 70 days (ten weeks) but the 1966 season was 97 days (fourteen weeks less a day) -- 1966 was better (i.e. longer) than 1965 by 27 days.

4. The dates and figures above are based on escorted shipping only. They are also my estimate of the situation and no one else's, though it [doesn't] disagree markedly with those selected by the icebreaker masters.

5. I was not in the area when the opening date for shipping was decided upon in 1965 -- August 11th. Captain Fournier told me he considered August 8th a more realistic date. But as his closing date of October 18th was two days earlier than mine, the length of the 1965 season was not effected.

6. This year Captain Fournier's date for the end of the navigation was October 27th. In my opinion an escorted ore carrier could have sailed from Milne Inlet as late as October 30th. If the JOHN A MACDONALD hadn't been recalled on October 30th it would have been possible to determine how late shipping could have continued beyond that date, and just how long it would have been before freeze-up really closed [its] grip on the area.

7. On the evidence of just two seasons I would make the following observations:-

(a) 1965 was probably an 'average year' -- i.e. a 10 week navigation season.

(b) 1966 could therefore be considered an 'above average' year -- i.e. a 14 week navigation season.

(c) For every 'above average' season there'll inevitably be an off-setting 'below average' one at some time.

(d) Elation at a slow freeze-up and extended season must be balanced by the need to exploit this unexpected bonus by last minute re-scheduling of ships. This may not be practicable.

(e) Rather than counting on a late freeze-up it would be preferable to open Milne Harbour to navigation as early as practicable, though not at the risk of damaging ships in ice such as we experienced in Eclipse Sound this year on July 20th -- see Photo 'B' in PART IV.

(f) If arctic navigation seasons are growing longer as some people maintain, then 1966 could represent the 'average' rather than 1965. Two years experience is still too little to draw meaningful conclusions about the 'average' length of such seasons.

PART IV

PHOTOGRAPHIC SURVEY OF 1966

The remarks accompanying the photographs in this Part are a paraphrased version of the Narrative in Part II.

The locations of the scenes depicted in these pictures are keyed to the corresponding letters on the pull-out map at the end of this report.

[Editors' note: We have not reproduced these photos, which are available in the original file.]

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PHOTOGRAPH 'E' July 21st 1966

Still in Eclipse Sound. This is intended to give a closer view of the ice offering such stubborn resistance to the D'IBERVILLE.

When there is no open water an icebreaker must thrust the ice she has broken underneath her hull or push it up on the unbroken ice beside her. In either case tremendous power is required. Eventually the ice-breaker is slowed in very heavy ice and finally stalled.

The more powerful the icebreaker the more ice she can defeat. Increasing the power entails an increase in hull size to accommodate it - a process which can be self-defeating.

PART V

General Remarks

1. Foxe Basin - A Possible Alternative

In my report last year I observed, from a seaman's point of view, that there would be advantages in using Foxe Basin and Steensby Inlet in preference to Milne Inlet and Baffin Bay.

There were, and are, attractive advantages to this, but the use of such an alternative would be dependent upon deep water in Steensby Inlet and suitable terrain between Mary River and tidewater at Steensby Inlet in Foxe Basin.

This year I had the opportunity to fly from Mary River to Hall Beach and our route lay over the area in which I was interested. I was appalled at the ruggedness and lake infested nature of the land. For this reason, and this reason only, I [have] withdrawn my suggestion of Foxe Basin as an alternative to Milne Inlet.

2. Icebergs in Milne Harbour

Icebergs circulating in Eclipse Sound can find their way down Milne Inlet. Most run aground en route but occasionally one will succeed in finding [its] way right into Milne Harbour.

This year, when we arrived on October 13th, a medium sized iceberg was observed on the west side of the harbour. Opinion was divided whether or not it was aground.

Last year a bergy bit, euphemistically described by some as 'cottage size', was beached by the camp.

Icebergs lucky enough to float all the way into the harbour and which are large enough to damage man-made installation will, because of their size, ground before they can get close enough to wreak damage.

But if small enough to be driven by wind or current up to docks and piers they would also be small enough to be pushed out of harm's way by a tug or an icebreaker.

3. Availability to the Chartered TRANSAIR Beave[r] Aircraft

Earlier in this Report there is an implied criticism of the employment of the chartered Beaver. My understanding was that it would be available to fly ice reconnaissance.

But during the period I was particularly interested in, namely the break-up of the ice in the Sound and Inlets between July 22nd and August 1st, it was away exchanging [its] wheels for floats. I don't deny the need for this but there's a conflict of interest here that could be sorted out with better planning.

The ice in Sheardown Lake, and off the camp at Milne Inlet, goes out days, maybe weeks, before the ice in Eclipse Sound and other areas of interest to shipping. This is when the aircraft should arrange for [its] change-over. It should also make an effort to be away as briefly as possible. Winnipeg, it seems to me, is too far away.

I have no criticism whatsoever of the pilot of this aircraft, simply the timing of the change-over plus the length of time required for it.

4. The Phillip's Creek Bridge Wash-out

While at Milne Camp in July I watched the D-6 Tractor operator expend a considerable effort in placing culverts (ones we had delivered in the D'IBERVILLE) on the bed of the creek, and then pushing in fill to make a roadway to the west bank.

By October it had been washed away. The culverts were nowhere to be seen and most of the fill had gone.

In the summer some doubt was expressed by us, as sidewalk superintendents, as to whether sufficient culverts had been used to carry the spring run-off. Obviously not, and by quite a margin, for even the autumn rains had been sufficient to wipe out this inadequate man-made bridge.

Doc. 3: T.C. Pullen, Report to Baffinland Iron Mines: Concerning Ice Conditions Affecting Navigation to Milne Inlet by way of Baffin Bay, Pond Inlet, Navy Board Inlet and Eclipse Sound, 1967.

HBC Archives H2-141-1-3 (E 346/1/9)

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R E P O R T

TO

BAFFINLAND IRON MINES

Concerning Ice Conditions
Affecting Navigation to
Milne Inlet by way of Baffin
Bay, Pond Inlet, Navy Board
Inlet and Eclipse Sound.

. . . .

Photograph a.

POND INLET – NORTH BAFFIN

ISLAND – July 19, 1967

Here the JOHN A. MACDONALD is entering POND INLET between BAFFIN [ISLAND] and BYLOT ISLAND. The dark land mass to the right is BYLOT and the ice-clad mountains of BAFFIN can be seen to the left of that. It is apparent that the visibility within the Inlet is marginal.

The ice immediately ahead of the ship is scattered winter ice and of no consequence. Once inside, though, the ice became landfast and 3-1/2 to 4 feet thick.

Ice conditions here, and inside, were worse than at the same time last year.

6 am – Kodacolour – ASA 80 - 1/250 - f 8

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1 9 6 7

R E P O R T

TO

BAFFINLAND IRON MINES

1. Forwarded herewith is this, my third, annual report to BAFFINLAND IRON MINES concerning the length of the navigation season and the opening and closing phases of navigation for shipping destined for MILNE INLET during the 1967 Arctic Shipping Season.

2. I embarked once again in the Canadian Coastguard Ship JOHN A. MACDONALD (Captain P.M. Fournier) in MONTREAL and sailed from that port on July 8 for MILNE INLET. I remained onboard until August 4 disembarking at POND INLET just before the ship departed the area for CAPE DYER on the BAFFIN ISLAND coast.

3. The Canadian Coastguard Ship D'IBERVILLE (Captain W. Dufour) supervised the close of ice navigation conditions. She remained in the MILNE INLET/POND INLET area until October 23 by which date, having decided that her work was completed, course was shaped for her home port in QUEBEC.

4. Other commitments prevented me from personally witnessing the final freeze-up and the close of navigation for 1967. Captain Dufour, however, helpfully supplied me with sufficient data for this report to be completed. I have every confidence in the information he supplied.

5. Once again I am indebted to Marine Operations of the Department of Transport in OTTAWA, and to the Captains and Officers of the Icebreakers, for their assistance to me in my work on behalf of the Company.

6. This 1967 Report is laid out as follows:

Part I. Highlights of the 1967 Season.

Part II. The 1965, 1966 & 1967 Seasons Compared.

Part III. Narrative Review of Conditions in 1967:

(a) The Opening of the Navigation Season.

(b) The Close of the Navigation Season.

Part IV. Giant Tankers and Ore Carriers in the Arctic – Some Thoughts.

Part V. Photographic Section.

7. Two pull-out maps - one of the ECLIPSE SOUND/MILNE INLET area and one of the BAFFIN BAY/DAVIS STRAIT area - are included at the back of the report to assist the reader in relating names to places. The black letters on these maps correspond to the lettered photographs in Part V.

8. Details of the different types of ice encountered in the Arctic are included again as a marginal addition to the pull-out map of the ECLIPSE SOUND/MILNE INLET area.

[Signed: T.C. Pullen]
T.C. Pullen
Captain R.C.N. (Ret'd)

Ottawa, Ontario. 15 December 1967.

Part I.

HIGHLIGHTS OF THE 1967 SEASON

1. While ice conditions, especially in ECLIPSE SOUND and the approaches to MILNE INLET, were worse this year than last, and while there was pessimism at the outset that we were in for a poor year because of heavy ice, matters turned out quite well after all.

2. Again this year, as for last, the opening of MILNE INLET to navigation by (imaginary) ore carriers would have been governed by ice conditions in ECLIPSE SOUND and not the ice in BAFFIN BAY.

3. The closing of MILNE HARBOUR to ore carriers was governed by ice conditions in BAFFIN BAY as was the case last year.

4. The first ore carrier, escorted by icebreakers, could have reached the ore loading facility in MILNE HARBOUR on August 5.

5. It is not possible to give a date when the first unescorted ore carrier could have reached MILNE HARBOUR, because the JOHN A. MACDONALD had to depart the area for CAPE DYER on August 5, but it is considered that August 20 is a reasonable estimate. The C.D. HOWE reported the western half of ECLIPSE SOUND still congested with ice as late as August 15.

6. The last unescorted ore carried should have sailed from MILNE HARBOUR on October 15.

7. The last escorted ore carrier should have sailed on October 22.

8. The length of the 1967 navigation season to and from MILNE HARBOUR was 78 days (11 weeks and 1 day) which was not as good as 1966 but better than 1965 - See Part II for a more detailed comparison of the three seasons.

9. Steaming distances through ice of all types were:

(a) At the Opening of Navigation in 1967.

250 miles in BAFFIN BAY plus 120 miles in POND INLET, ECLIPSE SOUND, MILNE INLET & MILNE HARBOUR -- a total of 370 miles -- more than double the ice encountered in 1966 but much of the BAFFIN BAY ice was of little consequence.

(b) At the Close of Navigation in 1967.

When D'IBERVILLE departed MILNE HARBOUR on October 21, the ice there was found to be 21 inches thick with three inches of snow. The ice thickness diminished as the ship made her way north up the INLET. There was no significant amount of ice in ECLIPSE SOUND except that which was packed along the shore and which had no effect on shipping at this time -- a total of about 100 miles and most of that was new, young and medium winter ice.

10. A highlight which I think is worthy of mention here was the circumnavigation of NORTH AMERICA later in the season by the JOHN A MACDONALD after completing the NORTHWEST Passage by a new route. In the western Arctic she also assisted in the rescue of the damaged United States Icebreaker NORTHWIND trapped in heavy pack 450 miles north of POINT BARROW.

Part II.

THE 1965, 1966 and 1967 NAVIGATION SEASONS COMPARED

1. The navigation seasons for shipping destined for the proposed ore loading facility in MILNE INLET, with icebreaker escort, are considered to have opened as follows:

1965:	August 11
1966:	July 26
1967:	August 5

2. The navigation seasons for shipping, with icebreaker escort, are considered to have closed as follows:

1965:	October 20
1966:	October 30
1967:	October 22

3. Therefore the duration of the navigation seasons for icebreaker escorted shipping for the three years for which data are available becomes:

1965:	70 days (10 weeks)
1966:	97 days (14 weeks less a day)
1967:	78 days (11 weeks plus a day)

4. For unescorted shipping the duration of the navigation seasons, based on observed ice conditions, can be estimated only for 1966 and 1967. Complete data are not available for 1965. For what it is worth, therefore, the seasons work out as follows:

1965: August 20* - October 10 (51 days or 7 weeks plus 2 days)

1966: August 1 - October 26 (87 days or 12 weeks plus 3 days)

1967: August 20 - October 15 (56 days or 8 weeks)

* - Estimated -- no shipborne observers were in the area at this time.

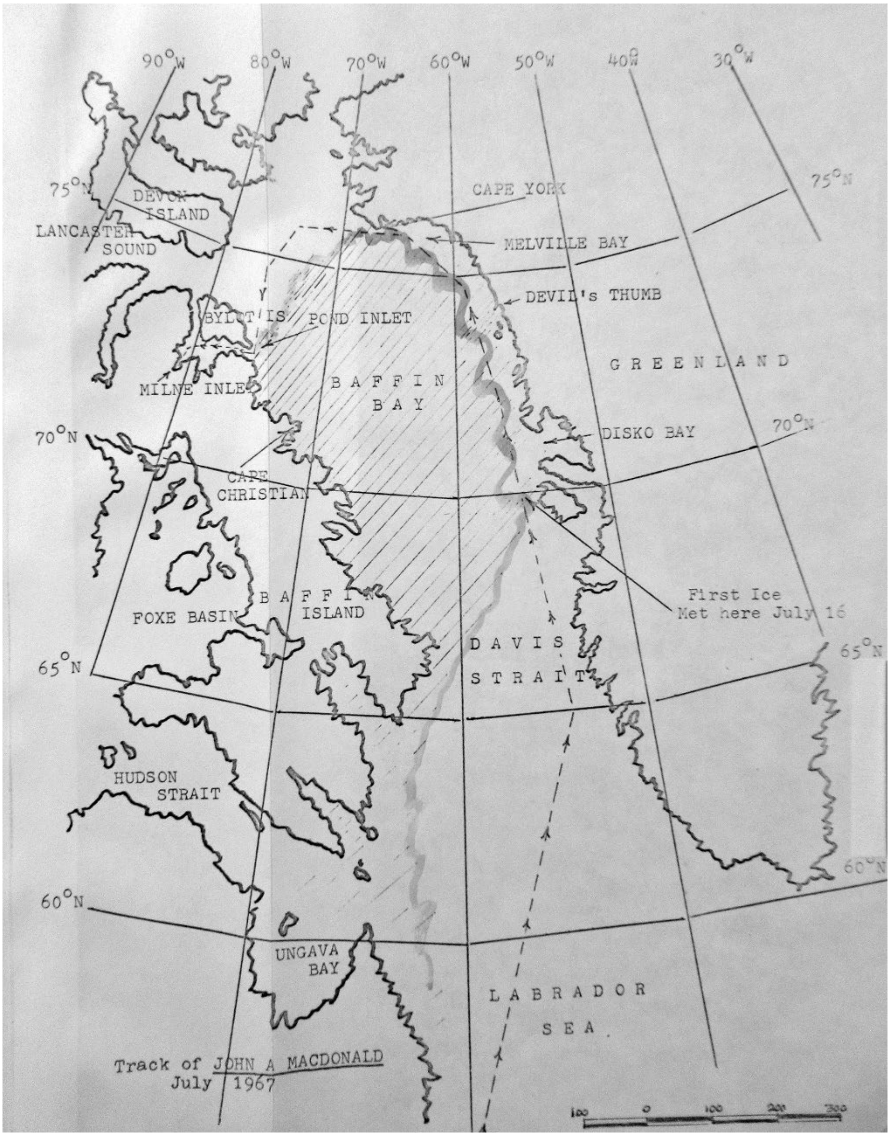
5. The duration of the "unescorted" navigation season is of interest mainly to those who might wish to schedule additional ships into the area during the very best ice-free period of navigation. Presumably such additional shipping would be non-ice strengthened and would not require, and could not expect, icebreaker escort unless it got into difficulties. To be on the safe side, the length of the navigation seasons given in para 4. above should be even further curtailed though to offset this additional reduction icebreakers would invariably be in the offing to provide assistance. In any event, marine underwriters would probably have a great deal to say on this subject.

6. This year, as the JOHN A MACDONALD was bludgeoning her way through ice in ECLIPSE SOUND more formidable than that encountered there last year at the same time by the D'IBERVILLE, I began to suspect that 1967 would turn out to be a bad ice year for navigation. This view was shared by Special Constable Kyack, R.C.M.P., at POND INLET to whom I spoke on August 4 about ice conditions in the area. He told me the chances were good that the ice might never go from ECLIPSE SOUND in 1967. Eventually, of course, it did. I am sure he is a much better Special Constable than he is a long range ice forecaster! But the Arctic is no place for an impatient person and one should never jump to conclusions. When it was all over, 1967 turned out to be a reasonable navigation year for those imaginary ore carriers after all.

7. Generally speaking, ice conditions in 1967 were worse than those experienced in 1966 by a substantial margin, but better than those experienced in 1965 from what information is available for that year.

8. In my report to the Company last year an opinion was expressed to the effect that 1966 might be considered an "above average" year for ice navigation -- i.e. 14 weeks in duration. As a result of my experience this year that opinion is reinforced.

9. There is little to choose between the 1965 and 1967 seasons. It seems reasonable to conclude that they both represent what could prove to be "average" years for ice navigation to MILNE INLET -- i.e. 10/11 weeks in duration.


90°W
80°W
70°W
60°W
50°W
40°W
30°W
75°N
DEVON ISLAND
LANCASTER SOUND
CAPE YORK
MELVILLE BAY
DEVIL's THUMB
BYLOT IS
POND INLET
MILNE INLET
BAFFIN BAY
GREENLAND
70°N
DISKO BAY
CAPE CHRISTIAN
FOXE BASIN
BAFFIN ISLAND
First Ice Met here July 16
65°N
DAVIS STRAIT
HUDSON STRAIT
60°N
UNGAVA BAY
LABRADOR SEA
Track of JOHN A MACDONALD July 1967
100 0 100 200 300

Part III.

NARRATIVE REVIEW OF ICE CONDITIONS IN 1967

(a) The Opening of Navigation to MILNE INLET.

1. On July 8, at 10 pm. the Canadian Coastguard Icebreaker JO[H]N A MACDONALD (Captain P.M. Fournier) cast off from her berth in MONTREAL and manoeuvred out into the stream. Laden with cargo, both in her hold and on deck, she was embarking on her 1967 Arctic voyage which was destined to become her most successful and famous. Leaving the bright lights and gay sounds of EXPO '67 behind her she slipped quietly and unnoticed down river and into the night.

2. After pausing briefly off QUEBEC to embark last minute additions to the crew the ship continued on her way into the GULF thence north via the STRAIT of BELLE ISLE. A visit was made to GOOSE BAY there to embark the ship's two helicopters after which her northbound track was resumed.

3. Wallowing northbound through the lumpy waters of the LABRADOR SEA and DAVIS STRAIT the interest of those onboard focussed on ice conditions to be met further north. But information from the long range ice reconnaissance aircraft already overflying that area was not calculated to satisfy that curiosity. Ice charts received by the ship's facsimile equipment showed nothing but "estimated" ice boundaries for those areas in which the ship was particularly interested -- namely MELVILLE BAY and the CAPE YORK AREA (see pull-out map at the back of this report). The explanation for this lack of data was of course, largely due to the low cloud and fog which prevails there at that time of year.

4. At 3 pm on Sunday, July 16, scattered ice (3/10 medium and thick winter ice plus an assortment of heavy polar floes) was encountered 40 miles northwest of DISKO ISLAND (70° 30' North 56° 28' West). The ship ignored one such floe, a hefty relic of a pressure ridge 25 feet thick, off which she bounced. The distribution of this sort of ice is what makes for difficulties when escorting shipping. It is sufficiently spread out to appear of little consequence yet the movement of an icebreaker through it sets up eddies which can pull

heavy floes into the path of oncoming ships. Low visibility can add to the difficulties of ships being escorted.

5. This belt of ice extended for ten miles or so until once again the JOHN A MACDONALD was gliding along in open water with nothing in sight but birds and bergs. Various belts of ice were negotiated in this manner and these conditions continued until 3.30 pm the following day. July 17, when off the DEVIL's THUMB in MELVILLE BAY, she entered more ice -- 9/10 young ice, not thick enough to be classified as medium winter ice, interspersed with a few old heavy floes. It was glassy calm with marginal visibility. One of the ship's helicopters took off on an ice reconnaissance flight in conditions which were less than ideal for flying. So far so good for that imaginary ore carrier following along behind.

6. By 1.30 am on July 18, the JOHN A MACDONALD was back in open water and feeling her way past the steep rocky cliffs in the vicinity of CAPE YORK just visible through the mist. At this time of the year there is, of course, no darkness in these latitudes.

7. The ship's route took her up the west GREENLAND coast, north around the worst of the BAFFIN pack, west across BAFFIN BAY, thence south to the entrance of POND INLET and was, on the whole, accomplished without too much difficulty.

8. By 6.15 am, on July 19, we rounded CAPE GRAHAM MOORE on BYLOT ISLAND and steered into POND INLET. The ice here was heavier than it was the year before. 10/10 thick winter ice in the narrowest part of the inlet with a few lateral tidal cracks. Fog and low cloud obliterated the magnificent ice-clad mountains towering above us on both sides.

9. As the ship slowly advanced the ice became thicker. By BELOEIL ISLAND it measured 3-1/2 feet and from there on it became a matter of repeated butting and backing. An extract from the ship's log gives a good indication of the state of affairs at that time: "0328 (i.e. 3.28 am) - Stuck. 0358 - Finished with engines, no progress, very heavy ice. 0400 - 72° 47.7′ North 77° 39 ′ West. Fog. Stopped in heavy ice. 0703 - Ship freed." In 24 hours the mileage achieved was 24-1/2. On July 19, between 4 pm and 9.30 pm the ship advanced a paltry 4 miles.

10. Our struggle to cross ECLIPSE SOUND, a distance of 110 miles, while slow and tiresome, was conducted in brilliant sunshine and perfect weather. At one point the ice measured 68 inches in thickness.

11. On July 20 the long range ice reconnaissance aircraft appeared and at our request examined ice conditions in MILNE INLET and NAVY BOARD INLET. In due course it reported 1/10 ice in the southern portion of the former and 10/10 ice in the latter.

12. On July 21 I flew in one of the ship's helicopters up NAVY BOARD INLET to inspect conditions there and found them somewhat better than those through which the icebreaker was picking her way. While the ice in NAVY BOARD INLET was certainly 10/10 there was very much more melt water present and rotting had progressed much more than it had where the ship was. Off the mouths of all the rivers, streams and glaciers there were expanding semi-circular areas of open water created by the presence of so much fresh water.

13. For the 24 hour period from midnight July 21 to midnight July 22 the ship carved a channel 21 miles long in ice which averaged 50 inches in thickness. The previous day the distance made good was 13 miles. Fuel consumption was 50+ tons per day. This is a lot but not to be compared with the thirsty old D'IBERVILLE who, in similar conditions the year before, lapped it up at the rate of 180 tons a day.

14. By July 24 the ship was approaching LOW ISLAND in MILNE INLET and was still enmeshed in heavy ice. At 3 am she became stuck in a large floe, the thickness of which measured nearly seven feet or so I was informed. She parked there for the remainder of the night to give her crew (and passenger) an opportunity to sleep undisturbed by the incessant crashing and banging of icebreaking. Nearby land was invisible because of dense fog.

15. Later in the day it took an hour and a half of icebreaking for the ship to sunder that heavy floe and continue on her way. Still in fog the JOHN A MACDONALD fought her way down to STEPHEN ISLAND where, last year, we found open water. This year there was ice all the way to the entrance of MILNE HARBOUR. However the ice did become progressively thinner and more rotten. In the harbour itself there was open water -- surely a gladsome sight.

16. At 5.37 pm on July 24, after covering 4076 nautical miles since leaving MONTREAL, the ship anchored in 45 fathoms of water off the Company's camp site. The only other occupant of the harbour was the iceberg reported by me last year. It lay in the western part of the harbour obviously aground in 42 fathoms (252 feet) of water.

17. Ice conditions from POND INLET to the entrance to MILNE HARBOUR were impossible for shipping and it was a matter of waiting for nature to reduce the hardness and thickness of the ice to manageable proportions. 24 hours of daylight, bright sunshine, temperatures above freezing and a heavy fresh water run-off, all these accelerate the melting process -- one which takes place with remarkable swiftness in high latitudes.

(b) <u>The Close of Navigation to MILNE HARBOUR.</u>

1. This year the Canadian Coastguard Icebreaker D'IBERVILLE (Captain W. Dufour) supervised the freeze-up of MILNE INLET and the sea approaches thereto.

2. She reported that, as in former years, the ice started to form in MILNE INLET in late September. This year, on September 28, ice began to appear in both KOLUKTOO BAY and MILNE INLET.

3. On October 22 the northern part of ECLIPSE SOUND was ice free while its southern shore was packed by 10/10 medium and thick winter ice driven there by a strong northwest wind.

4. NAVY BOARD INLET was still navigable to ships on the same date (October 22) provided they had icebreaker escort. What ice remained there consisted primarily of medium and thick winter ice rafted and ridged. POND INLET was almost ice free thanks to a 40 knot wind from the northwest -- the same wind which had cleared the northern part of ECLIPSE SOUND.

5. On October 21 the ice thickness in MILNE HARBOUR measured 21 inches with three inches of snow cover. At the entrance to the harbour area, off CAPE KWAUNANG, the ice was reported to be a foot thick. The upper reaches of MILNE INLET had only 8/10ths new ice.

6. D'IBERVILLE, in the opinion of her master, considered that October 15 was the latest date an ore carrier should have sailed from MILNE

HARBOUR unescorted. With icebreaker escort, October 22. October 23 was the final date for navigation by ice-breakers in and out of MILNE INLET.

7. The key to the close of navigation was not, however, ice conditions in this and other inlets, but rather ice conditions in BAFFIN BAY. The accumulation of heavy ice which drifts south late in the season from SMITH and LANCASTER SOUNDS, when it reaches the latitude of POND INLET is, in the opinion of the D'IBERVILLE, what closed the area to ships this year. This, and the general freeze-up conditions then prevailing, is certainly what governs the end of navigation.

8. By the middle of September, BAFFIN BAY and DAVIS STRAIT were completely ice free, as they were last year at the same time, permitting ships to route themselves by the shortest route down the BAFFIN coast to CAPE CHRISTIAN and thence south. D'IBERVILLE herself started south on October 23 and went this way.

Part IV

GIANT TANKERS & ORE CARRIERS IN ARCTIC WATERS -- SOME THOUGHTS.

1. A tanker now in service displacing 150,000 tons deadweight, the TOKYO MARU, is hailed as the world's largest ship. 1,005 feet long, 156 feet wide and drawing 53 feet she has a speed of 17 knots and is largely automated with remote controls for machinery and cargo systems. Her crew numbers 29.

2. A design study for a tanker of 500,00 tons has been completed and the press recently reported that the MITSUBISHI interests in JAPAN are to undertake a design study of a tanker displacing 750,000 tons deadweight.

3. It should be explained that deadweight tonnage is the actual weight of the cargo carried by a ship. To such tonnage must be added the displacement tonnage of the ship herself when empty to arrive at total displacement. For a ship of 750,000 tons deadweight then, her total displacement when loaded could soar to an unprecedented total of nearly 850,000 tons.

4. It is certainly as practicable to build ore carriers of such dimensions as it is oil tankers though in the event of hull damage there would be more risk to the former type. A laden tanker whose plating has been holed, say by ice, simply exchanges oil for water with no appreciable effect on her ability to remain afloat. An ore carrier, however, because of the heavy nature of ore, has a great volume of air in her holds even when fully laden and can endure comparatively little flooding before being in danger of foundering. For ships intended to navigate in ice this possibility would obviously receive special consideration from the naval architects.

5. No matter where they operate in the world, such giants will create problems by virtue of their size. The 750,000 tonner, for example, would be at least 1,400 feet long and 250 feet wide -- dimensions which could complicate berthing and, possibly, loading. She will require an unconscionable amount of water in which to float. When the draft of a ship can be measured in fathoms instead of feet it is enough to make an "old salt" turn in his telescope. Even when trimmed level such a ship will draw 80 feet or more when loaded. Because of such drafts they will be denied access to many of the world's major ports and waterways.

6. Heavily laden behemoths, once they are moving along at speed, are mighty difficult to stop. It requires five miles or more before they can be brought to a standstill -- a sobering thought should fog or ice be met with unexpectedly. In such circumstances they would be advised to steam dead slow

yet fast enough to maintain steerage way. The addition of bow thrusters should enable them to sidestep the heavy floes scattered about BAFFIN BAY.

7. The advent of these ships has a special significance when one considers the Arctic and resource development there. Compared to the smaller ships of the type which hitherto have operated in those waters, they will have very thick plating and heavy framing. For ice navigation there would be additional strengthening. Large tankers of the type being discussed here are invariably built with bulbous bows which would, in a ship drawing 80 feet of water, be far far below any sea ice likely to be encountered. Winter ice does not exceed seven feet. With their great size, draft, momentum, and the shape which could be designed into their bows so as to lift and plow ice aside, great things could be achieved in many types of ice.

8. Icebreaker escort for such ships would, in most cases, be futile and unnecessary. A comparison of their "vital statistics" should explain why:

	Typical Polar Icebreaker	Giant Bulk Carrier
Length	350 feet	1,400 feet
Breadth	80 "	250 "
Draft	30 "	80+ "
Displacement	10,000 tons	850,000 tons

Obviously an icebreaker could not carve a path wide enough to be of much use. Should she ever become stuck in heavy ice one can imagine the unfortunate icebreaker captain watching in horrified fascination as half a million tons or so of ore, encased in a monstrous steel c[o]coon, overwhelms his ship. Giant bulk carriers will be their own icebreakers.

9. It is worth mentioning that in the early days of year-round navigation in the GULF of ST LAWRENCE, ore carriers there asked for, and got, extensive icebreaker escort. The masters of these carriers, having survived a few seasons of this sort of treatment without meeting serious difficulties, now confidently navigate the Gulf on their own with little, if any, escort. And escort is not really necessary. It is really a case of experience breeding confidence. With good men and well-found large ships the same should pertain to Arctic waters of interest to the Company.

10. I look forward with enthusiasm to the day when great feats will be accomplished by such ships in our Arctic waters. More's the pity our country hasn't a Merchant Marine capable of meeting this Canadian challenge.

11. Nearly everything I have written about navigation in ice-infested waters, in my reports to BAFFINLAND IRON MINES, has been based on "small" ships up to, say, 30,000 tons. Such ships will continue to require extensive icebreaker support.

SUMMARY OF ICE AGES AND THICKNESSES

NEW ICE	Up to 2 inches thick - includes SLUSH, PANCAKE and ICE RIND.
YOUNG ICE	From 2 to 6 inches in thickness
WINTER ICE	MEDIUM WINTER - 6 to 12 inches thick.
	THICK WINTER - More than 12 inches thick and all the way up to 7 feet.
	Winter Ice is ONE year's growth.
POLAR ICE	YOUNG POLAR - Up to 8 feet thick.
	ARCTIC PACK - Over 8 feet thick.
	Polar Ice is MORE than one year's growth.
GLACIAL ICE	ICEBERG - A large mass of floating or stranded ice, more than 17 feet above sea level, which has broken away from a glacier.
	BERGY BIT - A medium-size piece of ice, generally less than 17 feet above sea level and about the size of a cottage, mainly originating from glacier ice but occasionally a massive piece of "sea ice".
	GROWLER - A piece of ice smaller than a Bergy Bit, frequently appearing greenish-brown in colour and barely showing above water.

Doc. 4: T.C. Pullen, Preliminary Report to the Coppermine River Limited, 1968.

HBC Archives H2-141-1-3 (E 346/1/11)

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<u>P R E L I M I N A R Y</u>

<u>R E P O R T</u>

To

<u>THE COPPERMINE RIVER LIMITED</u>
Suite 420 159 Bay Street
Toronto 1 Ontario

This Report examines some of
the problems associated with
the movement of copper concentrates
from the COPPERMINE area to certain
ports overseas.
It also touches on matters having
to do with the movement of fuels
and freight into the COPPERMINE
area.

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PRELIMINARY REPORT TO

THE COPPERMINE RIVER LIMITED

1. Forwarded herewith is this Preliminary Report to the Company concerning certain aspects of the problem of shipping copper concentrates by sea from tidewater at Coppermine (Expediter Cove) to terminal points overseas.

2. What has been attempted here is a superficial examination of some of the factors involved in a project which, taken as a whole, is really most complex and which calls for an all-embracing transportation study. Early in my work on this matter it became apparent that information essential for me to submit a meaningful report was just not available or lay outside my field of competence. Until all aspects of the matter can be examined, until the various alternatives can be considered, only then would it become practicable to draw sound conclusions and to present meaningful recommendations.

3. Experience shows that the traditional 'bits and pieces' approach to Arctic transportation problems has usually been an unsatisfactory and costly exercise. What is required here, it would seem, is a preliminary study to rule out uneconomic alternatives and to settle on a single system (with approximate costs) from the mine to the discharge point overseas.

4. In more detail what is needed is an overall consideration of the following interdependent factors, all of which overlap, all of which bear heavily on the shipping problem:

a. The movement of concentrates from Hope Lake to tidewater at Coppermine.

b. The mode of stockpiling or storage.

c. The type of terminal and handling equipments required.

d. The type of wharfage required.

e. An examination of the type of shipping required.

f. The length of the navigation season for the different types of shipping examined in e. above.

g. The shipping cycle and the relation it has to the production cycle.

h. An examination of the 'off-season' employment for the vessel considered suited for the Coppermine operation.

5. There are other factors, too, calling for consideration. These too are variable and add to the complexity of the problem. A list of these would include:

a. Marine Insurance.

b. Ice.

c. Hydrography, Meteorology, Oceanography and Climatology.

d. Routes for shipping[.]

e. Navigational aids.

f. Ice reconnaissance.

6. From the work I have done thus far on this subject it would appear that the case for tug and barge operations as the prime means for moving the product has much to commend it and should receive the closest scrutiny. The advantages of being able to winter a barge at the Coppermine and using it for stockpiling is an attractive possibility.

7. At this time the only recommendation I would care to make is that what is obviously needed here is a systems approach to the problem covering all aspects of the operation, from the point where the concentrates leave Hope Lake until they are discharged at whatever distant overseas terminal is decided upon.

[Signed: T.C. Pullen]
T.C. Pullen
for NORTHERN ASSOCIATES REG'D.

Ottawa, Ontario. 31 May 1968

INTRODUCTION

1. This report is divided into two parts. Part 1 is an attempt to investigate various factors governing the movement by vessel of copper concentrates to ports overseas. For the purposes of this paper, TACOMA, near Seattle, and YOKAHAMA, near Tokyo, have been selected as terminal ports.

2. Part I is laid out as follows:

- i Assumptions
- ii Freeze-Up and Break-Up - Some General Observations
- iii A Table of Distances
- iv Considerations of Time & Distance
- v A Coppermine/Tacoma Schedule and a Coppermine/Yokahama Schedule
- vi Some Remarks on Ice Conditions
- vii Transport Configurations

3. The quantity of copper concentrates to be shipped each year, certainly in the early years of the operation, has been taken to be 30,000 tons.

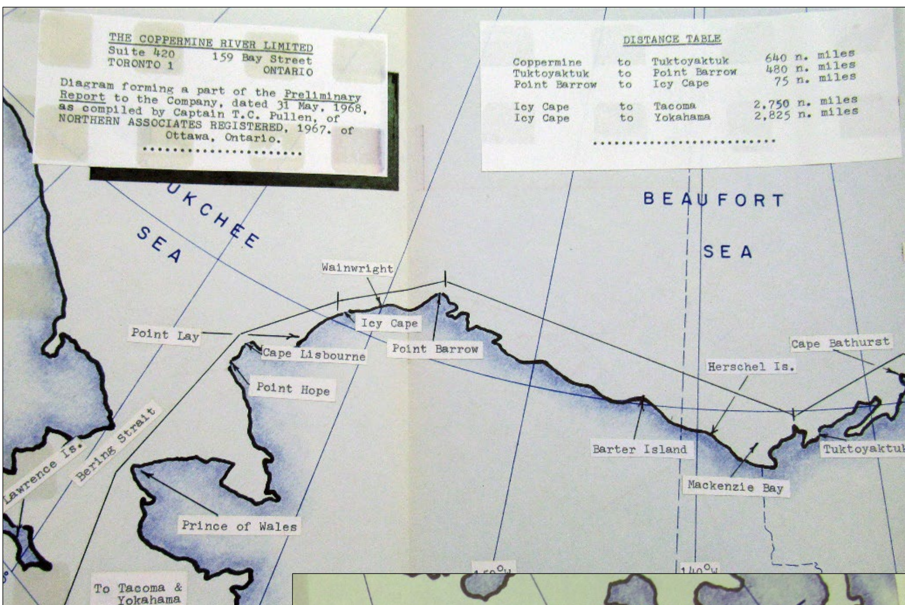
4. A diagram of the western Arctic is included to show the locations of the various places referred to in the text.

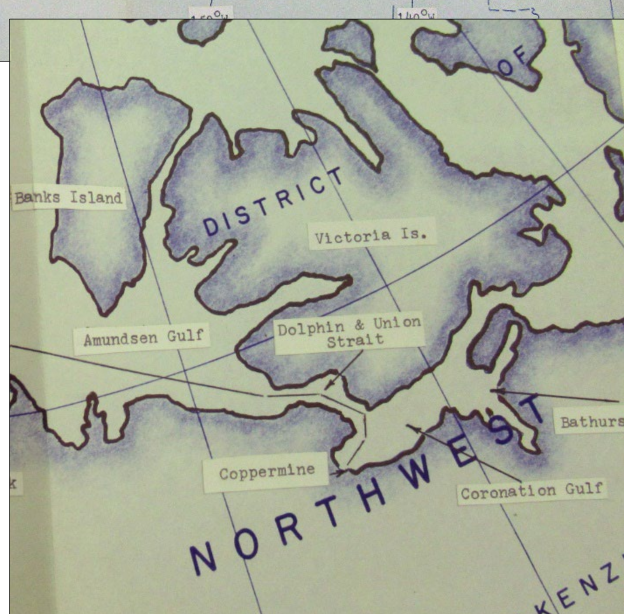
5. The validity of the assumptions, specially those relating to speed, may be questioned by some. There are those who hold to the view that an average speed of 7 knots in ice is high but considering that the period being considered spans the 2 best months of the year for the movement of shipping, the speed selected seems a reasonable one.

6. Part II is a cursory look at the cost of moving fuels to Coppermine and the Hope Lake area via Northern Transportation Company's facilities. However, until a realistic figure can be established for the requirements for fuels and freight for an established operation at Hope Lake, it is virtually impossible to arrive at transportation costs which are meaningful. In any event, the Northern Transportation Company has indicated that special rates would be negotiated once tonnages can be calculated together with the duration of the contract by the Coppermine River Limited.

7. Arrangements are in hand for the writer to embark in the Canadian Coastguard Ship CAMSELL during that vessel's annual Arctic patrol this year. She departs Victoria, B.C., 5 July and it is intended to embark in the vicinity of Point Hope about 15 July for passage to the Coppermine permitting a first-hand survey of conditions in the western Arctic.

8. The writer also plans to undertake ice reconnaissance flights, in company aircraft and, if it can be arranged, in the Department of Transport's long range ice reconnaissance machines operating in that area.





PART 1

The Shipment of Copper
Concentrates by Sea from
the Coppermine.

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ASSUMPTIONS

1. The following assumptions have been made to permit an examination of this particular aspect of the shipping problem:

a. Along the sea route between the Coppermine and Icy Cape (see diagram), vessels will encounter varying conditions of sea ice, compelling them to travel at reduced speed. Because of this fact an average speed of 7 knots has been used to calculate time on passage.

b. From Icy Cape southward, to Tacoma or Yokahama, the route will be free of ice for the period under consideration and a speed on passage of 14 knots has been used to calculate times.

c. Delays caused by fog and storms have not been taken into account.

d. A turn-around interval of 3 days has been used for loading at the Coppermine and 2 days for unloading at Tacoma and Yokahama.

e. The earliest date an ore carrier should pass Icy Cape, inbound to the Coppermine for ore, would be 1 August.

f. The latest date on which a ship laden with ore should depart the Coppermine would be 1 October.

g. Transhipment of ore at some intermediate port has not been considered.

h. That shipping by sea is the agreed means by which the product will be moved from the Coppermine.

Note: A 'voyage' is a round trip while a 'passage' is a one-way journey. Speed 'on passage' is the same as speed 'en route.'

FREEZE-UP & BREAK-UP - SOME GENERAL OBSERVATIONS

1. General. The waters of the Beaufort Sea are dominated most of the year by winter ice and polar pack which includes heavy drift ice from the Arctic Ocean. Of lesser importance is the fast ice which covers the bays and fringes the shores of Northern Alaska for at least 8 months of the year.

2. Generally August and September are the months with the least ice. During this period the Northwest coast of Alaska should be free of fast ice northward to Point Barrow and eastward to Herschel Island. However the polar pack, which lies off the coast at varying distances depending upon conditions, can advance onto the shore at any time.

3. The existence of an open coastal waterway in the Chukchi and Beaufort Seas is strongly dependent upon favourable winds. Easterly and southerly winds hold the pack off the coast, whereas northerly and westerly winds force the floes against the shore.

4. Young ice forms along the margins of the drift ice and in any open water that may exist between the pack and coast by mid-September.

5. Ice formation and growth proceed rapidly in early October, and shipping is usually not feasible north of Bering Strait after about mid-October.

Note: The foregoing information is based on material published by the U.S. Navy Hydrographic Office.

6. Freeze-Up To support selection of 1 October as signalling the end of navigation in the western Arctic, insofar as the Coppermine operation is concerned, the following U.S.N. data were consulted:

Freeze-Up

Location	Earliest Date	Latest Date	Average Date	Years Data
Cape Prince of Wales	8 Oct	24 Dec	21/25 Nov	10
Point Hope	21 Nov	1 Dec	25/29 Oct	1
Point Lay	15 Oct	27 Nov	7/11 Nov	4
Wainwright	16 Sep	25 Oct	3/7 Oct	8
Point Barrow	3 Sep	19 Dec	1/5 Oct	26
Barter Island	24 Sep	24 Sep	---	1

7. Break-Up Similarly, the choice of 1 August as the earliest recommended date for vessels to pass Icy Cape, inbound for the Coppermine, is based in part from the following data from the same source:

Break-Up

Location	Earliest Date	Latest Date	Average Date	Years Data
Cape Prince of Wales	15 May	17 Jun	23 May) 3 June)	10
Point Hope	19 Jun	8 Jul	25 Jun) 1 Jul)	2
Point Lay	20 May	9 Jun	11/17 Jun	3
Wainwright	7 Jun	26 Jul	23/29 Jun	8
Point Barrow	15 Jun	22 Aug	17/23 Jul	24
Barter Island		----- no date -----		

DISTANCES

1. The following distances (in nautical miles) have been established for reference purposes:

Coppermine	to	Tuktoyaktuk	640
Tuktoyaktuk	to	Point Barrow	480
Point Barrow	to	Icy Cape	75
Icy Cape	to	Dutch Harbour	1,020
Dutch Harbour	to	Seattle	1,700
Seattle	to	Tacoma	20
Icy Cape	to	Yokahama	2,825
Yokahama	to	Tokyo	18
Yokahama	to	Seattle	4,245

2. The distances which are particularly relev[a]nt to this report are as follows:

Coppermine to Icy Cape (i.e. that portion of the route involving ice navigation)	1,200
Ice Cape to Tacoma	2,750
Icy Cape to Yokahama direct	2,825

CONSIDERATIONS OF TIME & DISTANCE

1. The time required to cover the distance from the Coppermine to Icy Cape at 7 knots, thence to Tacoma at 14 knots, a total distance of 3,950 miles, is 15 days.

2. The time required to steam from the Coppermine to Icy Cape at 7 knots, thence to Yokahama at 14 knots, a total distance of 4,025 miles, is 16 days.

3. Taking into account 3 days for loading at the Coppermine loading facility, plus another 2 days for unloading and turn-around at either Tacoma or Yokahama, we have a voyage cycle of 35 days for the Coppermine/Tacoma run and 37 days for the Coppermine/Yokahama run.

4. It has already been assumed that the opening of navigation for ore carriers can be taken to be 1 August, and that the closing date would be 1 October. Therefore, to take full advantage of the brief shipping season, a vessel or vessels should be off Icy Cape by 1 August ready to make a move into the ice-littered waters leading to the Coppermine.

5. Unless break-up conditions were far advanced, it would be unwise to attempt an earlier entry than 1 August. To do so would be to risk crippling damage which could endanger the success of the shipping operation later when conditions became, as they inevitably do, truly favourable.

6. By 1 August, ice reconnaissance flights in the area are scheduled more often and much data on ice conditions have been accumulated. This information can make a substantial difference to ships in the area in locating the safest, easiest and most expeditious route to their destination.

<u>COPPERMINE/TACOMA SCHEDULE</u>

1. From the foregoing information a schedule for ships operating between the Coppermine and Tacoma, near Seattle, could work out along the following lines:

Place	Arrive	Depart	Remarks
Icy Cape	--	1 Aug	For Coppermine
Coppermine	7 Aug	11 Aug	Loading
Icy Cape	17 Aug	17 Aug	Into Open Water
<u>Tacoma</u>	25 Aug	28 Aug	Unloading
Icy Cape	4 Sep	4 Sep	Ice Zone
Coppermine	11 Sep	15 Sep	Loading
Icy Cape	22 Sep	22 Sep	Into Open Water
<u>Tacoma</u>	30 Sep	--	Unloading

COPPERMINE/YOKAHAMA SCHEDULE

2. And for ships operating between the Coppermine and Yokahama direct a schedule could work out as follows:

Place	Arrive	Depart	Remarks
Icy Cape	--	1 Aug	For Coppermine
Coppermine	7 Aug	11 Aug	Loading
Icy Cape	17 Aug	17 Aug	Into Open Water
Yokahama	26 Aug	29 Aug	Unloading
Icy Cape	6 Sep	6 Sep	Ice Zone
Coppermine	13 Sep	17 Sep	Loading
Icy Cape	24 Sep	24 Sep	Into Open Water
Yokahama	3 Oct	--	Unloading

3. The earliest dates on which a ship could return to Icy Cape, either from Tacoma or Yokahama, bound for the Coppermine for a third load, would be approximately 17 and 21 October respectively. Freeze-up is by then too far advanced for a ship to get into the Coppermine, load and get out.

4. If the criteria used in drawing up these schedules are fairly representative of conditions as they exist, then 2 voyages could be completed each year by one ship. Should they err on the optimistic side, then only 1 voyage could be assured while in rare circumstances, a third voyage might be possible. This last event might become possible during those years when break-up occurred particularly early, freeze-up was delayed and ice conditions during the season were specially propitious.

5. If turn-around times could be speeded up, if speeds on passage could be increased for the run through the ice zone (now scheduled at 7 knots) and for the ocean passages (at 14 knots) then a third voyage might come closer to reality. But at the moment this is all conjecture. Until the writer has visited the area and got an 'on the spot' assessment, the assumptions already made seem reasonable ones in the circumstances.

SOME REMARKS ON THE EFFECT OF ICE CONDITIONS ON SHIPPING DURING THE NAVIGATION SEASON.

1. Throughout the year the greater part of the Beaufort Sea is filled with the heavy ice floes and pack ice typical of the Arctic Ocean. The mainland coast from Point Barrow eastward to Amundsen Gulf and the west coast of Banks Island lie exposed to this moving pack.

2. Westerly winds bring the Beaufort Sea ice in to the land and if they prevail throughout much of the summer, it will be a bad ice year when even shallow draft vessels may have great difficulty in forcing a passage along the coast.

3. Where shallow water extends seaward for miles, as it does off much of the north coast of Alaska, grounded floes can be encountered throughout the season. Medium and giant floes, particularly those which are heavily hummocked, often ground in 10 fathoms of water, some in 9 fathoms and some in 8 or less.

4. When grounded floes are encountered and the ice fields thrust against them on their seaward side it will become necessary for a ship's master to decide whether to try and run on the shore side of the grounded floes or work the ice on the seaward side. These grounded floes can be good or bad. They are good if there is onshore pressure and a vessel is on the shore side of a floe grounded in an area where the bottom gradient causes the floe to ground some distance from the beach. Then, if there is manoevring room and 6 or 7 fathoms on the shore side, there will be some protection and if the draft of the vessel is not too great, it may be possible to navigate along the shore inside this protection for long distances.

5. Also, on some sections of the Alaskan coast, the bottom gradient between the 4 fathom and 10 fathom curves is so steep that the heavy floes may be very close to the 4 fathom curve and a vessel of over 20 feet draft cannot remain inside them. On such sections of the coast deep draft vessels will be compelled to move further offshore into ice which may be under pressure from onshore winds.

6. In most years the ice is too close to the north coast of Alaska to permit an ice-free route direct from Point Barrow to Cape Bathurst. It thus becomes necessary to edge along the coast between the ice and the minimum safe depth in which the vessel can navigate, following the least hazardous route which can be found. With deep draft vessels and ice near the shore, it is probable that the best route will be inside the 10 fathom curve from Point Barrow to about Longitude 150° West, and then proceed outside the 10 fathom curve.

7. Medium and shallow draft vessels can follow the inshore route almost as far as Barter Island, taking advantage, in places, of the shelter afforded by the islands lying off parts of this coast.

Note: The foregoing is a paraphrased extract from the Pilot of Arctic Canada, Volume III First Edition.

TRANSPORT CONFIGURATIONS

1. Having considered factors of time and space in the shipment of concentrates by sea, and having introduced the influence of ice and climate on such an operation, all in the briefest terms, it might be helpful to take account of the various types of vessel which could be employed to transport the concentrates and do it economically, adequately and reliably.

2. The following could be considered:

a. Ice-strengthened Conventional Shipping.

i. Ships in this category, built and strengthened for ice navigation to standards laid down by such classification authorities as Lloyds would, depending upon their size and displacement, be suited for this trade.

ii. One such ship, with a deadweight capacity of 15,000/20,000 tons, could probably handle the output of concentrates in 2 voyages. While an attractive prospect such a plan would be risky should the vessel suffer damage from ice or otherwise be delayed.

iii. The disadvantages of using such a large and unwieldy ship in those waters are very real. 3 or 4 smaller ships, displacing about 5,000 tons, would be more suited to western Arctic waters, are certainly more manoevrable, draw less water but are, dollar for dollar, more expensive to build and to operate than one large ship with the same total lift capability.

b. <u>Specially Configured Shipping Designed for this Trade</u>.

Here reference is being made to ships already ice-strengthened but with the addition of proven icebreaking features. An example of this would be the fitting of an icebreaking bow, one type of which has already proved itself in ice, enabling ships to operate in ice of certain types hitherto considered to be impenetrable to vessels not so equipped.

c. <u>Conventional Tug & Barge</u> (Towing Mode)

This method would be perfectly practicable in open water in the Arctic between Icy Cape and the Coppermine. In ice, however, the tug simply hauls the barge close up to her stern and the two proceed as a unit in this fashion. While this is effective in certain conditions, there are newer and better methods to be considered.

For that portion of the run which lies south of Icy Cape, the tug would tow the barge in a conventional manner at long stay and ... nothing new is involved here.

<u>Note</u>: With reference to barge operations there are, however, substantial advantages in considering their use in lieu of ships for this type of operation, but chiefly in the 'pusher mode' rather than the 'towing mode.'

Barges do not draw anywhere near as much water as a ship with a similar capacity. Indeed, drawing so little water, depending of course upon the design and the load to be carried, they can exploit the inshore routes and the passages behind the coastal islands already referred to and which are denied to deep draft ships. In this way the heavy ice floes lying grounded further offshore can be avoided and faster passage times achieved.

Barges could be spotted for loading while the towing vessel was profitably employed elsewhere.

Barges could winter over at Coppermine so that they could be used for stockpiling thus saving an additional handling process. They would also be ready for moving earlier the following year as there would be no delay for loading.

Tug and barge operations have been, and will obviously continue to be, the norm for moving cargoes in the western Arctic and this form of transportation must have compelling advantages which should be thoroughly examined.

d. Specially Configured Tug & Barge (Tow Mode & Pusher Mode)

A barge of suitable capacity, and including a specially ice-strengthened hull with icebreaking qualities, could handle the concentrates from the Coppermine very effectively. Teamed with a powerful tug this combination would move through ice with the tug acting as a pusher. On passage in the open sea, tug and barge would change positions with the former reverting to a towing mode.

Certainly this approach to the matter, together with other promising solutions, bears investigation.

e. Specially Configured Articulated Shipping

Specially configured articulated shipping is a new scheme using one power plant as prime mover for each component of a fleet of cargo-carrying elements in rotation. These elements can be used for storage at terminal and others for transportation to final destination as desired.

This category must, of course, in its design be compatible with all the environmental factors involved in the trade including its employment during the period it is not engaged in carrying copper concentrates.

Barges displacing 25,000 tons, lifting 18,000 to 20,000 tons deadweight, with a locked-in pusher tug, would certainly qualify for closer study.

3. The following categories cannot, for the reasons stated, be considered:

a. Cargo-carrying Submarines

Cargo-carrying submarines, however propelled, large enough to carry a profitable payload would draw too much water to merit consideration for operations in the shallow waters of the western Arctic.

b. Conventional Shipping

Bulk carriers of suitable size would be available but such vessels are not strengthened for ice navigation. If they are large ships then they lack manoevrability and draw too much water. All of them would be extremely vulnerable to crippling ice damage.

Indeed, being so manifestly unsuited to the task, marine insurance rates would be prohibitively high.

4. Conclusion

a. The alternatives which have been listed have been done so after consultation with NORTHERN ASSOCIATES to ensure no aspect has been left unexplored. The prospects which have been mentioned are technically feasible using no new techniques but using methods which are in use to-day.

b. Only passing reference has been made of the need to have profitable alternative employment for whatever vehicle is used during the off-season period when the Coppermine operation is shut down insofar as shipping is concerned. There are several possibilities, one of which might be, for example, the shipment of coal from British Columbia to Japan.

c. It is hoped that sufficient emphasis has been placed on this segment of the overall operation to highlight the need for a more thorough system study.

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PART II

The Cost of Shipping Fuels and Freight into the Coppermine - A Brief Survey.

FUELS & FREIGHT INTO THE COPPERMINE/HOPE LAKE AREA.

GENERAL OBSERVATIONS

1. Much useful information was supplied by the Edmonton and Ottawa offices of the Northern Transportation Company. The Imperial Oil Company, here in Ottawa and also the Toronto Head Office, supplied figures relative to their operation at Norman Wells. The Standard Oil Company of California have been approached for information relating to product price and availability at various locations in Alaska but to date no reply has been received.

2. Transportation charges for bulk quantities of freight and fuels, such as would be required by an operating mine at Hope Lake, would be negotiated and would be substantially less than those quoted in the Northern Transportation Company's Freight Tariff.

3. The Northern Transportation Company has indicated a need to know in good time the scope and duration of a possible freighting commitment to the Hope Lake area so that preparations to handle it can be put in train.

4. The routes by which freight and fuels could be shipped into the Hope Lake area include:

   a. Fixed wing aircraft from points south. See Note 1.

   b. By winter tote road from railhead at Hay River via Great Slave Lake, the Camsell River and Great Bear Lake using trailer motor transport. See Note 1.

   c. By ocean freight, through Alaskan waters, to Coppermine.

   d. By tug and barge down the Mackenzie, thence coastwise to Coppermine. See Note 2.

e. By tug and barge across Great Bear Lake thence overland to Hope Lake. See Note 2.

Note 1. a & b above are not considered to fall within the scope of this preliminary report.

Note 2. Appendices I, II & III tabulate the costs of Diesel and Aviation Fuels by this route.

5. For the route across Great Bear Lake the writer was advised by Northern Transportation Company to use the rates quoted for the run from Norman Wells to Port Radium even though laden barges would probably land in the vicinity of Fort Confidence (Dease Arm) or Hornby Bay.

6. Prices and quantities for fuels, and their availability, in Alaskan ports are not yet available. In the case of Diesel fuel the price is unofficially understood to be 10¢ a gallon at Dutch Harbour and Kodiak.

7. The price of Esso Marine Diesel fuel in Vancouver is understood to be 15¢ a gallon for fuels intended for domestic use and not intended for export.

8. Once the annual quantities required for resupply of the mining operation become known, and once the shipping problem has been clarified, then a useful study can be undertaken to determine the best method of moving fuels and freight into the Hope Lake area.

APPENDIX I

	DIESEL FUEL (See Note 1 below) By Tug & Barge from Norman Wells down the Mackenzie thence by sea to Coppermine - 1170 miles (See Note 2 below)		Via Fort Norman & Great Bear Lake thence overland to Hope Lake - 350 miles (See Note 3 below)	
	Bulk	Drummed	Bulk	Drummed
Price per gallon FOB Norman Wells	20.1¢	23.1¢	20.1¢	23.1¢
Northwest Territories Tax of 6¢ a gallon (See Note 4 below)	6¢	6¢	6¢	6¢
Transportation Charges per NORTHERN TRANSPORTATION COMPANY's Freight Tariff	33.2¢	49.5¢	20¢	30¢
	------	------	-----	------
Totals (Costs per gallon for quantities in excess of 25,000 gallons)	59.3¢	78.6¢	46.1¢	59.1¢

Note:

1. These prices are for DIESEL FUEL with properties of -30 Cloud and -40 Pour.
2. To these figures must be added the cost of moving fuel, from tidewater at Coppermine, 45 miles to Hope Lake.
3. To these figures must be added the cost of moving fuel, from touchdown point of the barges at the eastern end of Great Bear Lake, to Hope Lake, about 50 miles.
4. The tax on fuels used in vehicles is 6¢ a gallon. For use other than in vehicles or for heating purposes, the tax drops to 3¢ a gallon.
5. Calculated at 10 pounds per gallon.

APPENDIX II

AVIATION FUEL (100/130)

	By Tug & Barge down the Mackenzie (see preceding sheet)		Via Great Bear Lake (see preceding sheet)	
	Bulk	Drummed	Bulk	Drummed
Price per gallon FOB Norman Wells.	56.5¢	61.5¢	56.5¢	61.5¢
Northwest Territories Tax of 1½¢ a gallon	1.5¢	1.5¢	1.5¢	1.5¢
Transportation Charges per Northern Transportation Company's Tariff	33.2¢	49.5¢	20¢	30¢
	--------	-------	------	------
Totals (Costs per gallon for quantities in excess of 25,000 gallons)	91.2¢	$1.12	78¢	93¢

APPENDIX III

AVIATION FUEL (80/87)
(Light Aircraft)

	By Tug & Barge down the Mackenzie (see preceding sheet)		Via Great Bear Lake (see preceding sheet)	
	Bulk	Drummed	Bulk	Drummed
Price per gallon FOB Norman Wells	54.5¢	59.5¢	54.5¢	59.5¢
Northwest Territories Tax of 1½¢ a gallon	1.5¢	1.5¢	1.5¢	1.5¢
Transportation Charges per Northern Transportation's Tariff	33.2¢	49.5¢	20¢	30¢
	--------	-------	------	-------
Totals (Cost per gallon for quantities in excess of 25,000 gallons)	89.2¢	$1.10	58¢	91¢

STANDARD OIL COMPANY OF CALIFORNIA,
WESTERN OPERATIONS, INC.
1318 FOURTH AVENUE SEATTLE WASHINGTON 98111

May 22, 1968

Northwest Associates Registered
c/o Mr. T. C. Pullen
1306 Chattaway Avenue
Ottawa 8, Ontario, Canada

Dear Mr. Pullen:

Thank you for your letter dated May 8, 1968.

Please note the attached sheet where you will find most of your questions answered. The sheet covers our port locations that could meet your requirements. A few items should be pointed out in using these locations:

(a) This would be an export shipment and we would have to issue an export declaration on each shipment which includes showing consignee and actual destination.
(b) U. S. Customs representatives are at Ketchikan and Kodiak only - any other loading points would require special arrangements between customer and U. S. Customs, relative to vessel's clearance as well as issuance of export declarations. This can be handled, but will require advance notice.
(c) From a transportation and supply standpoint, we recommend Ketchikan, Dutch Harbor, or Valdez.

As you know, Mr. Pullen, shipping by water presents timing problems as there are only limited periods the Northern waters can be sailed. This being the case, may we also suggest the possibility of air freighting it from our supplier in Whitehorse (Yukon Territory). If this inland air route fits into your plans, our distributor can be reached by writing, White Pass & Yukon Route, 510 West Hastings Street, Vancouver, B.C.

Thank you again for the opportunity to serve you, and if any further questions arise, please contact us.

Sincerely,
CHAS. SCHLEGEL
By *[Signed: W.M. Samuel]*

Product	Ketchikan	Dutch Harbor	Kodiak	Valdez
##H/F #1 (-30° Cloud -45° Pour)	$.183	$.201	$.194	$.204
AvGas 80/87 $.04 Fed. .03 State * .08 State (Non-Aircraft)	$.322	$.338	$.331	$.331
AvGas 100/130 Same Av. Tax as 80/87	$.372	$.388	$.381	$.381
Motor Gasoline (Reg. Grade) $.04 Fed. .08 State	$.326	$.342	$.335	$.335
Used Light N.R. Bbls. (Subject to availability)	$.14 gal.	$.14 gal.	$.14 gal.	$.14 gal.
# Buy Back - Usable Bbls. (At our option)	$3.00 ea.	$3.00 ea.	$3.00 ea.	$3.00 ea.

We are quoting H/F #1 in order to meet your Pour and Cloud Point Specs. The quoted prices are ex-tax; however, if used in D/F applications, the State of Alaska requires .08 MFT be included. Sales for export is exempt of .08 MFT if exportation is made by Common Carrier; therefore, it is necessary for you to contact the Alaska State Revenue Service to figure your tax status.

NOTE - ALL PRICES (U.S. DOLLARS) ARE POSTED PER PRICE BOOK
ALL GALLONAGE - U.S. GALLONS

Doc. 5: T.C. Pullen, Preliminary Report to Pacific Petroleums Limited: On the Practicability of Conducting Drilling Operations in, and Supply Operations to and from, the NORWEGIAN BAY area of the ARCTIC, January 1969.

HBC Archives H2-141-1-3 (E 346/1/12)

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P R E L I M I N A R Y   R E P O R T

T O

P A C I F I C   P E T R O L E U M S   L I M I T E D

On the Practicability of
Conducting Drilling Operations in,
and Supply Operations to and from,
the NORWEGIAN BAY area of the ARCTIC.

Prepared By

NORTHERN ASSOCIATES REGISTERED

of Ottawa and Montreal

January 1969

....

GENERAL CONCLUSIONS OF THE CONDUCT OF OPERATIONS IN NORWEGIAN BAY.

Generally speaking, the key to successful Arctic shipping operations is determined by the dates of "break-up" and "freeze-up" which are of all-consuming interest to planners and mariners alike. But in the case of NORWEGIAN BAY, there really is no navigation season as such, indeed "break-up" if it occurs at all, is confined to about three areas defined elsewhere in this Report. "Break-up" is followed so quickly by "freeze-up" that the interval between the two for shipping activities is brief indeed compared to more salubrious Arctic areas.

In good ice years, icebreakers will find conditions relatively easy for their resupply run across the bay en route to EUREKA. Nonetheless there will always be ice of one sort or another to battle through or circumvent. In bad ice years this transit will become a non-stop slugging match. It may even transpire that the breaker will be compelled to turn back and wait for better conditions if the age of the season permits.

It becomes, then, a matter of turning this state of affairs to the company's advantage. This can be accomplished by exploiting this ice cover and using the brief navigable interval between "break-up" and "freeze-up" when access to the bay by shipping becomes feasible for re-supply and the re-siting of equipment mounted in vessels. Our concern, then, becomes: a. Determining every year at what date the process of "freeze-up" has advanced sufficiently to permit drilling operations using the ice as a platform: b. How long such a platform exists for such operations to carry on with safety : c. Finally, at what date does the onset of "break-up" threaten operations so that, for safety's sake, they should be temporarily suspended.

This, then, is the basis of our report to the company. It is clear that if drilling operations are to be undertaken in the area, they must be accomplished during the Arctic winter and that the brief summer navigation period (whether it be easy or difficult) be used for the movement of whatever shipping is required into the area. This report attempts to define these periods.

Strange as it may seem, the longer the ice remains in the bay the better this should be for successful operations. Except for re-supply by sea and the relocation of floating platform(s) in open water, it would be preferable if there was no "break-up" at all because this is when the dangers are greatest.

Once "break-up" is in progress, or has been completed, the area is extremely vulnerable to invasions of pack ice being driven in from adjacent areas, particularly MASSEY SOUND. Powerful forces can be at work under such circumstances because man-made structures cannot withstand the pressures of OLD ICE, unless they are specially built.

The danger, therefore, is that drilling rigs may be caught on the ice by the progression of "break-up" or a rig-carrying vessel, anchored in open water, may be caught before the [inexorable] advance of wind-driven pack piling in through BELCHER CHANNEL, MASSEY SOUND or SVERDRUP CHANNEL. No anchors will hold under these latter circumstances and the only recourse would be to retreat and try to find a refuge. Logistic operations must be arranged so that equipment would never be exposed to such dangers. Likely it will be necessary to sacrifice drilling time just before break-up rather than risk losing valuable equipment by continuing operations when all the signs indicate trouble in the offing.

SUMMARY OF ICE CONDITIONS

Usually by 1 November "freeze-up" in the bay has progressed to the stage where the entire area has become frozen over and the ice so to speak has "set" for the winter. At this time the ice will have attained a thickness of approximately two feet and by 1 January a minimum of four feet.

This ice will continue to thicken (thus becoming harder) during the seven months from January to May inclusive. This ice cover is thick and strong enough to serve as a platform, depending on the distribution of load, and can be considered to be completely stationary except in the vicinity of HELL GATE and CARDIGAN STRAIT.

With warming temperatures, and under the benign influence of sunshine 24 hours a day, puddling begins in June and there are at least two factors which could disrupt 'on the ice' activities. Firstly, there is the weakening of the ice cover by this warming trend possibly endangering men and equipment using it as a platform. Secondly, the puddling process makes movement over the ice difficult and, eventually, dangerous because the thaw holes become progressively broader and deeper. June and July, therefore, cannot be relied upon for safe work on the ice.

The rotting, thawing and partial break-up process continue apace through August and into September. This latter month is the period when, in a good year, conditions are best for shipping operations. Here the open water areas north of HELL GATE, south of EUREKA SOUND and north of the [GRINNELL] PENINSULA reach their maximum extent, each for a particular reason. September, therefore, is the month for re-siting whatever vessel is used for the operation. Depending upon whatever location is desired, it may be necessary to seek icebreaker assistance to help the vessel move through the ice to reach its next location. Icebreaker assistance may be required in a good year but assistance would be essential in most areas of NORWEGIAN BAY during a bad ice year.

October and November are an "in between" period in the ice regime of the bay. "Freeze-up" is well under way but, because of the disrupting effect of the fall gales and other factors such as thin ice, the normal ice cover cannot be used to support a load.

Generally, the average yearly ice conditions in NORWEGIAN BAY are as follows:

December to May inclusive	Assured safe use of the ice cover for operations
June & July	The onset of "break-up" & ice cover not available for use.
August & September	"Break-up" in August (if it occurs) with whatever open navigation is possible in September depending upon conditions.
October & November	"Freeze-up" under way but not sufficiently far advanced to permit "on the ice operations" without risk.

There is, therefore, a period of six months minimum for "on the ice" operations during which period the sea ice cover will remain stationary except for minor horizontal movement. If there is any horizontal movement it is both local in nature and small in extent (probably not more than six feet) as otherwise ridging would be apparent.

PART I.

Being a Description of the
Behaviour of Ice in all its forms,
together with matters related to
Meteorology, Climatology, etc.

DEFINITION OF THE AREA COVERED BY THIS REPORT

The area of NORWEGIAN BAY embraced by this Preliminary Report is bounded on the west by LOUGHEED ISLAND, on the east by the BJORNE PENINSULA, on the north by AXEL HEIBERG ISLAND and on the south by CARDIGAN STRAIT.

SEA ACCESS TO NORWEGIAN BAY

For more than 20 years, icebreakers of the United States Coastguard and the Department of Transport have been carrying out re-supply missions to the weather station at EUREKA in SLIDRE FJORD. The route followed by these ships is the best for the purpose and is the only one that can be recommended to gain access to NORWEGIAN BAY over the long haul.

This preferred route, after following the customary track up the west GREENLAND coast to MELVILLE BAY to skirt the BAFFIN BAY pack, trends west across the bay to JONES SOUND by way of LADY ANN STRAIT or GLACIER STRAIT, depending upon ice conditions. Entry into NORWEGIAN BAY proper is then achieved either by HELL GATE or CARDIGAN STRAIT. Whichever route around NORTH KENT ISLAND is decided upon will be as a result of ice conditions then prevailing in those two passages.

Every year, as a matter of established routine, an icebreaker attempts a re-supply voyage to EUREKA via this route. It is suggested here that PACIFIC PETROLEUMS should consider timing any sealift operation into NORWEGIAN BAY to co-incide with this mission, thus benefitting from an icebreaker escort right into the bay.

This icebreaker re-supply mission is usually scheduled for the fourth week in August, or thereabouts, when conditions for navigation are good but on occasion it can take place later than this. On at least one attempt in the past 20 years, ice conditions in NORWEGIAN BAY were alleged to have been so bad that the icebreaker was compelled to turn back, her mission unfulfilled. However, the most favourable ice conditions in NORWEGIAN BAY exist during September and up to "freeze-up" in mid-October.

There is another sea route which should be mentioned. It is by way of WELLINGTON CHANNEL, QUEENS CHANNEL, PENNY STRAIT and BELCHER CHANNEL, but ice conditions usually encountered here, especially in PENNY STRAIT and BELCHER CHANNEL, seldom permit an easy passage. The writer has personal knowledge of this having attempted this route as Commanding Officer in H.M.C.S. LABRADOR in 1957 and was obliged to retreat because of an impenetrable wall of polar ice in the vicinity of NORTHUMBERLAND SOUND in PENNY STRAIT. As a generalization, it could be stated that if ice conditions are easy via this route then they will be even easier by way of JONES SOUND.

For shipping which is routed to NORWEGIAN BAY by way of BAFFIN BAY, the shorter route is obviously through JONES SOUND. Also the route is better charted and for the most part the only ice to be reckoned with in JONES SOUND is ONE YEAR ICE.

In the case of the alternative route via WELLINGTON CHANNEL-BELCHER CHANNEL, it is certain that MULTI-YEAR ICE will have to be coped with at some point along the way.

Because of ice conditions there are no other surface sea routes into NORWEGIAN BAY.

Doc. 6: T.C. Pullen, Remarks of the Second Voyage of the S.S. MANHATTAN to the Arctic, April - June 1970.

HBC Archives H2-141-1-3 (E 346/1/14)[1]

Remarks of the Second Voyage of

the S.S. MANHATTAN to the Arctic

April - June, 1970

Introduction

Humble Oil & Refining Company's giant icebreaking tanker, the S.S. Manhattan, sailed from Newport News, Va., May 3, 1970, on her second Arctic voyage. Two days later, off Halifax, N.S., she rendezvoused with the Canadian Coast Guard icebreaker Louis S. St. Laurent and together the two ships proceeded, first east about Newfoundland and then north, en route to Baffin Bay.

While Manhattan's first Arctic voyage last year was, in most respects, a success, insufficient test data were garnered to permit a final decision to be made respecting the feasibility of giant tankers operating year-round through the Northwest Passage. At the time the ship undertook her first voyage, ice conditions were unquestionably at their easiest. Much of the level First-year ice had melted and that which remained was in such an advanced state of dissolution as to be useless for test purposes. There was no shortage of rough and hummocky Second-year and Multi-year ice but such ice was not conducive to meaningful testing. What was particularly desired was a sheet of smooth level ice of uniform thickness. Such conditions only obtain in the period January-

[1] Editors' note: This report actually appeared as volume 2 of Pullen's *Feasibility Study: Arctic Transportation to Milne Inlet, Baffin Island; Volume I, Ship Data and Manhattan Second Voyage*, Prepared for Baffinland Iron Mines Ltd., 1970. The first volume is reproduced as Doc. 6, but we have placed this section first to highlight how the 1970 voyage of *Manhattan* influenced Pullen's appraisal of feasibility for Arctic transportation.

May before the full impact of the summer melt period, under the influence of 24 hours of daylight is felt. Hence the justification for a second test voyage.

Had there been no voyage in the spring of 1970 it would have been pretty reliable evidence that the results obtained in 1969 were insufficiently encouraging to justify further investigations on the tanker solution. But what test results which [*sic*] were obtained, and the overall performance of the ship in heavy ice, made it sufficiently encouraging to proceed with further testing.

Summaries of ice conditions encountered by the <u>Manhattan</u> during her second voyage are included at the back of Volume III of the Feasibility Study.

Conclusions from the 1969 Arctic

Voyage of the Manhattan

As a result of her 1969 voyage Manhattan demonstrated that:

a. Giant ships can be the means of moving bulk cargoes out of the Arctic, especially the eastern half.

b. Such ships, suitably designed and manned for work in ice, must be their own icebreakers. If nothing else, Manhattan showed that giant vessels must be capable of proceeding in ice on their own without icebreaker escort.

c. Icebreakers, as we know them now, will never break ice in the grain of (ahead of) giant ships because of the very real danger of them being run down. Their role will, instead, be to supply help in the vicinity of the bulk carriers on those hopefully rare occasions when they get into difficulties.

d. The larger the bulk carrier the better she will be as an icebreaker. Mass and momentum are truly effective in ice. A deadweight tonnage of 225,000 would be more than twice as effective as Manhattan was at half that figure, providing of course that sufficient power is installed.

e. To be successful in ice, giant bulk carriers will have to possess very much more power (ahead and astern) than their more conventional brethren. They will also require a proven design for effective icebreaking (bow and hull) and be built to near true icebreaker standards to give them the necessary strength. A heeling (rolling) capability will be needed, also a helicopter deck at the stern, at least two radars (probably 3 cm and 10 cm), two depth finders, ahead-looking sonar if such an aid is practicable in ice, together with rudder protection and strengthened propellers.

Significance of Manhattan's Second Voyage

The route taken by the Manhattan on her second voyage was of considerable significance to Baffinland Iron Mines. She followed the same track which ore carriers bound for Milne Inlet would take, viz, from open water in the Atlantic, up the west Greenland coast to avoid the worst of the middle pack in Baffin Bay, thence across the top of the bay to Bylot Island. Once in Lancaster Sound the tanker attempted a penetration of Admiralty Inlet to the west of Navy Boa[rd] Inlet. Defeated there by heavy ridging she then essayed an entrance into Navy Board itself but again, bec[au]se of pressure and heavy ridging, was obliged to retreat. Circumnavigating Bylot Island the ship, still accompanied by her Canadian icebreaker, entered Pon[d] Inlet from the east.

It was in the entrance to this Inlet that ideal ice conditions for testing were found. Here was smooth, level ice which grew from two to six feet in thickness as the ships penetrated the inlet. It was crisp and hard, probably the hardest that First-year ice can attain. Snow cover varied from a few inches to more than a foot contributed to the useful performance data collected by the two ships.

Ice conditions became progressively more difficult as the Inlet was penetrated until the ships were seven miles east of Albert Harbour when it was decided to press on no further. Sufficient data were obtained by this time and there was little to be gained by continuing. The ice thickness at this location exceeded six feet.

While Manhattan had her problems in such conditions, it does not follow that a very much bigger and more powerful ship would have experienced difficulty. If giant ore carriers operated through these waters they would exert a substantial influence on the ice regime and during the period of freeze up would establish tracks through the area which is normally covered by fast ice which would remain open throughout the winter. This would ease the icebreaking task by a significant amount.

Conclusions Arising from the Second Manhattan Voyage

At the outset it must be iterated that Manhattan was a test vehicle and, in the opinion of her owners, a half scale model of the ultimate ship. For this reason, plus the fact that she was a conversion and not a true icebreaking tanker, it was inevitable she would encounter ice conditions which were more than she could handle. Her function was to obtain those data needed to define just how much power is required to force a passage through the types of ice to be encountered in the Northwest Passage, and to determine what sort of hull form and icebreaking bow would best enable a suitably powered ship to do this on a regularly scheduled basis year-round.

With the foregoing in mind it is possible to conclude the following as a result of the second voyage:

a. The ice conditions met, and this was expected, were entirely different from those experienced in 1969. On the latter occasion conditions were at their easiest, there was the maximum amount of open water and summer melt had wrought its greatest effect. The ice types which caused the most problems for the tanker were old hummocked and ridged floes of various sizes and thicknesses. It is probably fair to state that in 1969 it was the amount of ice and its thickness that were her chief problems. On the other hand, in 1970, her chief difficulty was the hardness of the ice plus the fact that it was 10/10 in extent. This latter fact meant there was no place for the ice to be pushed other than under the ship or on top of the unbroken ice on either side of her bow as she advanced. To do this she did not have enough power.

b. Pressure was another problem. When pressure came on the ice, as it did off the Greenland coast when northbound, off the entrance to Navy Board Inlet and east of Pond Inlet just before the ships headed south, the two vessels experienced trouble and on occasion were quite unable to move. There was absolutely no risk to the hulls of the ships on account of ice pressure but they lacked the power to overcome its influence.

c. In a given thickness of ice the tanker made less progress through the hard, crisp, May/June ice than she did through the rotting September/October ice of last year.

d. The snow cover encountered this year appeared to cause more friction than last September and October when much of it had either melted or was saturated with melt water. In 1970 it retarded the ship's advance robbing her of power needed to break ice.

e. Manhattan would never have got as far as she did without the help of the St. Laurent. The reverse is also true. The master of the icebreaker was of the opinion that in the ice conditions they had to contend with, especially off the west Greenland coast when northbound, the greater size and power of the St. Laurent was essential (14,000 tons and 24,000 SHP). He went on to state that the John A. Macdonald (9,000 tons and 15,000 SHP) would not have been able to make it.

f. Lancaster Sound and Barrow Strait were completely ice covered with extensive ridging and hummocking. Locked in this were various ice island fragments, bergy bits and small icebergs. There was little doubt that Manhattan was better employed testing

in Pond Inlet engaged in collecting excellent performance figures than in attacking the jumbled ice further west.

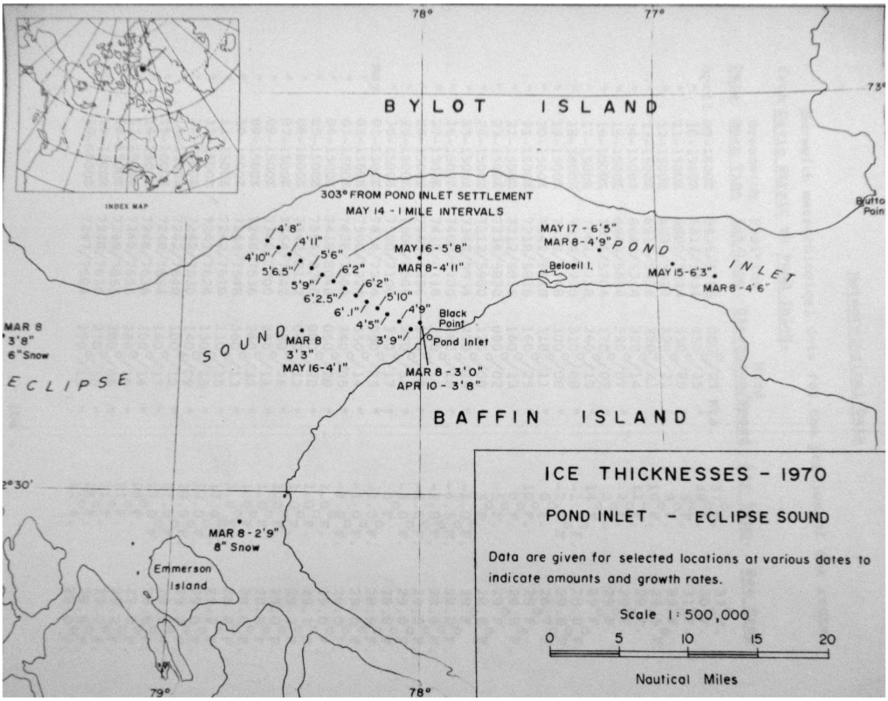
ICE THICKNESSES - POND INLET

Not a great deal is known of ice thicknesses, or ice growth, throughout the Eclipse Sound/Pond Inlet area. But this is an important part of the route to Milne Inlet and conditions there are of prime importance to any shipping operation. It was, therefore, of considerable significance to the company that Humble Oil agreed to carry out ice tests in that area during the second voyage of the Manhattan.

To assist Humble Oil in planning for these tests, Mr. Ron Sheardown of Baffinland Iron Mines on March 8 landed on the ice and took a number of measurements some of which are shown on the diagram accompanying this part. As matters turned out the tanker did not succeed in probing beyond Pond Inlet but this notwithstanding it was possible for further ice measurements to be made using helicopters. This was done on May 15, 16 and 17 including some locations where readings had been taken on March 8. In this way it was possible to get an indication of the amount of ice growth in the intervening 66, 67 and 68 days. This information is also shown on the attached diagram.

Among a number of locations where measurements were taken was one 6 miles due north of Pond Inlet settlement which measured 4 feet 11 inches plus 4 inches of snow. This was on March 8. 67 days later, on May 16 in the same spot, the ice measured 68 inches, an increase of 9 inches. Not a remarkable amount or rate of growth. Further east, in Pond Inlet proper, the ice measured 4 feet 9 inches on March 8. On May 17, it measured 6 feet 5 inches plus 8 inches of snow. This represents an increase of 20 inches, or nearly an inch of ice every 3 days during the period. The decrease in snow could be attributed to ablation to be expected at that time of the year with 24 hours of daylight.

Manhattan undertook a series of ice thickness measurements at one mile intervals from the settlement in a northwesterly direction. This information, too, is depicted on the attached diagram and indicates that the ice in the centre of Eclipse Sound is substantially thicker than that bordering the land (Bylot Island and Baffin Island).



<u>Meteorological Data</u>

Herewith meteorological data for the portion of the route from <u>Davis Strait</u> to <u>Pond Inlet</u>.

Date	Greenwich Mean Time	Position Lat/Long	Wind Direction/Speed	Air Temp.	Sea Temp.
April	09-1800Z	5936/5106	080°/23 Kts.	37°F.	37°F.
"	10-1500Z	6412/5424	350°/35 "	28°F.	30°F.
"	11-1500Z	6800/5624	350°/25 "	5°F.	31°F.
"	12-1500Z	6830/5624	330°/21 "	9°F.	29°F.
"	13-1500Z	6912/5436	320°/21 "	10°F.	29.5°F.
"	14-1500Z	6848/5354	320°/14 "	11°F.	29°F.
"	15-1500Z	6948/5654	320°/07 "	2°F.	29°F.
"	16-1500Z	7036/5706	170°/07 "	3°F.	29°F.
"	17-1500Z	7042/5718	260°/10 "	14°F.	29°F.
"	18-1500Z	7054/5730	310°/08 "	-1.0°F.	28.8°F.
"	19-1500Z	7118/5748	300°/08 "	-2.0°F.	28.8°F.
"	20-1500Z	7142/5818	110°/11 "	0°F.	28.7°F.
"	21-1500Z	7218/5836	160°/25 "	10°F.	29°F.
"	22-1500Z	7212/5836	160°/13 "	0°F.	28.8°F.

Date	Greenwich Mean Time	Position Lat/Long	Wind Direction/Speed	Air Temp.	Sea Temp.
"	23-1500Z	7236/5830	090°/02 "	5°F.	29°F.
"	24-1500Z	7312/5900	120°/09 "	5°F.	28.8°F.
"	25-1500Z	7348/5954	270°/25 "	-1.0°F.	29°F.
"	26-1500Z	7400/6100	260°/10 "	-4.5°F.	28.8°F.
"	27-1500Z	7418/6118	320°/16 "	-2.0°F.	28.8°F.
"	28-1500Z	7442/6336	270°/20 "	-4.0°F.	29.0°F.
"	29-1500Z	7506/6506	280°/12 "	-5.0°F.	29.0°F.
"	30-1500Z	7500/7100	320°/17 "	0°F.	28.8°F.
May	01-1500Z	7454/7224	050°/25 "	-2.0°F.	28.8°F.
"	02-1500Z	7500/7224	350°/14 "	-1.0°F.	29.0°F.
"	03-1500Z	7436/7600	340°/05 "	-2.0°F.	29.0°F.
"	04-1500Z	7418/8048	050°/20 "	1.0°F.	29.0°F.
"	05-1500Z	7354/8300	080°/20 "	1.0°F.	29.2°F.
"	06-1800Z	7342/8112	040°/12 "	1.0°F.	29.2°F.
"	07-1500Z	7354/7842	080°26 "	3.0°F.	29.0°F.
"	08-1500Z	7342/7700	280°/11 "	1.0°F.	28.8°F.
"	09-1500Z	7248/7536	260°/33 "	1.0°F.	29.0°F.
"	10-1500Z	7248/7548	360°/13 "	3.0°F.	28.8°F.
"	11-1500Z	7242/7618	110°/15 "	13.0°F.	29.2°F.
"	12-1500Z	7242/7624	150°/15 "	12.0°F.	29.0°F.
"	13-1500Z	7242/7630	140°/09 "	19.0°F.	29.2°F.
"	14-1500Z	7242/7648	100°/12 "	17.0°F.	29.0°F.
"	15-1500Z	7248/7654	140°/17 "	17.0°F.	28.8°F.
"	16-1500Z	7248/7636	100°/14 "	19°F.	29.0°F.
"	17-1500Z	7248/7655	280°/19 "	21°F.	29.2°F.
"	18-1500Z	7248/7655	280°/06 "	11°F.	29.0°F.
"	19-1500Z	7248/7636	270°/10 "	16°F.	28.8°F.
"	20-0600Z	7247/7604	270°/15 "	11°F.	29.0°F.

Photographic Summary

A selection of photographs depicting ice conditions encountered by the Manhattan and her icebreaker, the Louis S. St. Laurent including some of the difficulties experienced.

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POND INLET - MAY 1970

Pond Inlet as seen from seaward. Here the Manhattan is working in the 3 foot landfast ice which extended ten miles or more into Baffin Bay. The Louis S. St. Laurent, having loosened the ice to starboard of the tanker, has backed off to permit the larger vessel to back down in preparation for another charge at the ice.

Bylot Island is to the right and Baffin Island to the left. Immediately to the left of the Manhattan's funnel is the pyramid-like shape of Mount Herodier behind which shelters Albert Harbour where Captain Bernier wintered the CCGS Arctic in 1906-07.

POND INLET - MAY 1970

One noteworthy difference between ice conditions which exist during the normal navigation season (August-September), and in May when the Manhattan was operating in the area, is the hardness of the ice and the crispness of its snow cover.

This shows 4 foot ice being broken by the St. Laurent east of Pond Inlet in the Baffin Bay approaches thereto. Note the packed snow cover, 6 inches thick, with no evidence of melting so early in the season. Note, too, the clean sharp edge of the broken ice because of its hardness and coldness. The same ice in August will be covered with melt pools and the ice itself will be softer, more rotten and easier to break.

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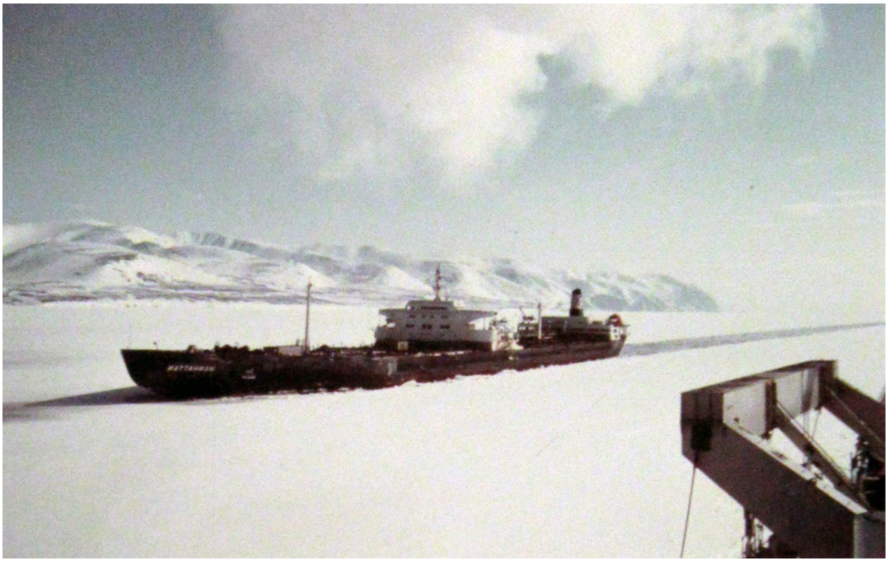
POND INLET - MAY 1970



Manhattan entering Pond Inlet under ideal conditions. Clear skies and virtually no wind. Her track, arrow straight, stretches out behind her through the fast ice ten miles or more into Baffin Bay.

At this point both ships were steaming parallel to each other and advancing with little difficulty through ice only a foot or so thick. But as they penetrated deeper into the inlet, ice thicknesses gradually increased. In the vicinity of Albert Harbour measurements in excess of 6 feet were recorded.

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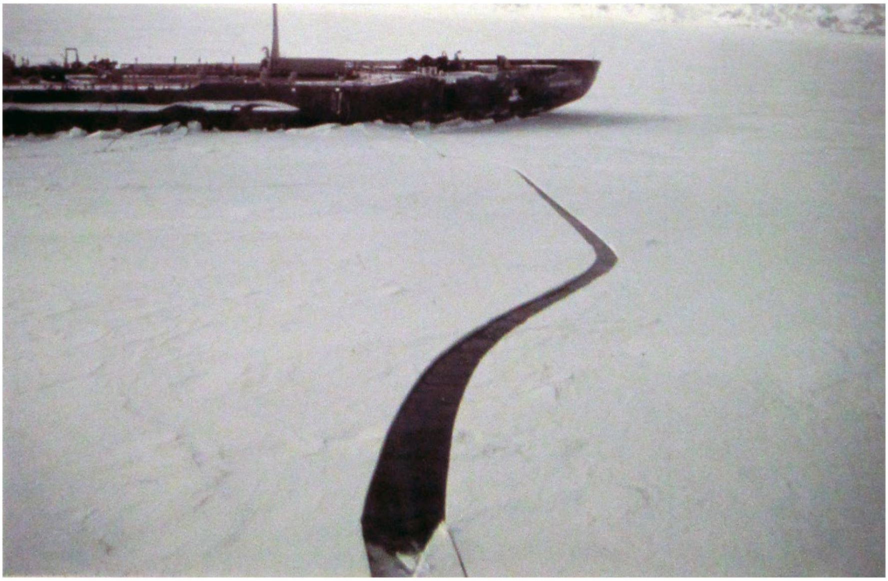
POND INLET - MAY 1970

This picture, and the one overleaf, depicts the technique evolved by the icebreaker St. Laurent while working in support of the Manhattan. Side by side, and separated by 2 or 3 hundred yards, the two ships would advance into the ice which, as can be seen, would crack and relieve between them. This is especially evident in the second picture where the First-year ice, about 4 feet thick, is cracking and breaking in square chunks, one of which is shown abreast the icebreaker.

When ice conditions became more difficult, either because of thickness or pressure or both, the leading ship would be slowed while the other would gain on her, breaking and relieving until she took the lead. Alternating in this fashion, both would continue providing most effective mutual support. The progress achieved being more, much more, than twice that which could have been accomplished in the same ice had each been operating independently.



POND INLET - MAY 1970

Second of two pictures depicting the icebreaking technique evolved by the two ships described on the preceding page.

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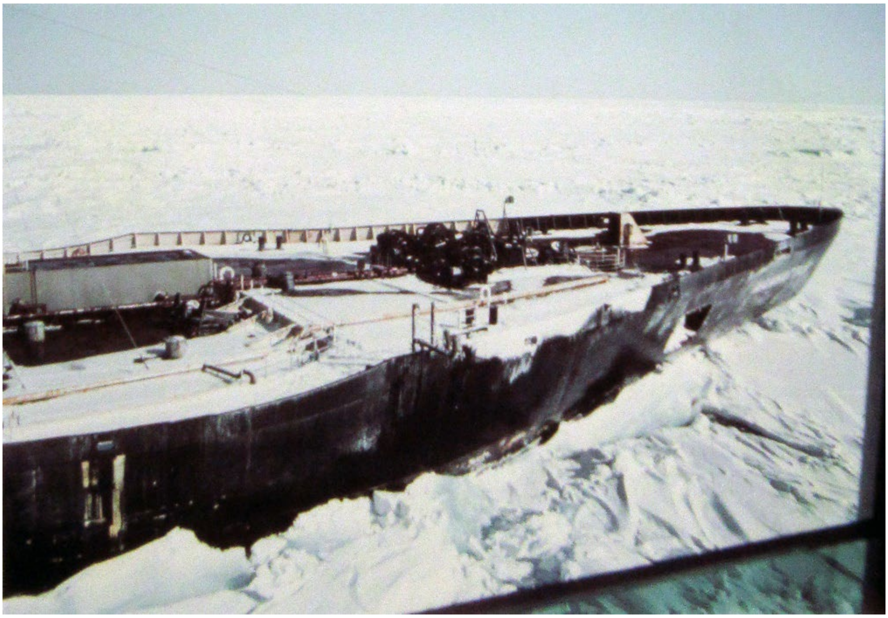
POND INLET - MAY 1970

One of Manhattan's difficulties in ice was caused by the design of her icebreaking bow. The shoulders of this were wider than the rest of the hull in the hope that ice, once broken, would pass around these shoulders to escape along the ship's sides where it would not exert any pressure or cause any friction.

However, in the event, ice tended to accumulate at the widest point, shown here at the extreme bottom left corner of the picture. Ice, tipping on edge, would jam and effectively stop any further advance.

Ice floes can also be seen tipped on edge around the bow. To lessen this tendency a design which enabled ice to escape down and under the hull would be a big improvement.

On this particular occasion the Manhattan was stopped while the St. Laurent was working up her starboard side loosening the ice so that the latter could back down for another charge at the unbroken ice ahead of her.



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POND INLET - MAY 1970

A companion picture to the preceding one. Here the St. Laurent has loosened the ice holding the Manhattan permitting her to back down. Note the size of the broken floes between the two ships and the quantity of debris and brash ice ahead of the tanker. The point where the Manhattan's bow came to rest on her last charge can be seen in the top right corner.

The slow progress of the Manhattan can be attributed to her inadequate power and, in some measure, to shortcomings in her hull form and bow design.

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POND INLET - MAY 1970

Reference has been made to the problems created by the wide bow of the Manhattan which acted rather like a barb on a fish hook. Once embedded in ice it was difficult to extricate the ship. This picture shows the tanker stuck with ice gripping her around that bow yet with easy conditions apparent from there all the way to the stern.

Here the icebreaker is once more loosening the ice up the tanker's starboard side thus permitting her to break free of the ice and back down.

To the right Bylot Island and, to the left in the distance, Eclipse Sound.

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POND INLET - MAY 1970

In mid-channel of Pond Inlet the ships came upon an area, several miles in extent, of particularly heavy ice comprised of Multi-year floes, growlers and bergy bits, the whole being welded together during the winter just past. This ice had been blown into the inlet the previous fall, before freeze-up, during a period of strong easterly winds. Once in there this ice was caught and held by the onset of freeze-up.

The ships, having made moderately good progress hitherto through the First-year fast ice, attacked this formidable obstacle but, as the pictures show, it proved too tough and eventually both retreated and skirted it.

This picture is a general view of this inhospitable ice with the tanker's bow thrust into it. She is stopped and endeavouring to back down for another charge. Much of the area is covered by hard-packed drifted snow.

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POND INLET - MAY 1970

This shows Manhattan breaking some of this Multi-year ice, in this instance it is 8 feet thick. A thin crack can be seen at the stem of the ship running towards the icebreaker from which the picture was taken. Beyond the tanker can be discerned the boundary of this area of heavy ice, beyond which is the smoother, easier, First-year ice through which both ships should have travelled in the first place.

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POND INLET - MAY 1970

This exemplifies the calibre of the ice the ships were hoping to defeat. This was taken from the St. Laurent and shows her breaking ice more than 22 feet thick. This fragment, if such a term is appropriate, has been fought until it has been rolled on edge thus revealing its true nature. At this stage the icebreaker was about to retreat, it obviously being too time-consuming, if not impossible, to continue.

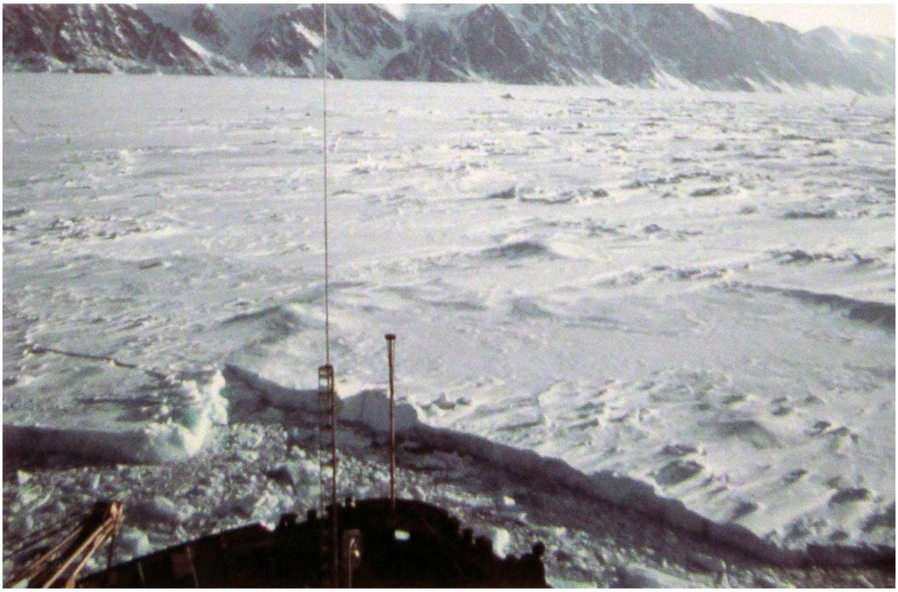
--oo0oo--

<u>POND INLET</u> - <u>MAY 1970</u>

This was t[a]ken when the two ships, having wisely decided to find an easier way to continue westwards, were attempting to work their way around to the south of the giant floe. Here the ice surface is standing proud of the water by a good 2 or 3 feet, reliable evidence that the total ice thickness was probably in the neighbourhood of 15-25 feet.

Except for trials purposes, which was the reason these ships attacked this ice in the first place, a ship no matter how mighty should always seek the easier conditions if these are known to exist as in this case they did.

In the background, well to left of centre, can be seen 4 black dots on the ice, the 3 quite close together and one further to the left. These were Ski-doo-borne Eskimoes [*sic*] from the <u>Pond Inlet</u> settlement who had travelled 20 miles over the smooth, fast ice to determine why the ships were taking so long to attain <u>Eclipse Sound</u> and sight of the settlement. They have stopped at the edge of the rough ice area.



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<u>POND INLET</u> - <u>MAY 1970</u>

Another picture of the area of very rough ice already referred to. The boundary between it and the smooth fast First-year ice is clearly visible in the background.

It has been held that ridges, which are the product of severe pressure between two adjoining ice sheets, would be much stronger and therefore to be avoided than the surrounding undisturbed ice. Here, it seems, is evidence to the contrary as the ice is failing along the ridged area and a ship heading in that direction would probably find the going easier by following this fault than by attempting to break through the level ice on either side. It is a matter which bears investigation.

There is considerable drifted snow visible here. The thickness of the ice, while extremely variable, on the average was about 10 feet.

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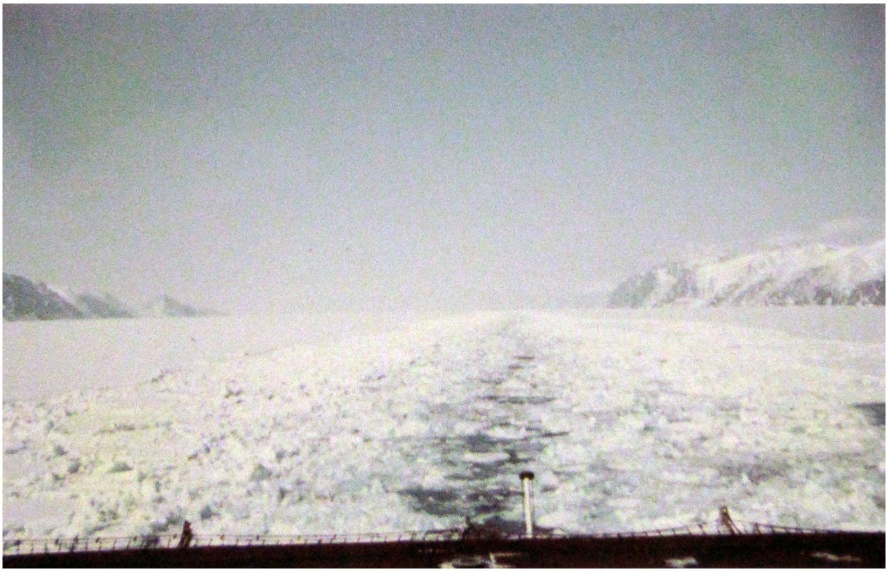
POND INLET - MAY 1970

Some interest has been expressed in the possibility of ships using the tracks made through ice by others which have preceded them. This would unquestionably not be practicable in the exposed areas of the Northwest Passage but, as the two pictures here indicate, such would certainly be the case in the fast ice of Eclipse Sound and the approaches thereto from Baffin Bay.

Once it had been decided to probe no further westward, a decision taken when the ships were still 7 miles or so east of Albert Harbour, it required the best part of a day to get the tanker turned around and headed east. But once this feat was accomplished there was no difficulty in moving along the path taken by the ships a few days earlier.

This picture looking westward through Pond Inlet towards Eclipse Sound shows the effect on the fast ice of two ships churning through it inbound and outbound. It is thoroughly chewed up and would present no difficulty to a ship attempting to pass through.



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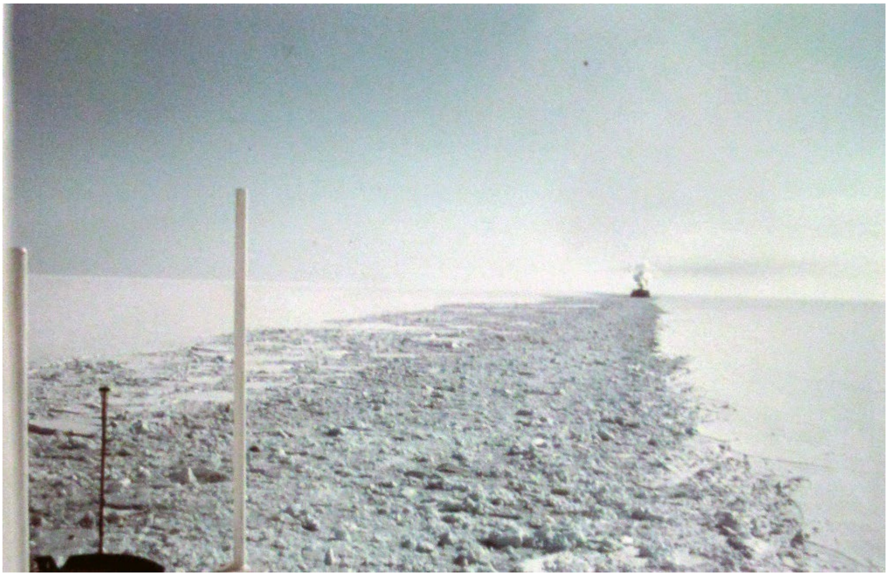
POND INLET - MAY 1970

This picture, taken at the same time as the one preceding and in the same location but looking eastward and seaward towards Baffin Bay. Passage through the ice by the tanker and the icebreaker westbound, and by the tanker eastbound, has left nothing but brash and slush making it a preferred route for any ship contemplating an entry.



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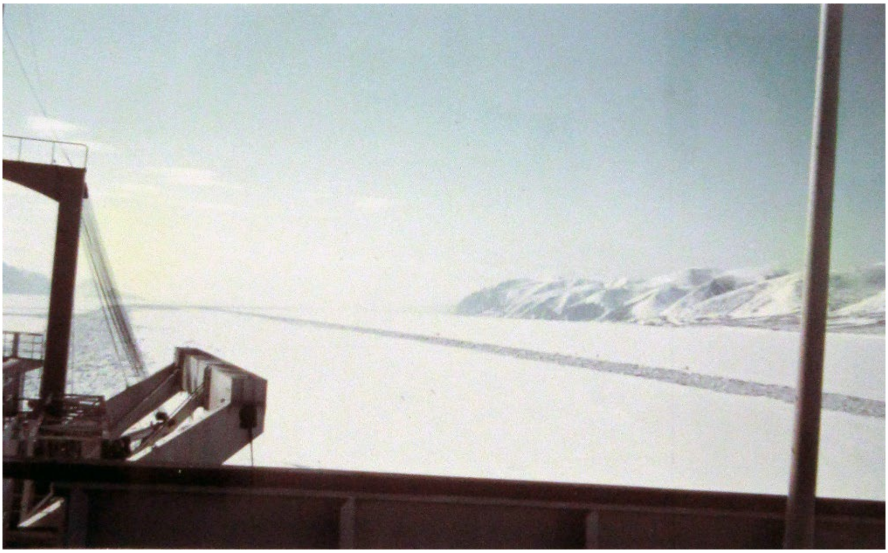
POND INLET - MAY 1970

The tracks left by the two ships, on the left the wake of the St. Laurent and on the right that of the Manhattan. The activities of these vessels in the entrance to Pond Inlet will probably contribute substantially to the process of break-up in this area in July and August, if not before.

24 hours of sunshi[n]e at this time of the year will wreak havoc in these tracks and the large piece of ice in the centre will, when a west wind springs up, be moved out into the Bay.



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POND INLET - MAY 1970

Taken from the St. Laurent as she was heading eastward into Baffin Bay through the refrozen track taken by the two ships when they were inbound nearly a fortnight before. The icebreaker's jackstaff is just visible in the bottom of the photograph.

The Manhattan, also eastbound, can be seen carving a fresh track through ice which, at this point, was only 2 feet thick.

This refrozen portion of the track was found to be strong enough to permit men and snowmobiles to cross over safely even if with some difficulty. The ship certainly had no difficulty in retracing her steps through this stuff. Indeed so fast was she able to steam that her swell caused the unbroken ice on each side to crack and break, thus widening the track by several hundred feet.

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Doc. 7: T.C. Pullen, *Feasibility Study: Arctic Transportation to Milne Inlet, Baffin Island; Volume I, Ship Data and Manhattan Second Voyage*, Prepared for Baffinland Iron Mines Ltd., 1970.

HBC Archives H2-141-1-3 (E 346/1/15)

NORTHERN ASSOCIATES REGISTERED 1967

FEASIBILITY STUDY

ARCTIC TRANSPORTATION

TO

MILNE INLET, BAFFIN ISLAND

VOLUME I

SHIP DATA

AND

MANHATTAN SECOND VOYAGE

PREPARED FOR

BAFFINLAND IRON MINES LTD.

NORTHERN ASSOCIATES REGISTERED
OTTAWA AND MONTREAL

GERMAN & MILNE
NAVAL ARCHITECTS & MARINE SURVEYORS
HALIFAX MONTREAL VANCOUVER
SUITE 401, DOMINION SQUARE BUILDING
MONTREAL 110, QUEBEC

DESIGN
SUPERVISOR OF CONSTRUCTION
SURVEYS

APPRAISALS
ECONOMIC STUDIES
BROKERAGE

July 23, 1970.

Captain T. C. Pullen
1306 Chattaway Avenue
Ottawa, Ontario

Dear Tom:

RE: BAFFINLAND IRON MINES STUDY

Here are the two (2) copies of Volume I (less photographs) as arranged. We will enter the loose pictures you sent us in our office copy giving one spare complete copy for use as required.

Regarding the large maps, etc., in Volume III, Robbie has asked us to re-draw some typical maps on a smaller scale for use for future work and he has prepared smaller sized data sheets to go with them. These will be much handier and easier to read than the old ones.

Trust we will soon have the opportunity to get together again on something new.

Yours very truly,

GERMAN & MILNE

[Signed: Ron]
Ronald Sinclair
Naval Architect

Enc.

July 22, 1970.

Mr. Murray Watts,
President,
Baffinland Iron Mines Limited,
P.O. Box 28,
Toronto-Dominion Centre,
Toronto 1, Ontario.

Dear Sir:

We are pleased to forward fifteen (15) copies of a "Feasibility Study Arctic Transportation to Milne Inlet, Baffin Island" in three (3) volumes:-

Volume I: "Ship Data and MANHATTAN Second Voyage."
II: "Analysis of Ice Data"
III: "Area Maps, Climatological and Meteorological Data". 'MANHATTAN' Track Charts are also contained in Volume III.

Submission of this Report was deferred in order to include observed data of environmental conditions experienced during the second 'MANHATTAN' voyage in April, May and June of this year. The undersigned was present for that part of the ice testing which took place in Pond Inlet, indeed it was he who originally recommended that Humble Oil carry out their testing program in the vicinity of Pond Inlet to the advantage, hopefully, of that Company and of Baffinland Iron Mines Limited.

Never before have ships attempted, nor indeed have they been capable of operation in the Baffin Bay/Pond Inlet area so early in the season. This is always the period of heaviest ice conditions and so the information thus collected is of prime value.

We trust you and your colleagues will derive substantial benefit from these documents which do contain large amounts of original work in fields so important to your transportation needs. Your letter to us of February 17, 1970, has been closely studied and the questions raised in that document have been answered to the degree that is pertinent.

In our view the information contained in this Report can serve as a useful planning and operational tool, thereby providing a competitive edge which too wide a distribution might tend to negate.

We take this opportunity of thanking you for placing your trust in Northern Associates and we look forward to serving you in a similar capacity in connection with marine transportation in the future.

Respectfully Submitted,
NORTHERN ASSOCIATES REGISTERED
[Signed: T. C. Pullen]
T. C. Pullen

FEASIBILITY STUDY

ARCTIC TRANSPORTATION

TO

MILNE INLET, BAFFIN ISLAND

Volume I

SHIP DATA

and

MANHATTAN SECOND VOYAGE

Prepared for

BAFFINLAND IRON MINES LTD.

CONCLUSIONS OF STUDY

The major conclusions arrived at during the course of this study to determine the feasibility of operating large bulk ore carriers on an extended season from Milne Inlet, Baffin Island to the Port of Rotterdam are as follows:

1) Unstrengthened vessels and strengthened vessels up to and including Lloyd's Ice Class 1 are not considered suitable for the service under study. Technical considerations and present uncertainty regarding the prohibition of certain classes of vessels under the forthcoming anti-pollution regulations contribute to this statement.

2) Strengthened vessels to Lloyd's Ice Class 1* should be suitable for a four month navigation season.

3) Strengthened vessels to Icebreaker Class, fitted with sufficiently powerful propulsion machinery, should be suitable for an eight to twelve month navigation season. The form and proportions of this class of vessel would differ considerably from normal to minimize the additional power requirements.

4) An analysis of the ice data shows that the routes to and from Milne Inlet as detailed in Volume II will vary, depending on the time of year and the prevailing ice cover. The recommended routes should, therefore, be followed and any departure from these be made only when aerial ice reconnais[s]ance shows easier conditions on another route. Such ice reconnais[s]ance should cover the entire route from Present Position to Destination if cul-de-sacs are to be avoided.

5) The most severe ice conditions encountered would occur in May, and would be predominantly first year ice of average thickness 5 feet, but increasing to about 6½ to 7 feet in certain areas. Multi-year floes, 20 feet or more in thickness, would be met but should be sufficiently widespread to be avoidable in the majority of cases.

6) It cannot be emphasized too strongly that the vessels be equipped with the navigational instruments and equipment outlined in Vol. II.

If schedules are to be maintained, it is important that Decca or some similar type of navigational aid be established, covering the approaches to Pond Inlet, not only to assist the navigation of vessels, but also to provide a common position fixing system between them and ice reconnais[s]ance aircraft.

7) On completion in 1973, new terminal facilities at Europoort-Rotterdam should be suitable for the docking and unloading of bulk ore carriers of up to 150,000 tons deadweight.

8) That a training program be established for Masters and Officers before the opening of this trade. The curriculae for such a program should include:

A. Understanding of all shipborne navigational equipment and appreciation of their limitations in Arctic waters.

B. Appreciation of the environmental factors peculiar to this area and their effect on operations.

C. Polar Meteorology.

D. Ice. Movement, concentration, dynamics, deformation, recognition and identification.

E. Effect of ice on shipping. Besetment, pressure, navigation, pilotage.

F. Effect of winds, tides, currents on ice movement and patterns.

G. Icing of superstructures and equipment.

H. Search and Rescue.

I. Survival.

J. Canadian Law as it affects these waters.

9) A detailed economic study would be required before firm recommendations regarding number, size and type of vessel may be made.

ICE NAVIGATION BY STRENGTHENED AND UNSTRENGTHENED SHIPS

INTRODUCTION AND SUMMARY

When considering ice navigation by strengthened and unstrengthened vessels it is desirable at the outset to make certain points before a meaningful discussion becomes possible. Arctic ice is infinite in its variety and defies generalization. In the context of this discussion, therefore, the following factors must be taken into account:

a. The proposed route will extend from open water south of Greenland into Davis Strait and Baffin Bay, thence to Eclipse Sound by way of either Navy Board Inlet or Pond Inlet and so to Milne Inlet.

b. All ships intending to operate over this route will require to meet the exacting standards of navigation and navigational equipment, and communications and communications equipment that will be laid down for ships entering these waters. In addition, the new anti-pollution regulations, now being prepared in Ottawa, will, it is understood from preliminary information available, contain clauses prohibiting vessels from each area of the Arctic unless these vessels meet certain requirements for ice classification. The degree of ice classification required will vary with the season in each area. Although the bulk carriers considered in this study do not carry bulk oil, the fact that they do contain oil in the ship's bunkers would appear to bring them under these new regulations.

c. Prevailing ice conditions along the route vary from year to year. There will be occasions when any ship, no matter how powerful or well handled, may require assistance of some sort from an icebreaker to help her on her way, unless she is prepared to wait out the period of pressure. In this connection the "icebreaker" could well be another unit of the fleet of icebreaking bulk carriers.

d. Not only must ships be equipped with suitable navigational and communications equipment but they will have to be manned and handled by men experienced in ice navigation or have experienced ice navigators on board to provide professional guidance. The initiation of a suitable training program is recommended in this instance.

e. To provide the degree of agility which experience has shown to be essential in avoiding ice fields and icebergs in Baffin Bay, ships designed especially for this trade will have to be considerably more manoeuverable than their more conventional brethren. "MANHATTAN", with twin screws and rudders, demonstrated this sort of capability, having approximately twice the manoeuverability of a single screw, single rudder vessel and a similar arrangement of rudders and propellers is recommended for vessels specially designed for Arctic Service. It is not possible at this stage to give exact areas for the rudders for each class of vessel, these figures being obtained during the detailed design process, but it can be stated that larger rudders than for normal ocean service would be essential. Protection against damage from ice would be obtained by the fitting of strong ice horns adjacent to each rudder stock.

f. To confer that measure of flexibility essential for an icebreaking bulk carrier of large size to enable the vessel to withdraw when nipped, full astern power, equal to that ahead, must be available for unrestricted use for prolonged periods. The speed at which the machinery may be changed from full ahead to full astern is also of vital importance.

g. Vessels designed for Arctic service should have the capability to ballast to, or close to, their load waterlines when not carrying cargo so that their icebreaking and ice strengthening features are always best deployed. It is not acceptable to have ships of this sort flying light in ice at any time. The ballast draft desired should be adjusted to the ice conditions prevailing at any particular time, full load draft may not necessarily be required in light ice conditions.

h. The extent of the fast ice (i.e. ice that is frozen from shore to shore and immovable) with which ore carriers must contend will extend from the loading facility at Milne Harbour, up Milne Inlet, to Eclipse Sound and either through Navy Board Inlet into Lancaster Sound or through Pond Inlet into Baffin Bay depending upon which route the ships may take. Apart from this, most ice is perpetually on the move. Little, if any, data are available on the effect in an Arctic ice environment of ship traffic through it but it is considered that the coming and going of large bulk carriers through areas of fast ice should tend to make conditions easier for subsequent ships. Information on this point has just become available and these conditions are described in the section describing the "MANHATTAN" second voyage, included in this volume. Indeed, once freeze up has occurred it should be possible to create a lane of broken ice in the fast ice areas through which ships could steam maintaining it in a comparatively easy state until break-up the following spring. The thickness of the new ice forming around the broken ice would depend on the frequency of the traffic passing through.

i. Recent experience shows that, in conjunction with power, sheer size and consequently mass, is truly effective in breaking ice. There is, therefore, for each set of ice conditions a minimum size and power of vessel for effective continuous performance.

The MANHATTAN, with a deadweight tonnage of 114,000 tons and total ahead power of about 40,000 S.H.P. was under-powered for the more rigorous ice conditions met on the second voyage, and had unavoidable shortcomings in her bow and hull design. Astern power was of a very low order (about 7000 S.H.P.) and this could not be maintained under continuous output. It must be remembered of course, that this vessel was not built for ice navigation in the first instance and no increase in power was possible during the recent conversion to an icebreaking tanker. The provision, therefore, of machinery installations capable of producing powers greatly in excess of those found on normal ocean going bulk carriers is essential for vessels engaged in ice navigation for an extended season. These power requirements can be reduced, however, by the adoption of specially designed hulls incorporating the latest knowledge in icebreaking theory and practice.

The most efficient use must be made of this additional power in terms of thrust, in particular at low speeds of advance when traversing heavy ice. Specially designed propellers, perhaps incorporating fixed annular rings on a similar principle to the Kort Nozzle, will be required. Exact details must await the preparation of the various ship designs, when particulars such as number of blades will become known.

j. In future the Canadian Government expects to impose a user charge for icebreaker and other services supplied to shipping entering Canadian Arctic waters. For this reason underpowered vessels, unstrengthened or lightly strengthened vessels and vessels of insufficient size may find it uneconomic to attempt operations on an extended basis in the North. In addition, as already described, such vessels may be prohibited from navigating in those waters for much of the year.

Not only will ice conditions along the route be infinite in their variety but the type of ship contemplating operations there can take a number of forms. The voyages of the MANHATTAN proved conclusively that size and power are key factors in defeating sea ice. The bigger the ship and the more powerfully she is engined the better progress she will make through thick ice. Any discourse on ice navigation by strengthened and unstrengthened ships is only meaningful if the ship type is taken into consideration. For the purposes of this discussion the following variations will be examined:

<u>Type A</u> A full-fledged icebreaking ore carrier of 150,000 tons deadweight, built and outfitted to full Arctic standards, suitably powered, not less than 125,000 S.H.P., manned and equipped for the task.

<u>Type B</u> Ice strengthened (Lloyd's Class 1*) ore carrier of 100,000 to 150,000 tons deadweight with outfit suitable for Arctic conditions for a limited season. Propulsion machinery to Class 1* standards of 23,000 to 30,000 S.H.P.

<u>Type C</u> Ice strengthened (Lloyd's Class 1*) ore carrier of more modest deadweight (50,000 tons) with machinery of 16,000 S.H.P.

<u>Type D</u> Unstrengthened ore carrier built and engined for normal ocean service, 50,000 to 200,000 tons deadweight.

With these categories in mind the following forecast of their performances in ice can be attempted:

Type A. The full-fledged icebreaking ore carrier of 150,000 tons deadweight.

This type of vessel should be capable of maintaining virtually year-round service to Milne Inlet from the Atlantic. Being the ultimate ship especially designed for this trade she would have a loaded displacement in the order of 190,000 tons giving her the power and momentum needed to maintain headway in heavy ice. With power of not less than 125,000 SHP she should have the means, ahead and astern, to keep moving in heavy going and to extricate herself when having to resort to backing and ramming techniques. With the best icebreaking form available she should be capable of defeating all but the worst possible ice conditions to be expected. With twin screws, and twin rudders, she would possess the agility essential for navigating safely through the iceberg infested waters of Baffin Bay in fog, storm and darkness. The predominant type of ice she would encounter would be five feet first-year ice with a maximum thickness of seven feet. Multi-year floes, 20 feet or more in thickness, would be met but should be sufficiently widespread as to be avoidable. Failing this such a vessel should be capable of sundering these if not too large in area.

Type A vessels under average conditions would never need or expect escort by icebreakers for, to be successful, they must be their own icebreakers. Failing this they would not be able to maintain the service. Icebreakers or another icebreaking ore carrier might, however, be needed on certain occasions when ice conditions were particularly bad and the assistance of another ship was essential to get moving again. Such a technique was in constant use with the MANHATTAN and her accompanying icebreakers, made necessary in this case, of course, by the lack of power in this converted vessel.

Type B . Ice-strengthened (Lloyd's Class 1*) of 100,000 to 150,000 tons deadweight.

Type B ships could expect to navigate through this area, unescorted or unaccompanied, from 1 August to 1 December, a period of four months. This would be during an average ice year. There would be seasons when ice break-up would be delayed and such ships could not get into Milne Inlet until mid August or even later. On the other hand, it might prove practicable for them to continue operations into

December thus making up for any delay at the opening of the season or, even better, extending the season in good ice years beyond four months.

Fast ice in Eclipse Sound and Milne Inlet can persist into August and might be more than a match for a Type B. class vessel with her limited power and without risk of structural damage. In such circumstances the services of an icebreaker might be required to break track into Milne Inlet. Once this was done Type B vessels could operate unassisted as late as December or longer.

In bad ice years, when the Baffin Bay pack was especially heavy, type B vessels might find conditions more than they could handle from the vicinity of Disko Island, on the Greenland shore, north and west across the top of Baffin Bay to Bylot Island. In such cases icebreaker assistance would probably be essential at the beginning of the season. It should be emphasized that what is intended here would be assistance and not escort.

<u>Type C.</u> Ice Strengthened (Lloyd's Class 1*) of 50,000 tons deadweight.

Type C vessels could expect to operate into Milne Inlet at least during what is presently known as the 'navigation season', i.e. from approximately 1 August until the close of navigation about 1 November, and on occasion to December 1. Such ships, however, would require escort and assistance from icebreakers at the beginning of the season to see them through the fast ice areas already described. They might also need help in the more difficult parts of northern Baffin Bay and at the end of the season to ensure they attained open water south of the latitude of Cape Dyer on the Baffin Coast.

There is no reason why these ships could not supplement the service provided by, say, Type A ships but with their limited capacity it is for consideration whether the cost and exertion would be justified. What is certain is that Type C ships would be far better qualified than Type D.'s, even in the largest sizes of this class, to attempt operations into Milne Inlet.

<u>Type D</u>. Unstrengthened ore carrier, 50,000 to 200,000 tons deadweight.

Such vessels could, on the average, expect about six weeks during which conditions might permit operations into Milne Inlet. A bad ice year in Baffin Bay or a pressure situation there would bar them completely. Continuous icebreaker assistance would probably be required along most of the route. Such vessels would also have difficulty in obtaining marine insurance and in any event Canadian Government regulations relating to Arctic shipping will probably bar such ships completely.

A type D. vessel's major attribute in breaking light ice would be its size. But instead of being an asset, this would probably increase the risk of this 'thin skinned' type of vessel being damaged. Whenever ice was encountered, either along the route or in Milne Harbour, such vessels would have to be handled with great delicacy. Unexpected wind changes could jeopardize such a ship compelling her to work through moving pack ice to extricate herself and running the risk of becoming beset or damaged.

A type D. vessel should, in fact, never attempt, nor be permitted, to venture north of Davis Strait. But undoubtedly marine underwriters and the Canadian Government would see to that.

Manoeuverability at Loading Berth

For the Icebreaking Class of ore carriers the provision of twin screws, twin rudders, high power and quick response ahead and astern will greatly improve the handling qualities of these large vessels in confined waters.

A powerful bow thruster would also assist in positioning alongside, although this action would be slowed by the presence of ice. The alignment of the berth would play an important part in this procedure and it is recommended that this be positioned so that the loaded vessel can steam straight ahead up the Inlet and not be required to back and fill to get away.

However, in the presence of adverse wind conditions assistance from tugs might be necessary for the berthing and un-berthing procedure. These tugs which would of necessity be of the icebreaking variety, could also assist in clearing any large areas of free floating ice which might prevent close contact between ship and the loading berth.

The advantages listed in the first paragraph of this clause would not apply to unstrengthened or partially strengthened classes of vessels and more difficulty would, therefore, be experienced in docking and undocking, with more frequent use of tugs.

DEFINITION OF THE SHIP PROBLEM

NOTE:

Graphical presentation of ship data is given in Appendix No. 1.

For ships operating into the ice regions, there are many concepts which are unique to the problem. These features are environmental in origin and are reflected throughout the complete design, construction and operation of a successful vessel.

Two basic types of vessels may be considered: one is the icebreaker, having full structural and power capability to navigate in any of the ice-filled seas; the other is the ice strengthened vessel, having reduced strength and power requirements compared with the icebreaker to navigate through lighter ice during a limited season. These latter vessels operate only periodically in the ice and do not carry the economic penalties of very high powers and large structural weight increases associated with full icebreakers.

For operations in very heavy ice, the vessel, as it forces itself through the flow may be partially lifted out of water at the forward end. Thus, adequate longitudinal strength, in addition to local strength, is an important requirement. This is particularly important in smaller vessels since the effect is less marked as the displacement increases. Therefore, the vessel's size has a significant effect on particular requirements.

For many years, the St. Lawrence River & Estuary and the Gulfs of Bothnia and Finland in the Baltic Sea have provided experience in navigating in low thickness ice coverages. Small coasting type vessels, continually operating in these regions, are occasionally escorted by icebreakers though it is customary to proceed independently and expect help from escort icebreakers only when help is requested. Certain rules have been derived by the major Classification Societies which reduce the probability of damage during such winter operations

(oceangoing cargo and container vessels built to these high classifications now regularly trade in the St. Lawrence River on a year round basis.)

Experience with vessels operating in the St. Lawrence and along the Labrador Coast for many years has indicated areas in which improvements could be made to the basic rules. It can be stated categorically that ice conditions experienced in Eastern Canada are more severe than those found in the Baltic and thus design criteria for such operations should be more stringent than for European zones. This is a fundamental point frequently overlooked when opinions are offered by experts who are not experienced in both areas.

Recently, Lloyd's Register have adopted a new rule intended specifically for operations in the St. Lawrence River. This Ice Class 1* has been adopted for vessels operating in a liner trade during the winter, i.e., vessels which are required to maintain a required speed or regular schedule. Thus adequate power installations and ice breaking ability is necessary to permit them to proceed upstream without escort. This operation must take place under conditions where vessels not so fitted would either become immobilized or suffer severe damage.

The non-liner or tramp type vessel built to Ice Class 1 is known to be adequate for navigation in this area. Tramp operation is not so time dependent as is the liner operation, thus some waiting for improved ice conditions may be tolerated. Vessels employing these two classifications generally experience minimal damage and impairment of service when on winter service in this region.

Vessels built to a reduced ice class, that is Class 2 or Class 3, are more restricted in their operations into the river, requiring more escort and experiencing much greater time delays. Similar results are observed in the Baltic, but here large ice breakers are used specifically to keep ports open and to provide escort for all vessels as necessary after passing Southern Sweden.

Vessels with strength requirements which are less than Lloyd's Ice Class 1* or the Finnish equivalent have operated successfully into the Arctic and Antarctic Seas for many years now, during the so-called "summer" months. These vessels are inadequate for operating over an extended season as in the summer the ice is relatively soft and rotting. Additionally, environmental factors such as adverse temperatures, winds, etc. are minimized. Even so, icebreaker assistance must be nearly continuous under these conditions.

For vessels operating into Arctic waters for extended seasons, strengthened structural requirements will be those approaching that required for a conventional icebreaker. For year round operations in the area, full icebreaker capabilities are indicated in terms of structure, habitability requirements and other features, although power could be somewhat reduced, compared with that of a conventional icebreaker of equivalent size. Marrying of the appropriate environmental factors into the ship design parameters is a major element of design success for such a vessel, in order that a ship can perform its function adequately and in the most economical fashion. This tenant is the same as required in the operation of any commercial vessel. For vessels operating into different ice covered regions it is unlikely that the same design parameters will provide a suitable vessel in terms of economics and ice navigating ability.

Adequate and sufficient environmental data must be included in the design stage and will thus play a very important part in the profitability of the proposed vessel for its intended service.

During Arctic operations, the problem of ice pressure has an important bearing on the structural and mechanical design of the vessel. This pressure is not experienced to any degree in the southern regions of ice encounter. Conventionally the hull configuration plus the structure must be suited to this loading.

The classic icebreaking form is derived from that of “FRAM”, which is of ovoidal form below the ice surface. Increasing ice pressure would tend to lift the hull bodily out of the ice thus reducing the structural requirements of the hull. However, it is impracticable and exceedingly costly to build a commercial vessel which could operate in a similar manner. For large ships the ice is not strong enough to lift such great weights vertically. This, in fact, does not happen to any noticeable extent even on medium sized icebreakers. Thus, a practical solution is to design a structure which can stand full compressive loading of the ice flow. The appropriate environmental data provides sufficient information on the ice to determine such maximum loading.

Associated with the structure are the machinery and powering requirements for ice operations in the given regions. Powering requirements are based on

(a) the ability of the vessel to break a uniform ice field;
(b) the ability to overcome friction caused by the snow, ice and ice under pressure on the side of the hull.

Shock loading by the ice is probably the most serious problem which the vessel has to contend with. This shock is reflected back throughout the complete machinery installation, particularly during a period of propeller stalling. Thus, all systems associated with the main propulsion unit will undergo a similar shock or pulse surge before stabilized loading is achieved. The machinery design therefore has to be such that maximum continuous horse power plus the full shock capability can be absorbed continuously. This presents severe operational problems.

It must be emphasized here that any unbalance between the design features of hull form, structure and powering has the capability to jeopardize the vessel's ability to perform its function in a satisfactory manner. Furthermore, the design must incorporate, completely, all other necessary features for ice operations, such as habitability, in their entirety so that all concepts are completely married.

Habitability is particularly important during the winter months in the Arctic regions. During the summer the temperatures are moderate and therefore conventional merchant ship practice is normally adequate. The winter, while its extremes may not be much more severe than those experienced in regions further south, is such that lower averages are experienced for a longer period of the year. Of primary importance is that all work which must be performed in a regular and routine manner, should be done in an enclosed, heated area. Equipment which is exposed on deck and which is required either periodically or continuously and emergency equipment such as fire fighting equipment, lifesaving gear, etc. must be ready for use without any delay or warm-up period. Such equipment must be operable by a man in such a manner that he does not have to unnecessarily expose himself to the elements, that is, he must not have to remove his gloves or parka in order to make the equipment operable, or ready for its intended use.

Accommodation must have adequate insulation and heating and ventilating facilities. Insulation must prevent high heat losses to the outside (prevent the formation of frost lines) and excessive condensation. Condensation is a particular problem, specifically on the outside bulkheads and on the piping. Heating and ventilating must be such that by including the higher heat loss rates due to wind chill interior temperatures may be maintained at a comfortable level while ventilation provides clean air to all regions of the ship.

Internal access to all working regions of the ship should also be provided. This is particularly important when moving say from the wheelhouse to the accommodation spaces or from the deck up to a crows-nest for improved [n]avigation surveillance. Any exposure presents unnecessary risks to the personnel and ensures a real drop in efficiency.

Habitability considerations appropriate for the actual living space should also be applied to the ship's working areas, including the wheelhouse and machinery spaces. A machinery space inadequately heated or insulated can be as big a factor in reducing the ability of the vessel to perform its functions as neglecting any of the major areas such as structure or power.

For vessels navigating in heavy ice the problem of maximizing the deadweight-to-displacement ratio must be given considerable thought. In these ships, deadweight will always be less than for a similar size, unstrengthened ocean going vessel. Thus earning power will be somewhat reduced as well as the capital cost being increased. On the vessels which only meet classification society requirements, this penalty is quite low, but with full icebreaking capability, this may amount to a significant loss in cargo-carrying capacity. As experience with ships in these regions and as additional environmental data is obtained, this ratio is expected to improve marginally. Deadweight penalties must be accepted from the outset and employment of the vessel into regions where it can take advantage of its special features of strength and power should be pursued in order that the special features may be properly remunerated. The deadweight penalty is reflected in the capital cost; the cost rising very quickly for small increases in icebreaking capability. Minimum necessary increases in capital costs to ensure satisfactory operation in a given trade, result from employing the correct environmental data, early in the design stage. Thus, with the completion of the proper design, maximum economy should be achieved as all factors pertinent to the operation have been considered in depth.

For a vessel operating in normal ocean routes which is fully adapted to ice operation, there will be a considerable excess of power over that required for open water propulsion. Certain techniques are necessary to overcome this disproportion, for example the employment of multiple prime movers, some of which may be shut down for open water service, in conjunction with controllable pitch propellers.

The ship problem in ice filled waters therefore includes all aspects of ship design, construction, operations and economics. Sufficient environmental information, engineering study and experience of the design staff are fundamental to providing a satisfactory vessel which can operate successfully over its economic life.

Quite apart from the unnecessarily high cost of building an icebreaking bulk ore vessel to normal bulk carrier proportions due to power requirement being larger than necessary one must not overlook an additional operating penalty - that the heavier fuel load needed for the higher power, creates a further reduction to the cargo deadweight displacement ratio. An icebreaking ship having properly designed proportions and form will not only cost less to build but will, because of her lower power needs, require less fuel and thereby have an improved deadweight to displacement ratio.

DEVELOPMENT OF ICE OPERATING BULK CARRIERS

CLASSIFICATION SOCIETY RULES

Classification Society Rules for ice strengthened vessels are framed with two features in mind:

1) to improve the local strength and the related load transfer in the structure.
2) to negate the effect of shock loading due to impact with the ice.

The requirements for Lloyd's Register and the American Bureau of Shipping are very similar for each ice class. Weights derived are therefore virtually identical regardless of the Rules used. The correspondence between Lloyd's Ice Classes and American Bureau of Shipping Ice Classes are:

Lloyd's Class 1 & ABS "A"
Lloyd's Class 2 & ABS "B"
Lloyd's Class 3 & ABS "C"

There is at present no correspondence for Lloyd's Class 1*, whose nearest class relative would be found in the Finnish Rules. The class "Icebreaker" is that derived from individual experience and is classed by both Lloyd's and ABS on individual merits, being in excess of their highest regular classification. In this case full use would be made of the design criteria derived from German and Milne's own successful experience in icebreaker design for the Canadian Government and in ice strengthened merchant vessels for various trades over a long period.

In considering the design of a vessel, it must be understood that the balance of all the technical and economic factors involved must be maintained, while preferential weighing can only be advocated from the position of considerable experience in the design and evolution of such vessels.

PRELIMINARY

Determination of the elements of form for an ice capable bulk carrier will show certain significant departures from present practice for a normal ocean going vessel. However, provision of economic transportation for bulk cargoes, rather than the introduction of exotic design schemes, is the aim. Maintaining all the present design concepts which have application to the North, with substitution of specialized features as necessary, is the method which can be justified to technically achieve the operating objective and the economic priorities.

With this philosophy, the form relationship (Length to beam, L/B, Beam to draft, B/d, and length to depth, L/D ratio) would require close investigation and definite changes from open sea practice are indicated.

MATERIALS

In general, all materials that are liable to come into contact with low temperatures should be specially considered as to their suitability.

Machinery items are discussed in more detail later in this section, a major hull item being the type of steel used for the structure of the vessel which should be of a quality such as to prevent loss of mechanical properties under the lowest ambient temperatures which will be encountered.

STRUCTURE

The rules are basically additions to the normal oceangoing rules and thus the minimum requirements of hull and machinery strength are maintained. Strengthened components are only those which directly carry moderate ice loads, and rule increases below the class "Icebreaker" do not qualify the vessel to operate in a similar manner to the existing Government icebreakers.

Strengthening requirements are built around transversely framed ships, that is, the conventional cargo type vessel. Longitudinally framed vessels, such as the conventional tanker or bulk carrier, offer certain minor disadvantages related to framing sizes and thus to the overall structural efficiency when considering ice loadings. Generally it is possible to have a more efficient icebreaking structure with a transversely framed ship, if the rules are adhered to explicitly. But for vessels, other than icebreakers, rule requirements do provide adequate service with a corresponding weight penalty.

The Ice Class rules consist primarily of fitting intermediate longitudinal or transverse frames and associated stringers as necessary, together with increases in shell plating thickness in certain areas.

The two ends of a vessel require particular attention. The forward-end experiences heavy impact from the floes and this is partially dependent on the ship's speed. The aft-end strength will also be ship's speed dependent, as it must contend with the ice when going astern and also when ice is drawn down into the propeller from under the bottom. For all of the Ice Classes however, impact at the forward end is of primary importance and attempts to minimize the likelihood of shell-piercing by the large floes.

ICE CLASS 3

Ice Class 3 is the Classification designation for minimum ice strengthening. Requirements for this Class consist of an ice belt at the forward-end, extending to the shoulder of the entrance portion. Longitudinal intermediate frames and increased shell plating thicknesses are fitted in the ice belt. Minor stern gear strengthening of the shaft, rudder stock and rudder is required. This is minimal strengthening only, permitting the vessel to operate at moderate speeds in light broken ice conditions. Damage could result from operating conditions where the ice has full coverage, if service speed is high or if the ice thickness is too great.

Primary longitudinal and transverse strength is as for the basic ship and there is no requirement for further investigation as the loading imposed by the ice will not exceed that normally encountered under sea-going conditions. There is a minimum steelweight penalty for such classification and this amounts to a very small percentage of total deadweight. The power installed is that suitable to give the required open sea service, though minimum Classification requirements are given in the Appendix No. 1.

<u>ICE CLASS 2</u>

The requirements for Ice Class 2 are generally similar in nature to Ice Class 3, though shell plating, aft of the forward ice belt is increased in thickness by 15%. The stern frame, rudder and rudder stock receive additional strengthening. These factors indicate the minor weight increase over Class 3, but from experience, it is a worthwhile penalty in terms of reduced damage in Canadian operations. This Classification is the minimum which could be recommended for many areas, specifically the St. Lawrence River and Gulf, during the fall and spring.

<u>ICE CLASS 1</u>

Ice Class 1 is the first Classification which gives full length and breadth protection to the vessel. It has a full ice belt, made up of intermediate longitudinal frames and increased shell plating which run the full length of the vessel. While it is not expected that longitudinal strength would be inadequate, this would normally be investigated with the additional ice loading in mind. The stern gear is extensively stiffened to account for the higher loadings and the new modes of operation now possible with the increased hull strength.

It is expected that this class would be the minimum strengthening for operations in sheet ice and large floes where the thickness is not greater than about 6 to 8 inches or in broken ice up to 2 feet. These are very heavy conditions where the ship's master must proceed with caution.

<u>ICE CLASS 1*</u>

Ice Class 1* is the latest structural Classification in Lloyd's Register at this time and is somewhat similar to the Finnish Ice Class rules. It has been found that Ice Class 1 has not been completely satisfactory in Eastern Canadian winter waters and Class 1* was developed almost explicitly for winter navigation in the St. Lawrence River. This features full length heavy ice belt stiffening consisting of intermediate longitudinals equal to the main longitudinals carried over full length and depth of the vessel and increased shell plating thicknesses. Maximum scantlings, for the forward quarter length, are carried to the keel level. The bow form should be designed specifically for navigation in ice. All stern gear (rudder, sternframe and steering gear) is strengthened by between 30% and 50% over that of a standard vessel. The stiffeners and plating would be further increased, for power increases over that of the basic minimum requirements.

These requirements are normally effective for the dissipation of energy necessitated by encounter with moderate ice conditions. This vessel has the features required for an unescorted vessel, navigating in broken ice fields. A number of such vessels now operating into the Canadian Arctic during the summer months are doing so in a satisfactory manner. Included are tankers as well as cargo ships, giving adequate demonstration that this category is suitable for the region, but also defining the season's limits. However, for extended season operations in the Arctic, Ice Class 1* is not sufficient.

Ice Class 1* has a weight penalty totalling about 2% of the total deadweight of the vessel. Steelweight increases account for about 3/4 of the deadweight loss, and the resulting hull is quite capable of operating at service power under conditions where vessels of Class 2 and less would not be able to operate without escort.

ICEBREAKER CLASS

"Icebreaker" class vessels are not at present covered by Lloyd's or A.B.S. rules for ship construction. The structural details of these vessels are calculated by the Naval Architects concerned using ice loadings which have been found, from theoretical considerations and past experience, to give satisfactory results for the particular area of service. The plans of the vessels so derived, after submission to the Classification authorities, are then approved with the notation "Icebreaker".

Recent theoretical and practical work in connection with the design and construction of large icebreaking merchant vessels, has been considerable and it is understood the Classification Societies are at present reviewing their regulations in this field. The recent voyages of the icebreaking tanker "MANHATTAN" which suffered no significant damage in the ice strengthened areas demonstrated the feasibility of the structural procedures adopted for this class of vessel, even when navigating in very heavy ice conditions.

The structural details consist essentially in the adoption of the principle of utilizing small plating panels to achieve maximum efficiency from frames and longitudinal stringers in association with regularly spaced web frames. These frames and longitudinals would be spaced to approximately square panels, thus resulting in an efficient grillage system to resist the pressure and impact from the ice.

It will be realized that there is a feasible upper limit to the thickness of the shell plating which can be used, due to the limitation in the shipyard machinery employed to bend and set the plates, and additional strength is therefore obtained by the employment of closely spaced frames and longitudinals, thus reducing the span of the unsupported plating. Adequate transverse strength to accept the crushing action of the ice under pressure is maintained by the fitting of heavy webs, floors and deep beams forming continuous "rings" for the greater portion of the vessel's length. Transverse bulkheads, stiffened by horizontal girders, assist in providing the transverse strength required.

For bulk carriers the floors and webs would be fitted in the wing and double bottom ballast tanks, leaving a clear surface inside the ore holds.

The forward end of the vessel would, of course, require special treatment to give the strength adequate for the high impact loading in this area.

The remaining items requiring attention, rudder, sternframe, steering gear, etc. all would be further increased over the requirements of Ice Class 1*. The weight penalty arising from all these additions (and from the machinery items discussed in a later section) shows a corresponding increase, totalling about 9% of the deadweight of the vessel.

SUMMARY OF CLASSIFICATION REQUIREMENTS

The varying degrees of ice stiffening discussed in the foregoing sections represents the present (summer 1970) concept on ice capable vessels, but it is known that active work is going ahead on the formulation of new regulations specifically for Arctic navigation and full consideration of these rules would be required before proceeding with design and construction. The loss of deadweight ensuing from the above could be corrected by making modifications to the major parameters of the vessel or the deadweight reduction may be accepted within the given parameters of length, breadth, draft and block coefficient. As already mentioned the question of suitable proportions of form would also require close attention to give satisfactory results for navigation in ice.

While the Classification Society Rules give the basic requirements for strengthening for these operations, they do not go into the detailed considerations required in the accommodation and machinery, which while not impairing the safety of the ship, are necessary in order that the vessel may operate in a satisfactory manner. These will be detailed in later sections. It will be appreciated however, that operating continuously in weather having temperatures below freezing, requires much thought in terms of the vessels' functioning ability.

All vessels with ice strengthening, would be subjected to some competitive penalty though of a minor nature when in normal trades for the lower ice classes.

The power of the machinery installation for a normal vessel is that suited to provide adequate sustained speed in ocean service. Minimum power requirements for each Ice Class are specified by the Classification Society but are usually less than the normal service requirements of present day vessels. For the icebreaker Class of course, power requirements are much increased in order to navigate steadily through continuous ice.

Propulsion machinery strength requirement increases with Class and is related directly to the increased shock loads anticipated, in the regions of operations where a particular class may safely work. These strength increases are primarily in the propeller, shafting, gearing and bearings and a change in materials may also be necessary. Weight increases resulting from this over-strength of the propulsion machinery are fairly nominal for all regulation Classes, although where Classification requires that the turbines be isolated from the shafting by appropriate devices, which to date, has usually meant a turbo-electric drive, a further weight penalty will apply.

The weight increase of the total ship's machinery is also dependent on the tank heating requirements. Full consideration must be given to this factor for both oil and water tanks for operations in any cold region, this being made rather more severe by the presence of ice and low air temperatures. Such requirements are therefore independent of the ice classification of the vessel, being constant in capacity for ships of similar cargo arrangement operating in low air and water temperature regions, with water temperature being the most important factor.

MACHINERY - GENERAL

INTRODUCTION:

This machinery section is concerned primarily with the requirements for a full professional icebreaking vessel, similar to those which presently work in the Arctic. Such an approach to the machinery installation requirements for the cargo-icebreaking vessels under consideration is not necessarily implied. Rather, these deep draft vessels with large propeller immersions, will be less prone to ice ingestion and therefore heavy shock loading. However, the principles which govern the requirements for icebreaking machinery in this environment are important to the successful operation of the vessel. It will be made apparent that a relaxation of the most severe professional icebreaking requirements may be made, due to both the differing operations and the vessel size. The fully ice capable and economical conveyor of bulk cargoes will be governed to a very large extent, by the selections made for the machinery installation.

It is important at the outset to define three terms which are closely related, but represent substantially different service conditions:

1) Ice Navigating Vessel: A vessel which can proceed through relatively thin sheet ice without risk of serious damage and which can be exposed to considerable ice pressure. It is inadequately powered or strengthened to break through heavy ice. These vessels are constructed to one of the Classification Society Rule requirements.

2) Professional Icebreaker or Icebreaker: A vessel whose total design is directed toward its ability to navigate, manoeuver and assist other ships in heavy, unbroken ice fields. Its structure, hull form and machinery installation are required to withstand extremely severe operating conditions which other vessels do not encounter.

3) Cargo Icebreaker: A commercial vessel on whose primary trade, must independently make its own way through heavy unbroken ice fields. It must have sufficient strength to withstand the pressure and power to break through uniform ice and ridging, with the cost of providing the required capability being minimized.

PRELIMINARY:

Due to shock and vibrations generated by the impact of breaking ice and particularly the churning of ice blocks with the propellers, none of the machinery used on icebreaking vessels should contain cast iron. This includes the propulsion and auxiliary machinery chocks and shafting bearings.

Most seawater pumps including bilge and circulating water, etc. should have good quality bronze impellers and castings, with shafts of 304 (18-8) stainless steel. Fuel pumps, oil pumps and other positive displacement pumps should be of cast steel with shafts of 304 (18-8) stainless steel.

Piping must be well anchored and supported, with flexible connections of approved type fitted at all machinery which generates vibration such as diesel engines and air compressors; in general, all reciprocating machinery. Diesel exhaust flexible pieces should be of stainless steel with internal guide, 316L, below 850°F. and 347L above 850°F.

All piping handling sea water at low temperature should be insulated to prevent the build-up of frozen condensation on the outside. This can lead to accidental breakage of flanges and bolts. The air compressors should be radiator-cooled to avoid overcooling.

De-icing of all shipside valves is mandatory. To minimize the heat requirement, these valves should be placed at least 1 foot below the light load water-line to avoid exposure to freezing air. To avoid the loss of precious condensate, hot sea water may be used instead of steam for de-icing. This also has a better scrubbing action.

All exposed deck pipelines should be traced to avoid freezing; a liquid phase boiler circulating a high temperature synthetic oil at slightly above atmospheric pressure, is suitable for this purpose. This oil should be checked with the new anti-pollution regulations.

PROPULSION SHAFTING AND BEARINGS:

All propulsion shafting should be made of forged steel with solid couplings. An exception in some cases is the tail shaft, which may be fitted with a very heavy removable type coupling mounted on a taper and keyed in a manner similar to that of the propellers.

Shaft couplings which are removed hydraulically, i.e. the O.K. type coupling, are not recommended for icebreaking service due to shock and vibration.

The strength of the propulsion shafting should be well over that recommended by Classification Society's highest requirements. For large powers, when the weight of the shafting is of concern, hollow shafts should be considered. For icebreakers the strength increases beyond that required for Lloyd's Ice Class 1* should be:

Tail Shaft	increase in strength	100%
Intermediate Shafts	" " "	135%
Thrust Shaft (at collars)	" " "	135%

These increases have given satisfactory service in recent professional icebreaker designs.

Water lubricated cutlass rubber or lignum vitae bearings have given successful service running with tail-shafts fitted with bronze liner of ASTM B 143 grade 1A (88-10-2). For large vessels, it is expected that a relaxation of the coupling restriction and shaft strength may be possible after sufficient experience is gained due to the increased draft, with corresponding reduced possibility of the propellers striking heavy ice.

All protected shaft bearings should be of cast steel, preferably Michell type self-oiling and water-cooled. The aftermost bearing, ahead of the stern tube should be babbited top and bottom and be provided with a splash seal on the rear face. The tilting pad thrust bearings of Michell self-lubricated type with deep sump, seals and cupro-nickel cooling coils should be oversized to obtain a maximum pressure of not more than 300 psi under overload conditions.

Regardless of location and duty, shearing bars should be fitted for both ahead and astern.

STERN TUBES AND BOSSINGS:

The stern tubes should be made from centrifugally cast steel or from heavy fabricated steel plate, properly secured in the bossings and at the bulkhead. The two stern tube bushes, aft and forward should have lengths respectively of 5 diameters over the liner and 3 diameters. The bushing should be machined from a solid casting to take neoprene rubber individual staves and properly locked. The bushes should be bronze ASTM B 143 Grade 2A (88-6-2-4).

The water lubricated stern tube bearings should be pressurized by electrically driven pumps with a stand-by automatically cutting in.

Experience indicates that for multiple screw vessels, the stern tubes must be contained in strongly framed and plated bossings, capable of withstanding the severe impact loads imposed. Open shafts and shaft brackets are considered unsatisfactory for these operations.

PROPELLERS

Icebreaking propellers for a number of years were made from nickel Vanadium steel with detachable blades - vessels with these propellers also carried summer type bronze propellers. This resulted in twice yearly dry docking, causing a loss of time and additional expense.

On some more recent vessels, however, solid nickel-aluminum-bronze propellers of "Superstone 70" have been used successfully. These later propellers usually have better efficiency than those of steel, can be severely deformed without breaking and are not subject to pitting. As this material can also be repaired successfully, it is therefore recommended for such propellers. Other compositions of equal properties have also been used successfully for propellers working in heavy ice.

Propeller nuts of "PILGRIM" hydraulically-fitted type, give a controlled high locking capability that is impossible to obtain with regular nut and spanner methods. This type of nut is also recommended for locking the removable tail shaft coupling. New types of propellers to ease the repair and replacement problems of this service are presently being developed.

ANCHORING ARRANGEMENT:

Loading on a vessel, when anchored in ice regions, is more severe than under normal conditions. Anchors, cables, windlass and securing arrangements should be strengthened for such conditions. It is recommended that the equipment numeral for the vessel be increased to the next higher grade. Material quality should be to Lloyd's U3 grade with an ultimate tensile strength exceeding 44.4 tons per square inch. Cast iron should not be permitted in any of the machinery or fitting and the anchor should be a high holding power model of appropriate weight.

STEERING ARRANGEMENT:

The total steering arrangement for cargo icebreaking vessels requires very careful consideration due to the exposed position of the rudder and the type of loading which will be encountered, even for these deep draft vessels. The design condition at the full power trial speed is used to determine basic rule scantlings and pumping power for the electro-hydraulic steering gear.

The rudder area should be increased above that of conventional vessels in order to improve the manoeuverability in ice. The design configuration, if an open water stern is adopted, should depart from conventional practice to some extent. Spade rudders cannot be recommended as the stock must carry all loads, which is to be avoided if possible. A modified horn rudder, where the horn is extended further down the leading edge and having an extra pintle fitted, would be advocated. With the high installed powers, potential vibration problem and loss of propulsion efficiency may eliminate a rudder of the "barn-door" type. Twin rudders have been considered in the past to be too vulnerable for this type of service but successful experience in the "MANHATTAN" has revived interest in a twin rudder arrangement, and provided these are correctly located and protected good results should be obtained.

An increase of 43% in the basic Classification Society rudder stock diameter requirements (or 192% of the basic section modulus) has been found to give successful service. These increased scantlings are recommended for cargo icebreakers. Pintles should also adopt this strength factor.

In addition to the appropriately sized rudder carrier, a steady bearing should be fitted in the rudder trunk as close to the bolting palms as possible. This is to minimize the bending moment on the stock when backing into the ice. To protect the palms and exposed stock when backing in the ice, an iceguard of very heavy scantlings should be fitted.

Steering gears of the electro-hydraulic 4-ram type have given successful service and are recommended for ice operations. The strength of this equipment should be increased, proportional to that of the rudder stock and no cast iron components should be permitted. Rotary-vane machinery has recently been fitted in ice class vessels and is proving satisfactory for this operation. This should be of extra strong design and construction and gears manufactured by A.E.G. or Brown Bros. are recommended.

Two independent hydraulic pumps and motors would normally operate in tandem to provide a hardover to hardover time of about 20 seconds, at trial speed. Adequate pressure relief valves to protect the gear from ice damage are desirable.

MACHINERY: COOLING SYSTEM

The sea water cooling of machinery presents a major problem resulting from blockage caused by pieces of ice finding their way into the sea inlet grids, strainers, etc. and in general, rapidly choking all the inlets. This, of course, leads to machinery stoppages, a situation which cannot be tolerated.

As a preventative, systems have been specially designed and improved over the years and the most satisfactory system in use on Canadian icebreaking vessels is described. It is applicable for diesel, diesel-electric or steam operated icebreakers or other vessels navigating in ice-infested water.

In order to obtain a margin of operational safety, the cooling systems are centralized and collectively fed from sea-boxes, a high and a low suction in each on the port and starboard sides. These are of the same capacity so that if one box becomes clogged, the other can be used, while de-icing is carried out on the plugged box and strainer.

Icebreaking vessels do not carry removable sea inlet grids as these are invariably lost due to ice pressure shearing the securing screws. Instead, the hull is perforated in way of sea boxes with drilled holes of 1/2” to 3/4” diameter. These holes are suitably spaced and in sufficient number to give an inlet ratio of at least 5:1 on each side of the hull, with all machinery being served simultaneously. On larger icebreakers with deep draft, 3/4” holes are used. Services which are continually required include:

– Cooling of propulsion machinery
– Cooling of ship service generators
– Ballast pumps
– Fire Pumps
– Sanitary pumps
– De-icing hot sea water pump, etc.
– Evaporator - distilling units

The sea water received by the sea-boxes is directed through a strainer, fitted with isolating valves, to a sea well built within the double bottom. From this, all suctions are taken through removable tail pipes which have appropriate isolating valves. In addition, all sea boxes, strainers, sea well, condensers, etc. are permanently vented to upper deck to release entrained air, prevent air locks and overheating.

Between the sea box and the strainer, a tee piece is fitted to receive the full discharge re-circulation from main propulsion and auxiliary machinery cooling systems. The recirculation system is a useful arrangement as it allows warm water to pass through the main inlet strainers and keeps them free of entrained ice to a great extent. It also allows the sea well to contain tempered water in the region of 60°F. This prevents the build up of ice on the circulating water piping and prevents overcooling of machinery in the case of faulty thermostats.

This arrangement allows a low velocity entrance to the sea boxes. For example, in a system designed with flow velocities in the cooling system of 7 feet/sec. and having a grid ratio of 5:1, the grid entrance velocity is 7/5 = 1.4 ft/sec. in temperate climates.

When in ice-infested waters, it is not uncommon to re-use approximately 2/3 of the warmed cooling water as recirculation. This means that only one-third of the total cooling water flow enters the sea box through the grids. The velocity therefore becomes: 1.4/3 = 0.47 ft/sec.

In cases where slush ice is prevalent, the two sea boxes may operate simultaneously. The entrance velocity therefore becomes approximately 0.47/2 = 0.23 ft/sec. [S]ea inlet strainers may be jacketted to receive hot sea water circulation and further enhance the advantages of this system.

The foregoing arrangements have proven their worth in service and are now used exclusively on all recent Canadian icebreakers.

For large vessels, the basic principles and features of this system are recommended, with only one minor change. For the low sea suction, the hull penetrations may be increased in size, with the reduced likelihood of ice occurrence at such drafts. The inlet ratio of 5:1 should be maintained but hole diameters up to several inches are recommended.

MACHINERY: MAIN PROPULSION

PROPULSION MACHINERY REQUIREMENTS & CHARACTERISTICS

Only certain types of machinery are suitable for professional icebreaking work. The following outlines the principal characteristics which are mandatory for the propulsion plant of such a vessel. These are desirable features for all vessels designed for navigation in ice, but are not essential, for example, for cargo vessels operating on such routes. This latter relaxation of requirements is possible because of the differing operating methods and purposes of a cargo ship. Nevertheless, the professional [icebreaker's] propulsion plant must be capable of:

1) Maintaining at least full load torque or greater on the propeller shaft throughout the propeller speed range, from full power free running in open water, through the bollard condition and at all lower revolutions down to stall. When immobilized in the ice, maximum power and torque are required at a condition corresponding to bollard condition, both ahead and astern. Maximum torque at lower revolutions down to stall is needed

frequently when the vessel is backed into heavy ice. In this case, not only is the maximum torque required, but the entire shafting system must withstand heavy shocks continuously as the rotating propellers advance into broken heavy ice. Machinery which cannot maintain full torque down to zero shaft revolutions without stalling is, therefore, unsuitable. Oversize slip couplings, which will operate at high slip to enable a diesel prime mover to maintain revolutions and power output, are inadequate. In icebreaking operations, the backing and filling manoeuvers demand rapid response to bridge orders for reversals. Couplings having adjustable slip are not well suited to this requirement and cannot deliver more than engine torque. In addition, sustained operation at full power with high slip necessitates special cooling arrangements for the coupling. As manufactured at present, the largest available such couplings are suited only for installation on small icebreakers, unless installed on the high speed end of the gears.

2) Withstanding sudden shocks from heavy ice contact with the propellers and sudden seizures if the propeller is jammed: this is a normal part of icebreaking work. It is now standard in specifications for Canadian icebreakers to require the propulsion system to be capable of coming to a full stop from full ahead or full astern in one revolution against the application of the full load torque from the propeller shaft.

3) Bridge control of the propulsion machinery is essential, due to the many occasions when rapid and completely reliable response is required. It is important to be able to call up full power quickly should the vessel suddenly slow up owing to increased ice resistance. Often, too, when wedged or stuck in ice, the vessel will attempt to work herself free by applying full power reversals at short intervals. Bridge control coupled with fast response of propulsion machinery is clearly important.

4) Prime movers which need not be brought to a full stop and reversed in order to provide a propeller shaft reversal, are desirable. While this limitation is not too serious with the reciprocating steam engine, which can be re-started with high reliability and can

be reversed in a few seconds, it is much less acceptable in the case of diesel machinery. The interval required for the reversal may be too long, as well as accompanied by the risk of failure to re-start if there is much external ice constraint applied to the propellers. During the reversal, it is important that the full load torque can be developed throughout the cycle to overcome such outside constraint.

From the above, it can be appreciated that the most satisfactory types of propulsion machinery for icebreaking duty are those which embody rugged reliability, rapid response, at least full load torque throughout the range of propellers' speeds from zero to full ahead or astern, capability of absorbing heavy shock through the shafting system, and unidirectional prime movers capable of full power output while the propeller shaft may be reversing or seized in ice.

The successful main propulsion machinery types for full professional icebreakers presently are:

1) Reciprocating Steam - (Skinner type)
2) Diesel Electric
3) Turbo-Electric (oil and nuclear)

Reciprocating steam machinery can be eliminated from further consideration as possible main propulsion machinery. This type of installation is unsuitable for large vessels as it has very low thermal efficiency, necessary powers are unavailable and weights are excessive. It is an old technology, of little importance today.

Electric drive, to date, is the most successful icebreaking machinery type. These are, in most instances, diesel-powered. Three exceptions to this are: the Russi[a]n heavy icebreaker "LENIN" which is nuclear fuelled, turbo electric; the Canadian heavy icebreaker "LOUIS S. ST-LAURENT" which is conventionally fuelled turbo-electric; the Canadian medium icebreaker "NORMAN MACLEOD ROGERS" which is gas turbine turbo-electric.

The electric drive motors, both diesel and steam turbine driven, are constructed to give a constant torque over the full speed range plus overloads of 125% rated load for two hours and 140% rated torque intermittently when stalled by ice. Deceleration shock loading is to withstand stalling in one revolution, without damage. These DC motors are totally enclosed, being watertight up to the shaft centreline and water-cooled through air-water double tube heat exchangers.

A diesel electric installation is a successful icebreaker machinery installation due to high load response rate, ease of control, reliability, cost and flexibility of layout. Maximum powers to date are about 25,000 hp though until recently, the multiplicity of suitable small diesel engines which were required contributed to excessive complexity of the engine installation. Recently developed higher powered engines could reduce the complexity and give successful results, together with the high-powered propulsion motors now available, up to about 50,000 H.P. with the possibility of using A.C. motors geared down to shaft R.P.M.

Turbo-electric installations have been introduced in recent years, having particular application to the larger powers. Only two have been operative so far, the "LENIN" and the "LOUIS S. ST-LAURENT". The reported laying up of the "LENIN" is apparently unrelated to the conventional components in the installation. The new Canadian turbo-electric icebreaker "LOUIS S. ST-LAURENT" has been in service for approximately one year and has been most successful in ice operations constituting a significant advance in the adaption of such equipment to icebreaking work. Total power is 24,000 normal to 27,000 horse power maximum divided between three screws.

The gas turbine turbo-electric vessel "NORMAN MACLEOD ROGERS" has recently entered service and first reports show favourable results.

As with the steam version, such a propulsion method has necessitated an advancement in technology to a significant extent.

Apart from the "MANHATTAN" no ice navigating cargo vessels presently in existence are known which have been designed to be capable of breaking through continuous ice fields of significant thickness, without icebreaker assistance. Their method of operation is therefore very different from that of an icebreaker, but due to their small size (draft specifically), the shock loading requirements are severe as ice ingestion into the propeller is frequent. For such commercial work, the types of machinery which have been successful are:

1) Reciprocating Steam
2) Direct-reversing, direct drive low speed diesels.
3) Geared diesels with overstrength gears and hydraulic couplings.

Their operating requirements are thus a significant relaxation over those of professional icebreaker and, in fact, are very little different from usual ocean-going requirements.

An analysis of the various features of this machinery discussion will show that for the fully ice capable bulk carriers, machinery requirements similar to a full professional icebreaker, are not necessarily required. Certain ice conditions and areas of operation will undoubtedly demand this very sophisticated machinery, but the economic penalties of such are very high indeed. For vessels which have deep drafts and thus adequate propeller immersion, a new set of machinery requirements may be tentatively posed, which will permit reliable ice operation of a commercial vessel in those portions of the Arctic presently of interest.

They are:

1) Adequate power to break through the ice which will be encountered, developing high thrust at the bollard condition.

2) Maintain good torque characteristics down to low shaft revolutions.

3) Provide a propulsion installation with the minimum number of features required exclusively for icebreaking, while still maintaining the safety and reliability of the vessel.

4) Have a high shock loading capability but without the necessity to operate continuously at high fluctuating loads.

5) Have fast and reliable reversing of the thrust direction.

6) Full bridge control of the main machinery, where possible.

7) Provide economical ocean operation.

It is thus considered that the present low speed, direct connected diesel engine and geared medium speed diesel engines will be able to perform in a satisfactory manner in this operation. The major disadvantage is that the diesel experiences a rapid reduction in torque at low speeds. This feature is only important during propeller stall, the occurrence of which is expected to be reduced considerably from that of a professional icebreaker. Nevertheless, additional air compressor and air receiver capacity is recommended in order to give the ability to make frequent starts.

Manoeuvering of both types of engines could be facilitated using controllable pitch propellers, giving the rapid thrust reversals necessary in the ice. The ocean portions of the route would benefit from such an installation and it technically represents the most satisfactory way of providing high bollard thrust, rapid thrust reversals and good free running economy for such vessels.

The excess power which is installed for ice operations is not economically usable on the ocean legs. The C.P. propeller permits selected medium speed diesels to be de-clutched, the remaining engines to be fully loaded. The C.P. propeller also permits feathering of the propeller and shutting down of selected slow speed diesels in multi-screw installations.

STEAM TURBINES

Lloyd's Register of Shipping does not approve of geared steam turbine main propulsion machinery, as presently designed, constructed and controlled, for navigation in ice. There are two primary reasons:

1) The turbine suffers mechanical shock and vibration due to the high deceleration imposed by ice impact on the propeller.

2) The turbine suffers thermal shock, which may result in distortion when the throttle is not instantaneously closed on stall or near stall of the propulsion system.

Stall requires the installation of oversize condensers to absorb the heat contained in the large volumes of superheated steam passing through the stalled turbine and producing no actual work.

One solution would be the use of hydraulic or electro-magnetic couplings which, to our knowledge, have not as yet been designed or manufactured in the sizes contemplated. These couplings should be placed between reduction gear input shaft and turbine output shaft to allow the turbine to run when propeller and gear are stalled, thus avoiding the stall shock. Weak-link shear couplings or spool pieces could be used, but are not considered to be anything more than a short-term expedient, until an improved system could be adopted.

It is to be noted that Lloyd's Register of Shipping for navigation in ice (not icebreaking) states:

> "Ice Class 1* - gearing: Torque increase 50%. Where turbines are used for the propulsion of ships intended for Class 1*, 1 or 2 ice strengthening, the propeller shafting is to be driven by electrical or other approved means capable of protecting the turbines from shock".

However, the many advantages inherent in a geared steam turbine installation, from operational and economic considerations, should make it worthwhile to seek a reliable method of eliminating the effects of shock. The deep immersion of the propellers of large vessels substantially reduces the probability of serious ice ingestion into the screws, thus reducing shock transmittal to the turbines. This coupled with an automatic control system which could close the steam nozzles at a very high rate, could eliminate the undesirability of such machinery from icebreaking operations. Full astern thrust would be obtainable by the use of controllable pitch propellers which would be the limiting factor as far as maximum S.H.P. per shaft is concerned. The standard reverse turbines might also be retained to give an ability to reverse the rotation of the shafting and propeller to free it from ice clogging.

GAS TURBINES

The success of recent gas turbine installations for high powered container vessels has opened up the possibility of employing this type of prime mover for ice class vessels. The difficulties encountered by a steam turbine installation in the event of ice stalling the propeller are not so severe in a gas turbine arrangement. A further advantage in the quick availability of full power should heavy ice be encountered with little warning.

Reversing arrangements would be similar to the steam machinery installation employing C.P. propellers.

SUMMARY OF MACHINERY INSTALLATIONS

From the technical point of view the diesel electric propulsion system should give the best results for a vessel navigating in ice conditions. Ease of control, availability of full power ahead and astern, low possibility of damage under stall and reliability with multiple prime movers are all favourable factors; high first cost, increased weight and fuel consumption being the main drawbacks.

An additional feature which might well be adopted is the provision of boost power for heavy icebreaking supplied from gas turbine generators.

The remaining propulsion systems described all have their place, depending on severity of ice conditions, maximum power required and size and draft of vessel.

The final choice for the most suitable machinery installation would depend on all these factors in addition to running costs and reliability, this latter point being of particular importance to maintain the desired yearly tonnage flow.

BOW AND STERN THRUSTERS

To improve manoeuverability and help to provide a fluid film for lubrication of the forward end, all recent Canadian icebreaking vessels are fitted with a powerful bow thruster. Also, some vessels are fitted with a stern thruster. These are recommended installations for all vessels working in the Arctic. To date, there has been no criteria established for the size of a thruster installation which is necessary for a given ship size under Northern Conditions. In addition to the wind and sea conditions, ice contact loading, as the ship pivots around an ice floe to follow a lead, is unknown. Experience indicates the power requirements would be very high for large vessels.

Two basic types are manufactured:

1) Transverse tunnel type, fitted with reversible controllable pitch propellers, hydraulically operated, driven by constant speed prime movers, “KaMeWa” or similar.

2) Pump type mixed flow drawing water from the bottom of the ship and discharging through large valves and nozzles port or starboard side, below the waterline, through remotely controlled valves. "Peacock Brothers", Montreal or similar.

For pump types, the prime movers can be either 2-speed electric motors with reduction gears or single speed electric motors with scoop controlled hydraulic couplings and reduction gears.

Prime movers can also be diesel engines or gas turbines. It is to be noted however that the propeller in tunnel type requires less horse power per ton of thrust than the pump type.

The selection of the bow thruster is dependent, to a great extent, on the propulsion plant considered, it is usual, with diesel electric and turbo electric propulsion plants, to divert part of their [electrical] energy to drive the bow thruster. With steam turbine and diesel plants, it becomes mandatory to install self-contained prime movers for the bow thrusters, either diesel engines or gas turbines.

For very large powers, the weight and space required makes the gas turbine installation attractive since amongst other things, most of the cooling is done by air. Large intake and exhaust ducts are required however.

The pump type of thruster unit has been developed primarily for Canadian icebreakers and has given satisfactory service. It has a primary disadvantage in that the thrust to horse power ratio is less than for the transverse ducted type.

However, in ice-covered waters, this feature is overridden by the sea suction being in the ship's bottom, resulting in minimal ingestion of broken ice and debris. A large forward seabay, similar to that in the engine room, but permitting higher flow velocities through the suction perforations, passes water through the pump, for discharge to the appropriate nozzle. Thus the choking problem associated with the open duct type of bow thruster is minimized with this installation, resulting in an improvement in reliability and reduction of potential maintenance problems.

Considerable work in defining the powers necessary for these large vessels would be required.

AUXILIARIES

On steam vessels, the ship service generators would be condensing turbo-generators. At least one diesel emergency generator would also be carried. The capacity of this unit would be sufficient to maintain navigation aids, steering gear, lighting, and some of the propulsion machinery essential services, as well as bilge and fire pumps.

The boilers would be rated to meet the maximum power demand for propulsion, increased tank heating, accommodation heating, and de-icing systems. Individual boilers would be rated to provide the best economy for open water as well as full icebreaking power.

The main feed pumps would be driven from the main reduction gear for open water service and declutched and electrically driven when navigating in ice and icebreaking. All the other pumps, air compressors, etc. would be electrically driven. An auxiliary self-contained, automatic type heating boiler for accommodation heating is also recommended, in event of breakdown in Northern latitudes[.]

HEELING SYSTEM

All recently constructed professional icebreakers have been fitted with transverse heeling systems.

The purpose of these systems is to "rock" the vessel to port and starboard as rapidly as possible to assist in freeing it from the grip of the ice when further progress, either ahead or astern, is impossible.

An additional benefit from the heeling action is the wetting of the sides of the vessel for a short distance above the waterline, thus reducing the friction between the shell plating and the ice and snow.

For the large vessels under consideration in this study, which tend to have high initial stability, the quantity of water required to give the necessary heeling action is considerable. The normal system fitted in icebreakers consists of two wing tanks, one port and one starboard, connected by a large diameter crossover incorporating an axial flow pump. Controls are fitted to give a regular heeling action to port and starboard.

A basically similar system could be fitted to the bulk carriers in question, using several sets of wing ballast tanks, each set having its own pump or impeller. In the MANHATTAN it is understood transverse controllable pitch bow thruster units, mounted in tunnels, were used to transfer large quantities of water between the wing cargo oil tanks, these being filled with water ballast for the test voyage.

Other methods have been suggested to assist in the wetting action of the shell, including water jets through the plating either above or below the waterline, or the use of the bow thruster to agitate the water along the forward part of the vessel. A detailed design investigation is recommended in this regard before deciding upon the preferred system.

FUTURE PROPULSION SYSTEMS

The high power requirements of future large icebreaking bulk carriers will dictate that these vessels be at least of the twin screw type, possibly triple screw. This is indicated by a number of large convention[a]l bulk carriers and tankers already built of the twin screw type, the main reasons being the reduction in the propeller diameter and weight required. An addition is the improved reliability of multiple screw installations.

The icebreaker type of d.c. electric drive for these high powers, although extremely flexible and robust, is very costly. Diesels of medium speed range and of necessary power require a multiplicity of prime movers, leading to greater engine room space requirements and complicated piping systems. Also, electric motors for the powers required are difficult to obtain.

The steam turbo-electric system, on the other hand, requires very sizable boilers, in spite of the low water rates now achieved by the use of higher steam cycles and reheat.

A possible alternative to the use of d.c. electrics which is worthy of serious consideration at this time is the use of a.c. electric drive. Penalties must be paid in a reduced range of sp[e]ed variation, reversing difficulties and other problems related to frequency control. However, bulk carriers are commercial vessels, not requiring the great flexibility of a professional icebreaker.

The development of very large variable pitch propellers would permit elimination of the problems of frequency control at low speed and powers and reversing. An added feature is that under conditions of a normal ocean passage, auxiliary generators would be minimized, being only required when operating in the ice.

Nuclear propulsion would only replace the boiler in a conventional turbo-electric installation. For the commercial use of this source of power, it is considered that there are too many problems, political and technical, standing in the way of a successful operation at this time.

OUTFIT

Beyond the usual outfit items required, there are many considerations relating to preparing a vessel for Arctic operations which must be defined more completely. These include specialized equipment, habitability and additional features for the safe operation of existing standard equipment. Extra equipment required for operations in the ice are related to two specific problems: navigation and safety.

A most important though somewhat costly navigational assistance in the ice is the employment of a helicopter. Ice reconnais[s]ance will play a very important part in selecting the most appropriate route, by locating leads, thin ice, ridges and other features of interest for efficient operation of the vessel. This machine necessitates elaborate ship facilities, and is costly to procure, operate and maintain. These include: flight deck, hangar, servicing and maintenance equipment, fuel storage, well trained crew and appropriate accommodation.

The helicopter appropriate for such work is neither large nor elaborate. Its function is to carry a trained observer for a reasonable time interval on his duties, ahead of the ship. Good visibility and a suitable radio are necessary. There are a number of vehicles which are appropriate, with selection coming only after careful study of all factors involved. For the service under consideration in this study the carrying of a helicopter may not be necessary. However, a landing platform on the vessel is [recommended] for emergency transfer of personnel.

Adequate survival equipment, while hopefully never required, must be carried in instant readiness on board the vessel at all times. Specialized equipment should be selected for use should the vessel be abandoned or disabled to await assistance. Ship abandonment in the Arctic could develop into a disaster of major proportions, unless adequate precautions are forthcoming.

In the event of disablement of the vessel, but not its loss the basic survival elements of shelter, food and medical supplies would be still intact. Power, heating and communications equipment are normally the only special requirements to be provided while awaiting assistance. An emergency generator is essential while a suitable self-contained heating boiler could be located near the generator.

All other safety features require careful consideration for northern operations. Davits for lifeboats, firehoses, hydrants and pumps, foam canisters, CO_2 lines and nozzles, engine room emergency shut down trips, etc. must have appropriate provision made for instant operation at the lowest temperatures.

Basic questions which must be answered in relationship to all this equipment is:

(a) what elements may disrupt the functional ability?

(b) what effect has low temperatures on the operation and materials?

(c) can the minimum manpower easily and quickly make operable any non-functioning safety equipment, even under the most adverse conditions?

The successful functioning of these safety elements is of vital importance, requiring careful effort to achieve the design goal.

Habitability will have a great effect on the efficiency of the crew during their watchkeeping and on their general morale. Improved habitability is primarily strict attention to detail coupled with a judicious use of appropriate materials and equipment.

Thermal insulation applied in the accommodation and working spaces to the interior of all exterior decks and bulkheads plus frost line limitation serves two primary purposes:

(a) reduce the thermal conductivity and therefore rate of heat loss

(b) eliminate cold spots which would cause condensation or frost patches.

The importance of maintaining the accommodation temperatures at a comfortable level is self evident. Condensation in the interior spaces presents a morale problem, due to dampness. The naturally cold areas around windows, sidelights, doorways, etc. are thus subject to condensation and frost as the humidity immediately adjacent to these increases locally to a large extent.

Heating and ventilating are primary of concern both to maintain the comfort level in the living and working spaces and to maintain a continuous cycle of fresh air. Air movement helps to reduce condensation and keeps the accommodation dry. Systems used with success are high velocity hot air supplied from a central steam-heater - filter unit with partial electric reheat in the individual spaces. This provides both the necessary air changes and heat input. Supplementing this are convector heaters to become operative during extreme lows. Air conditioning can easily be tied into this system if felt necessary.

The total heating, ventilating and air-conditioning system would require consideration of all details and adequate knowledge of all components to produce the conditions which the crew ultimately will demand and which in fact, are desirable for working in this area.

The other items coming under the heading of OUTFIT requiring special attention at the design stage of a vessel equipped for cold weather service include:

<u>Deck Machinery</u> –

Where possible this should be of the totally enclosed type with protective covering to prevent the build up of ice or snow on all moving parts. All motors driving electrical deck machinery should have internal heaters continually energized while the equipment is lying idle and automatically disconnected when in use. In general, electrical equipment is preferred to steam driven equipment to avoid freezing problems in steam and return lines.

Where exposure of moving parts is unavoidable, suitable de-icing should be available, either steam, hot sea water or exhaust from a portable gas turbine. This latter having the advantage of not contributing to any further ice build up from a system using steam or water.

De-icing should be fitted to the hawse pipes and anchor pockets. Heated shelter should be available for personnel manning deck machinery for any length of time, or on duty forward.

Wheelhouse windows -

Electrically heated windows are required, suitably spaced around the wheelhouse. These should be heavy duty type able to cope with severe icing conditions. Heated window wipers and clear view screens are also recommended. A catwalk should be fitted under the windows to give access for manual clearing of snow or ice.

PORT FACILITIES

UNLOADING PORT: EUROPOORT - ROTTERDAM

A new ore terminal is at present under construction in Europoort which will combine the availability of deep water and high unloading capacity essential for the economic transportation of bulk cargoes.

Phase one of this project is due for completion in October 1970 and will provide almost 2000 feet of quaywall with a water depth of 59 feet at normal low water. Phase two providing a water depth of 69 feet at low water is planned for completion in early 1973.

The channel approach is at present limited to 62 feet draft vessels but by April 1971 this will be deepened to allow 65 feet draft vessels to navigate. An unloading rate of 4000 tons per hour will be available at each quay. There are no limitations regarding the length or beam of the vessels using these terminals.

For the purposes of this study, therefore, it can be taken that in the immediate future facilities will allow vessels of 56' draft to berth and by early 1973 vessels of up to 65' draft will be accommodated.

Reference to figure 4 in Appendix No. 1 shows that for a normal ocean going bulk carrier 56' draft corresponds to 180,000 tons deadweight and 65' draft to in excess of 200,000 tons deadweight.

However, for ice capable vessels two factors apply in this context:

1) Loss of deadweight due to additional ice stiffening and more powerful machinery.

2) Possibility of changes in basic dimensions, in comparison with normal bulk carriers, for efficient icebreaking vessels.

For these reasons, for the purposes of this study and rounding off figures to the nearest 10,000 tons, a realistic maximum deadweight under present conditions would be 100,000 tons, and under future conditions (1973) 150,000 tons. It should be noted that, partly due to technical difficulties in construction caused by the severe loading conditions, the maximum size of present day ore carriers has tended to fall behind those of oil tankers. The lack of suitable terminal facilities has also played a part in this disparity. As far as is known, the largest such vessel at present under construction is of 159,000 tons deadweight, although combined ore/oil vessels of up to 260,000 tons are on order.

LOADING PORT - MILNE INLET

Although a detailed examination of the loading facilities does not form a part of this study, the following comments are included for general information.

Due to the availability of deep water, it is assumed that the loading facilities will match the unloading port as far as maximum draft, length and beam are concerned.

Loading rate has been assumed also to be equal to the unloading rate, it being remembered that the rate of de-ballasting may be the limiting factor in this regard.

It would appear that arrangements will be required to provide reasonably ice free conditions at the loading berth, including the removal of free floating ice which might prevent successful docking.

This might be undertaken by suitable icebreaking tugs, which would also be available to provide docking assistance on the vessel's arrival and departure as required.

PASSAGE DRAFTS

Apart from the approaches to the terminal ports, as detailed in the preceding sections, ample depth of water exists over the proposed route to accommodate the largest types of vessels, and no restriction on deadweight on this account is contemplated.

SEASONAL LIMITATIONS

As stated elsewhere in this study, the Federal Government is at present drafting anti-pollution regulations with particular reference to the Arctic. These regulations, as the name implies, are designed to prevent as far as practicable pollution of the Northern environment from oil spills or other accidents. They will be principally directed toward bulk oil carrying vessels, but all vessels which carry oil either for their own use or as cargo will, it is anticipated, be affected.

From preliminary information to date, it appears that the Arctic will be divided into zones, and all vessels entering these zones will be required to meet regulations covering ice strengthening, propulsion horse power, navigational aids, etc.

The regulations for each zone are expected to differ according to the season of the year.

The existing Classification Societies (Lloyd's A.B.S., etc.) ice classes will have a place in the new regulations, but in addition two new ice classes may be developed specifying strength beyond that required by Ice Class 1*. These new ice classes will presumably encompass the present "Icebreaker" Class described in the section on Classification Rules.

Thus, until these new regulations are published, which is expected to be later this year (1970), no hard and fast decisions can be made as to the ice class to which any new vessels for Arctic Navigation should be designed and built.

However, from practical considerations and examination of the structural arrangements resulting from the application of the rules for the varying ice classes, taken in conjunction with the detailed knowledge now available of the ice and other environmental conditions, recommendations can be made as to the seasonal limitations of the vessels concerned.

In this connection the following table is taken from Lloyd's "Rules for Construction of Steel Ships, 1970"

"114. Strengthening for Navigation in Ice. Where an ice class notation is desired, additional strengthening is to be fitted in accordance with the special requirements given in the Rules which are based on Baltic conditions. Four classes of ice strengthening are detailed in the Rules: -

Ice Class 1* strengthening is for ships intended to navigate in extreme ice conditions.

Ice Class 1 strengthening is for ships intended to navigate in severe ice conditions.

Ice Class 2 strengthening is for ships intended to navigate in intermediate ice conditions.

Ice Class 3 strengthening is for ships intended to navigate in light ice conditions.

It is the responsibility of the Owner to determine which notation is most suitable for his requirements."

It will be appreciated that the terms describing the ice conditions are relative only, and are based on Baltic ice conditions which are not comparable with those met with in the Canadian Arctic. In addition, much navigation in the Baltic is in the wake of icebreakers and the vessels concerned have only broken ice to contend with.

For the large vessels considered in this study, this condition would not apply. Even if an icebreaker were available on a continuous basis, expert opinion has been given that the icebreaker would not proceed directly ahead of the ore carrier, the danger of being run down being too great, due to the long stopping distance of these heavy vessels.

In the regular service necessary to provide a steady movement of ore from Milne Inlet, only that portion of the route where the most severe ice conditions will be met (Milne Inlet Eastwards toward the Greenland Coast) need be considered in the context of this section of the study. In the section where average speed is computed, of course, conditions on all sections of the route are pertinent. Structural arrangements, however, must be sufficient to meet the worst seasonal ice cover.

(1) Unstrengthened Vessels

These vessels should avoid contact with ice at all times. While it has been the practice for vessels in this Class to join the annual Arctic supply mission, this has always been undertaken in convoy, under the protection of Government Icebreakers. Such vessels could, on the average, expect about six weeks during which conditions might permit operations into Milne Inlet.

However, a bad ice year in Baffin Bay or a pressure situation there would bar them completely. Continuous icebreaker assistance would probably be required along most of the route.

Such vessels would have difficulty in obtaining marine insurance, and in any event Canadian Government regulations relating to Arctic Shipping will probably bar such ships completely.

Although it is true that the shell plating thickness of the very largest vessels of this class approaches that of some of the smaller icebreakers, the internal stiffening is proportionately weaker, leaving large panels unsupported. Serious damage, including piercing of the plating, could therefore be expected as a result of contact with floating ice fragments. Confirmation of this was obtained during the first Manhattan voyage, when large penetrations were made in the original unstrengthened hull, even though this was only exposed at a considerable distance below the vessel's waterline, while the ice stiffened areas suffered practically no damage.

These vessels, therefore, are not considered suitable for the proposed service.

(2) Ice Class 3

A vessel with this minimal stren[g]thening can only safely tackle light scattered ice. These conditions, on the average, are only present during part of August and September. Such a vessel therefore could only make one voyage per year and would contribute little to the total tonnage flow. This class is not further considered in this section.

(3) Ice Class 2

A vessel with this stiffening, particularly of the larger sizes (100,000 ton deadweight and upwards) where the shell plating is thicker than in the smaller vessels, should on the average be able to make only two loaded voyages per year. This class is not therefore considered suitable.

It is entirely possible, in addition, that these classes (2 and 3) would be prohibited under the new regulations. Insurance would be much higher than for more highly stiffened classes.

(4) Ice Class 1

As described in the Section on Classification Rules, vessels with this class should be able to navigate (with extreme caution) through sheet ice and large floes up to 8" or through broken ice up to 2 feet in thickness. It should be pointed out that only normal power would be available in this class of vessel, leaving no margin to break free from pressure or through ridges.

This class of vessel would have a navigational season of 3 to 3½ months on the average, but might well require icebreaker assistance under severe conditions during this time. Round trip voyages would be 3 to 4. This class is not considered suitable under the context of this study.

(5) Ice Class 1*

This class is the highest at present covered by Lloyd's construction regulations. A formula is included which relates the shell thickness to the installed propulsive horse power. There is however an upper limit to this thickness (1-1/4") and increase in power does not require additional internal stiffening.

It will thus be seen that a large increase in power to provide icebreaking ability in a vessel of this class could create a dangerous condition in that the hull would be inadequate for the greater thrust, when traversing heavy ice. Vessels in this class should, therefore, be considered as normal ocean going ships, stiffened to withstand contact from moderate thicknesses of broken ice and able to proceed steadily through sheet ice of up to about 12" in thickness. They would not, however, have sufficient power to take care of unusually heavy conditions or free themselves from pressure.

These seasonal limitations would allow a navigation period of about 4 months, providing sufficient time for 4 to 5 voyages.

(6) Icebreaker Class

The design of a successful vessel of the icebreaker class may be divided broadly into two areas: structure and propulsion.

As stated in the section of this study covering Classification Society Rules, the development of the structural arrangements necessary to withstand the ice forces imposed on an icebreaker is undertaken by the designers of each vessel.

Recent experience gained from Arctic voyages of the Canadian Government icebreakers JOHN A. MACDONALD and LOUIS S. ST-LAURENT, designed by German & Milne, and the icebreaking tanker MANHATTAN, for whose conversion German and Milne were retained as consultants, have demonstrated the effectiveness of the theory and practice employed in developing hulls capable of withstanding very severe ice conditions.

The successful ice trials undertaken in April and May of this year (1970) by the LOUIS S. ST-LAURENT, in Pond Inlet and its approaches, when ice conditions were at their heaviest, are of particular interest when viewed in the scope of this study. These trials, and those carried out in the spring of 1969 on the Canadian Icebreaker WOLFE, both personally managed and attended by German and Milne, have provided the first available full scale results enabling predictions to be made of the performance of powerful vessels in heavy continuous ice cover.

It can now be stated, therefore, that providing all factors are correctly taken into consideration, it is feasible to construct large vessels which will safely withstand contact with the ice conditions which will be met with on the Milne Inlet-Rotterdam route on a 12 month basis. This does not, however, include heavy contact with icebergs, which must be avoided at all times. The two previous sentences apply to the structure of the vessel only, the provision of adequate thrust to propel the specially strengthened vessel through the ice fields being the next consideration. It will be appreciated that the form and proportions of the vessel will play a large part in the determination of the thrust and horse power required for differing ice conditions, as they do indeed for open water service.

However, the many years of experimentation and full scale trials which have contributed to the efficient hull form of present day vessels are not as yet available for the solution of the ice powering problem. The trials just completed in Pond Inlet are thus extremely timely in providing the full scale data essential to correlate the results from certain previously conducted tests in ship model tanks, using scale model vessels and ice.

Calculations and predictions have been made, therefore, of the powering requirements for the range of vessels covered by this study in the anticipated seasonal ice conditions. Two sets of calculations were undertaken, one using conventional bulk carrier forms and proportions but with the substitution of an icebreaking bow for the conventional bow, and one with forms and proportions differing substantially from the normal ocean going vessel, modified to reduce the resistance of the hull when breaking ice. As might be expected, the power for the modified vessel, when transversing the same ice at the same speed, is [significantly] below that for the more normal form.

150,000 ton deadweight vessel	"Conventional" Form	"Icebreaking" Form
S.H.P. for 5 knots steady speed 10/10 ice cover, landfast, 6' thick	190,000	125,000

The substantial saving in first cost, operational cost and weight in utilizing the "icebreaking" form is apparent from this example; similar savings are anticipated for other vessel sizes and speeds.

For these reasons, therefore, the following seasonal limitations are based on the assumption that the vessels concerned will be designed and constructed to the "icebreaking" form. To avoid confusion over terms it should be noted that this does <u>not</u> designate the normal type of vessel with the addition of an icebreaking bow.

As noted under the section on Port Facilities, the largest icebreaking vessel which it is anticipated could use the new terminal at Rotterdam will be of 150,000 tons deadweight. From volume II average ice conditions should not exceed 6' in thickness; the example given therefore indicates the predicted maximum calculated power requirements. For the 100,000 ton deadweight vessel of "icebreaking" form, a figure of 101,000 S.H.P. has been obtained, and for 50,000 tons - 75,000 S.H.P. A detailed design study on these vessels might indicate some increase in the above power figures to provide a margin for unusually severe ice conditions.

From these results, and taking into account all relevant factors covered elsewhere in the three volumes of this study, it is considered that it would be technically feasible to provide a year round service from Milne Inlet. This statement must be qualified by repeating that this service would not be easily accomplished; highly specialized vessels and fully competent crews would be required, delays are inevitable, particularly in the initial stages until crews become familiar with the new skills essential to navigate a vessel in ice, both by day and during the long winter darkness. Unusually severe conditions are bound to occur, bringing the vessel to a standstill until she can free herself or by assistance from another vessel, major mechanical breakdowns, although kept to a minimum by careful design and regular maintenance, cannot be ruled out entirely and might entail the assistance of a professional icebreaker.

For these reasons, it would be prudent for the first year of operation to anticipate a "closed" season when conditions are at their worst, on the average from mid February to mid June, giving an eight month operational season.

ANNUAL TONNAGE MOVEMENT

From the section on Seasonal Limitations it will be noted that vessels to Class 1* and Icebreaker only are considered suitable for prolonged service on this route.

"A" Vessels to Class 1*, average season, mid July - mid November (four months), average round trip voyages, 4 to 5. The larger vessels in this group should prove more efficient than the smaller ones when in ice.

Vessel, deadweight tons	Tonnage, 4 voyages	Tonnage, 5 voyages
50,000	200,000	250,000
100,000	400,000	500,000
150,000	600,000	750,000

<u>Notes</u>

1) First vessel assumed to be in position to enter ice at first opportunity, mid July.

2) Possibility of more than 1 vessel making 5 voyages is small.

3) To allow for unforeseen delays, it is reasonable that calculations be made on a basis of 4 voyages per vessel, as is undertaken in the following table:

Vessel	Annual tonnage 5 vessels.	Annual tonnage 10 vessels.
50,000	1,000,000	2,000,000
100,000	2,000,000	4,000,000
150,000	3,000,000	6,000,000

<u>Notes</u>

1) Average sea speed open water ocean passage 14½ knots loaded.
2) Average sea speed open water Baffin Bay & Davis Strait 12½ knots (fog and icebergs expected)
3) Average sea speed Northern Baffin Bay and Pond Inlet when ice present, 6 knots.
4) Extra day allowed early and late season.
5) Approx. 3 days allowed to enter and leave Rotterdam and unload and re-fuel.
6) Approx. 2 days allowed to enter and leave Milne Inlet and load.
7) Dry docking etc. undertaken during winter and not allowed for.

<u>“B” Vessels of Icebreaker Class</u>

1) <u>8 month season - mid June to mid February</u> - average round trip voyages, 9 - 10.

Vessel Deadweight tons	Tonnage, 9 Voyages	Tonnage, 10 Voyages.
50,000	450,000	500,000
100,000	900,000	1,000,000
150,000	1,350,000	1,500,000

<u>Notes</u>

1) First vessel assumed to be in position to enter ice at first opportunity, mid June.

2) To allow for unforeseen delays, it is recommended that calculations be made on a basis of 9 voyages for vessel, as in the following table:

Vessel	Annual tonnage 2 vessels	Annual tonnage 4 vessels
50,000	900,000	1,800,000
100,000	1,800,000	3,600,000
150,000	2,700,000	5,400,000

<u>Notes:</u>

Generally as for ice class 1* but with larger number of days allowed as a margin for unexpectedly severe ice conditions.

2) <u>12 month season</u> - average round trip voyages, 11 - 12

Vessel Deadweight tons	Tonnage, 11 Voyages	Tonnage, 12 Voyages
50,000	550,000	600,000
100,000	1,100,000	1,200,000
150,000	1,650,000	1,800,000

<u>Note</u>:

1) For a vessel making 12 round voyages per year, little down time is available for dry docking, repairs or maintenance and it is recommended that calculations are made on a basis of 11 voyages per vessel, as in the following table:

Vessel	Annual Tonnage, 2 vessels.	Annual Tonnage, 3 Vessels.
50,000	1,100,000	1,650,000
100,000	2,200,000	3,300,000
150,000	3,300,000	4,950,000

Notes:

1) Average speed in 10/10 ice during winter 5 knots

2) Other conditions similar to those listed under “B” (1).

CAPITAL COST

To fully evaluate the effect on the first cost of the vessel of the various ice classifications and other design and specification changes required for efficient navigation in ice, would require the preparation of a set of detailed ship designs.

This work being outside the scope of this study, reliance has been placed on past experience and cost formula based on the additional weights and horse powers associated with ice capable vessels, as indicated in the graphical presentation of ship data in Appendix No. 1.

These estimated costs are an average of Japanese and European construction at current rates and are in millions of Canadian dollars. It should be emphasized that they should be taken as indicating trends rather than as exact price estimates, this being particularly true in the larger sizes of vessels for which data is lacking. Building costs are steadily rising each year and prices for future delivery can be expected to be in excess of those given below.

Deadweight Tons	Normal Vessel	Ice Class 3	Ice Class 2	Ice Class 1	Ice Class 1*	Icebreaker Class
50,000	6.5	7.6	7.8	8.0	8.5	13.1
100,000	10.5	12.0	12.3	12.6	13.3	21.4
150,000	13.5	15.2	15.5	15.9	16.8	27.6
200,000	17.0	19.0	19.4	19.9	21.0	35.0

It should be noted that the increase in costs indicated for the various ice classes are due to:

(a) Increases in steel, outfit and machinery items for ice capable vessels, including additional automation, extra navigational instruments, etc.

(b) Increase in dimensions of vessel in order that the original deadweight may still be carried.

(c) Increases in heating, insulation, de-icing equipment, etc.

(d) For icebreaker class only, increase in power of machinery.

(e) Costs for icebreaker vessels approximate estimates only. Detailed design study necessary for more accurate figures.

OPERATIONAL COST

The purpose of this section of the study is to illustrate the effect of ice classification on the operating costs of the large bulk carriers considered suitable for the proposed trade.

A detailed calculation of the operating costs of a normal ocean going bulk carrier has not been undertaken, the increased costs only being considered, which may be added as desired by the ship owner to his normal costs to obtain the total operating cost for this particular service.

These increases may be summarized under the following headings:

(a) Increased first cost, giving increased capital charges.
(b) Increased insurance premiums.
(c) Increased fuel and [lube] oil consumption.
(d) Increased maintenance costs
(e) Increased time at sea due to loss of speed in ice.
(f) User charge for icebreaker assistance when required.
(g) additional crew (ice pilot) if carried.

(a) The estimated first cost for each size and class of vessel are listed in the section on Capital Cost, from which the increases may readily be obtained over a normal ocean-going vessel. Financing arrangements are normally such that the capital charges amount to between 50% and 60% of the annual operating cost; thus the effect on this figure from the increased cost of the vessel may be estimated.

(b) A detailed [treatment] of the present insurance position for vessels entering Arctic waters is contained in the section on that subject, and reference to the figures contained therein will give the increased operational cost from this item for each voyage.

(c) For the vessels up to and including ice class 1* it is not recommended that the propulsion machinery be substantially increased in power. For these vessels, therefore, little change in fuel costs should result; it being assumed that fuel would be taken on in Europoort for the round trip, unless a storage depot is established at Milne Inlet.

It is estimated that daily fuel consumption would be increased by about 10% due to the slightly larger machinery to handle the heavier vessel, and to increased boiler capacity for accommodation and fuel and water tank heating and de-icing.

For icebreaking vessels, however, large increases in power are required, as indicated in the following table:

The figures given are for vessels with "icebreaking" dimensions and form and might require some modification as a result of a detailed design study.

Vessel Deadweight tons	S.H.P. Normal Service	S.H.P. Icebreaking Services
50,000	16,000	75,000
100,000	23,000	101,000
150,000	30,000	125,000
200,000	36,000	149,000

In order to arrive at increased fuel consumption for these vessels it is assumed that the additional power will only be used as necessary when in ice; for the open water portion of the route power to be reduced to normal.

Vessel	Total fuel consumption divided by consumption for open water service on the same route	
Deadweight	8 months season (9 voyages)	12 months season (11 voyages)
50,000	2.05	2.65
100,000	2.00	2.60
150,000	1.95	2.55

By way of example, therefore, the average fuel consumption for a 100,000 ton vessel for an 8 month season would be twice that for a normal vessel of that capacity steaming the same distance.

To facilitate calculations by Owners using the above factors, reference to Volume II of this study will show that the round trip distance, Milne Inlet - Rotterdam - Milne Inlet is 6,860 nautical miles. For normal ocean going service fuel costs amount to between 15% and 20% of the total operating cost.

(d) Some increase in repair and maintenance costs for vessels working in heavy ice can be expected although this increase would be reduced when considering the heavily strengthened icebreaker class. Annual drydocking would be essential to check for underwater damage to hull, propellers, rudders, shafting, etc. Bottom paint would be stripped by the action of the ice, especially in the bow region and at the waterline. Some re-welding of shell seams & butts in way of the icebreaking bow may be necessary, and local setting in of the plating may be experienced after contact with hard ice.

It would be prudent to arrange for inspection of the stern gear, in particular propeller tips, by divers at Europoort after each voyage, until operational experience is gained in this arduous service.

Routine maintenance should be closely supervised, due to the possibly serious results from a breakdown in Arctic waters, far from repair facilities. Additional spare parts should be carried for all essential items. Ample supplies of food would be essential.

(e) For the round trip distance of 6860 miles, normal days at sea for ocean service at an average loaded speed of 14½ knots and an average ballast speed of 15½ knots would be 19, excluding final approaches to loading and unloading ports at reduced speed. Typical round trip steaming times for different seasons are estimated to be: (excluding loading, unloading, etc.)

Summer (some loss in speed required due to presence of icebergs and fog)	20 days
November (light ice)	23 days
Winter (February - May, heavy ice)	29 days
June - July (heavy ice, but becoming weaker)	25 days.

Approximately 5 days should be added to each of the above times for loading and unloading. In addition a margin of 2 to 3 days is recommended for each trip outside the summer months for possible delay in ice.

(f) No figures are available at present regarding possible user charges for government icebreakers, but these might be substantial in view of the high operating costs of those expensive and powerful vessels.

(g) Besides the addition of an ice pilot (who could be dispensed with when experience is gained by the vessel's crew), it could be advantageous to supplement the engine room complement so that emergency repairs could be carried out without delay. Continuous watch on all machinery components when working in heavy ice would be recommended, either visually or by automated means.

Improved medical services are indicated in view of the increased danger of accidents and the remoteness of outside assistance, especially for the winter voyages.

INSURANCE

The rates, availability and coverage attained for vessels operating into the Arctic will influence the economic and ultimately the technical operations of vessels concerned. To date, there is little experience for ships in the Lloyd's Ice Classes discussed, and none for the icebreaker class, operating in major ice conditions. However, contact has been made with underwriters concerning this field and some very tentative quotations have been received. To date, commercial vessels operating into the North have done so only in selected areas during restricted seasons, usually with icebreaker escort.

Canadian Government vessels are all self insured, with damage being fairly minimal in ice conditions. This is primarily because:

(a) very careful design based on long experience of these types of vessels.

(b) the vessels are suited to their roles (escort icebreakers, supply and research vessels.)

(c) they are manned by very experienced and capable officers.

(d) the Captains' do not have to take undue risks due to economic pressure.

While commercial operations should eventually be able to achieve the first three points, the latter point indicates that risks may necessarily be higher, than for government vessels.

When insurance rates are quoted, the main features which will go towards determining risk are:

(a) area of operation; effected by environmental factors, hydrography, communications, other prevalent dangers.

(b) route; features of inbound and outbound routes related to hydrography, environment, etc.

(c) escape route; provision to move to southern area due to occurrence of unusual happening on projected route. Risks involved on these alternates.

(d) ship; features of its ability to confront and overcome normal and abnormal dangers, ability to navigate under very heavy ice conditions, all with a minimum of damage, ice classification.

(e) Master of the Ship; ability to handle the vessel in the ice, knowledge of the ice and northern conditions, experience in dealing with ship problems in the North.

With operating experience in the North, skills will be improved, methods developed and new ideas introduced which would improve the safety of the vessel, thereby lowering attendant risks. Insurance coverage would then become easier to obtain, rates would become lower and hopefully a degree of normality would be introduced for northern operations.

At the present time, therefore, the following rates, based on preliminary quotations, are given as a guide only to the insurance question, and variations can be expected.

These premiums are all in addition to the normal insurance cover for ocean going service and apply to each voyage made into Arctic waters. In other words, [s]hould the vessel concerned make 10 annual voyages to Milne Inlet, total insurance costs would be as for ocean service plus ten times the additional Arctic premium.

Vessel Type	Additional Arctic Premium per Voyage
Unstrengthened Vessel	3½% of insured value
Class 3	3% " " "
Class 2	2½% " " "
Class 1	1-3/4% of " "
Class 1*	1¼% of " "
Icebreaker	¾% " " "

NOTE: a deductible amount would apply to every claim.

The above are for the summer navigation season (August - September) and double these rates have been mentioned for extension beyond or before that period. However, a 12 month season was probably not envisaged when this statement was made, and winter rates, in particular for the early years of operation, could be expected to be high. Classes below icebreaker in strength are unlikely to receive cover of any description for service beyond the short summer and fall season.

Doc. 8: Northern Associates (Holdings) Ltd., Marine Environmental Report; Queen Elizabeth Islands, Volume 1: Summary of Ice & Weather Conditions, Prepared for Imperial Oil Limited, 12 January 1972.

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NORTHERN ASSOCIATES (HOLDINGS)
LTD.

MARINE ENVIRONMENTAL REPORT

QUEEN ELIZABETH ISLANDS

VOLUME 1.

SUMMARY OF ICE & WEATHER CONDITIONS

PREPARED FOR

IMPERIAL OIL LIMITED
CALGARY.

January 12, 1972.

INTRODUCTION

The purpose of this report is to provide background information on the ice and weather conditions for the central region of the Queen Elizabeth Islands. The following ten aspects of the subject have been examined, each of which constitutes a section of this report and comprise VOLUME I.

Section 1 describes and depicts in map form the different types of ice normally present in specific areas of the Queen Elizabeth Islands at particular points in time.

Section 2 deals with the extent of land-fast ice in various parts of the Queen Elizabeth Islands at critical times during the year. The maps in this section portray both the pattern of ice break-up and of consolidation in the channels between the Islands.

Section 3 describes the areas of weak ice and includes maps showing the degree of ice movement between January 1 and July 1.

Section 4, which is closely related to its predecessor, outlines the amount of movement which may be expected in various parts of the region under discussion. In this section, the effect of temperature changes on ice sheets is also introduced.

Section 5 deals briefly with the variations of ice thickness over the region.

Section 6 provides a description of the roughness characteristics of sea ice for various parts of the region at different times of the year.

Section 7 deals with the distribution of glacial ice in the straits and channels, and draws attention to the fact that the region does not support significant numbers of icebergs or ice islands.

Section 8 describes the extent and duration of open water in the Queen Elizabeth Islands which is an extremely variable phenomenon.

Section 9 confirms that much additional hydrographic data could be provided, if desired.

Section 10 contains a comprehensive description and a concise summary of the weather conditions for each month of the year for the region.

Before turning to the individual sections of this report, attention must be drawn to certain important points of principle involved. Firstly, as will be appreciated, there have been substantially fewer ice observations taken in this part of the Arctic than elsewhere. For instance, the raw data used as the background of this report and provided in VOLUME II, whilst reliable, is based upon five recent consecutive years of observation, a somewhat shorter period than is customary for the presentation of ice data. Moreover, very few observations have been made during the freeze-up period from late October to the end of December. To overcome this, our best marine knowledge and ice expertise has been brought to bear on the subject to estimate the ice conditions during this hitherto unobserved period and provide information which is reasonably representative of actual conditions.

Secondly, it should be emphasized that whilst present observations are sufficient to establish the general ice configuration, they have been taken mostly from the air. Consequently, the lack of certain detail increases the difficulty of providing comprehensive information on ice movement and such associated factors. Indeed, there have been no precise measurements of small scale movements in the region except those undertaken by the Sun Oil Company in 1971-72.

Finally, there can be no absolute forecast of yearly or seasonal ice conditions until weather patterns and their inter-relationship with ice formation can be predicted with greater accuracy than is possible at present. Within the limitations of present terminology, a good year is one in which the ice cover in all channels breaks up, moves and becomes ice free in the summer. A bad year refers to a situation where there is a minimum breakup, minimum movement and minimum open water. A normal year lies somewhere between these two extremes. For instance, 1962 was a good year; 1964 was a bad year, and 1968 was average.

Accordingly, a decision has had to be taken in this report whether to describe the average or the extreme conditions. A compromise was decided upon with the result that, where practical, the maps show the extremes whilst the text describes the frequency of conditions in between. With all this in mind, most maps produced in this report show conditions for mid-June and mid-

October. These two dates typify the situation just before ablation commences and just before actual observations cease.

It is evident from all of the foregoing that there is need in this region for an intensive program of on-the-ice investigation of specific phenomena, which is made more urgent by the rapidly growing level of industrial activity now taking place there. Methods by which such a study could be carried out have previously been put forward for consideration.

In the meantime, the content of the various sections of this report and its companion Volume are up to date and as comprehensive as present data will permit. These two volumes are thus valuable reference documents for intended ice operations in the region of the Queen Elizabeth Islands, the geographical boundary of which is shown in Figure 1, together with the three area subdivisions employed in this Volume.

N.A.(H).L.

Doc. 9: T.C. Pullen, The Port of Churchill, Manitoba; Being Some Remarks on Its Present Inadequacies and How Good Prospects for Its Future Might Be Secured, March 1972.

HBC Archives H2-141-1-4 (E 346/1/19)

THE PORT OF CHURCHILL, MANITOBA.

Being Some Remarks on Its Present Inadequacies
And How Good Prospects for Its Future Might Be
Secured.

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The evolution of giant tankers, ships with a deadweight capacity of 250,000 tons or more, has had a profound effect on world trading patterns. The impact of this on Arctic shipping prospects will be equally profound for it has been amply demonstrated how extremely potent such ships are in an icebreaking role. The Manhattan voyages were proof of this. In simple terms the bigger the ship the better the icebreaker. A powerful properly designed 250,000 ton bulk carrier has so much mass and momentum she could overwhelm seven feet of sea ice with little effort compared to the struggle which would confront a 50,000 tonner. It is also self-evident that to move meaningful tonnages out of the far north ships must be big -- the bigger the better. It is because of these two facts that a navigation season, hitherto measured in weeks, can now be extended to span a period of months if not all year depending upon which Arctic location is involved.

But such behemoths draw 70 to 80 feet of water. Any thought they might use Churchill must be dismissed out of hand even though their tremendous size, shape and power would see them defeat the intervening ice to reach the harbour approaches. Putting it another way, a ship small enough to get into Churchill would be unable to get through the ice in Hudson Bay and Hudson Strait during the so-called 'off' season. An offshore loading/unloading facility could be created but it would be not only a prodigious undertaking but an immensely costly one to serve the purpose.

Turning now to Baffinland Iron Mines it is envisaged that the market for its Mary River iron ore would be Europe via Rotterdam. At the outset a minimum annual tonnage of two million rising, in due time, to five or six million tons is contemplated. There is no reason, however, why a percentage of that ore which is some of the world's richest, borne in ships capable of operating into Churchill during the summer navigation season, could not serve the needs of western Canada. Ice conditions north of Hudson Strait are, on the whole, no more difficult than those to be found in the strait itself.

One of the contradictions confronting planners in the Milne Inlet to Europe trade is the fact that a ship big enough to be assured of a 10 month shipping season through the heavy ice in Davis Strait, Baffin Bay and Eclipse Sound could be too deep for Rotterdam although it is understood that depths there are continually being increased. One solution, and one that has other advantages, might be to develop a transhipment port -- say in the Bay of Islands area of Newfoundland. From there smaller ore carriers could carry ores up the St. Lawrence, south to Philadelphia and Baltimore and, of course, east to Europe. Japan, too, must be considered as a potential customer. In this way the icebreaking ore ships could be employed in the environment for which they were designed and not carry their penalty in deadweight capacity any further afield where it is not needed.

The controlling factor when contemplating the shipment of ores from the eastern Arctic into western Canada through Churchill is not, as one might think, the heavy ice conditions to be found en route but simply the notorious and well documented inadequacies of the port of Churchill.

A recurring theme to be found in all studies made about Churchill is the brief navigation season there, together with the limitations of the port itself and the approaches thereto. The fact of the matter is that large ships, by modern standards of size, simply cannot use it and never will for the cost of enlarging and deepening the harbour, dredging its approaches and solving the ice problems in both locations, is prohibitive.

Churchill seems condemned to carry on as she has in the past on a seasonal basis (say three months) by vessels with a loaded draft of approximately 30 feet. Except for some marginal improvements in facilities and a moderate extension of the existing shipping season it will, in the view of many people, simply continue in its role as a summertime grain exporting facility.

If the movement of ores into Churchill from the eastern Arctic by ship would be worthwhile for three months out of every 12, always assuming there will be the means there of handling such a cargo so that grain loading will not be disrupted, then well and good. In my opinion, however, the cost and effort involved in improving and adding to the facilities isn't justified. Its future as a port is not bright if growth is the criterion of success. It has been poorly endowed by nature to be anything than what it is undertaking at present.

Mary River is not the only mineral deposit which should be considered. There are, for instance, several mining interests in Foxe Basin. There is iron ore in the vicinity of Eqe Bay on the eastern shore of the basin and which is controlled by the Patino interests. The waters of eastern Foxe Basin are, unfortunately, very shallow posing a serious transportation problem. This is a situation where a suitable tug and barge arrangement might offer the best solution. With such shallow water and excessive tides conventional ships would be out of the question.

These and other deposits in Foxe Basin could be transported during the summer navigation season (extended as much as possible by the use of new techniques and better vessels) to Churchill 900 miles to the south. But year-round operations from Foxe Basin are unlikely because the combination of heavy rafted ice and shallow water would defeat all forms of surface marine transport.

There are mineral deposits on the Ungava shore of Hudson Strait. There is a lead/zinc deposit near Strathcona Sound at the northern tip of Baffin Island. There are others and there will be more. All bear investigation if this concept of moving the mineral wealth of the Canadian Arctic into western Canada for processing by Canadians is to amount to anything.

The extract from the Royal Commission on Transportation embracing Churchill is a useful indicator of the future of that port. A. P. Low's remark made just after the turn of the century that "ships will go wherever cargoes can be obtained, and all that is needed to open Hudson Bay for ordinary commercial navigation is a line of rails to carry freight to one of its ports...." is still valid. In the event, of course, rails were laid to Churchill but one cannot help wondering, in the light now of burgeoning activity in the eastern Arctic and the demonstrable inability of that place to grow and adapt to meet new needs, why a better port located further north should not now be considered.

What is being suggested here is not a facility to displace Churchill's role but rather one which would complement that place in much the same manner, though in markedly less degree, as Greenock and Gourock complement Glasgow.

If it were possible now for ships to navigate year-round through the pack ice in Hudson Strait and northern Hudson Bay, if it were practicable to find a deep water port site on the western shore of Hudson Bay capable of accommodating the largest ships, and if it were feasible to extend the railroad from Churchill up the west coast of the bay to the aforesaid port, then surely there is merit in such a suggestion.

Indeed we have at least two of the three ingredients essential for the implementation of such a proposal. Firstly the <u>Manhattan</u> proved that icebreaking bulk carriers of the right size, design and power can surmount the one-year ice which inhabits Hudson Strait and northern Hudson Bay thus assuring year-round access. Secondly there is a site in the vicinity of Chesterfield Inlet satisfactory as a port to accept such vessels. Lastly the terrain between it and Churchill is not, according to those who know the country, unsuited for a railroad but this aspect of the matter is something which is beyond my competence to judge.

This new port would confer the following:

a. A year-round grain exporting capability.

<u>Note</u>: With Churchill continuing to export grain during the three month summer navigation season we would have what amounts to a 15 month grain shipping season every 12 months. If this didn't satisfy the western grain farmer then nothing would.

b. With the prospect of year-round service other cargoes might be attracted from the Canadian west and mid-west for export. The same thing could apply, too, for imports.

c. A terminal open all year for minerals destined for western Canada borne by ship (or tug and barge) from mines in the Foxe Basin littoral.

<u>Note</u>: While the port would be available it is probable that some, if not all, loading ports in Foxe Basin would be compelled to suspend operations during the winter months.

d. A terminal open all year for minerals destined for western Canada borne by ship from Milne Inlet and other developments in the high Arctic.

<u>Note</u>: During the summer season any size ship (even unstrengthened ones) could operate to this port. If necessary even the 200,000 ton

icebreaking ore carriers serving Milne Inlet could divert the occasional shipment of ore.

e. A pipeline terminal for oil from the Athabas[c]a tar sand development to the southwest.

f. A pipeline terminal for oil from the Mackenzie Delta, a distance which is several hundred miles shorter than that from the delta to Edmonton, Alberta.

g. A pipeline terminal for Alaskan north slope oil for it would provide tide water access to the east coast market, where the bulk of north slope is ultimately destined, involving a much shorter run of pipe than for any other alternative.

h. Access to tide water, on a year-round basis, to serve other oil and mineral developments which will appear in that general area.

i. A pipeline terminal for oil from the eastern Arctic islands.

<u>Note</u>: What is envisaged here is the carriage of oil from the islands by tanker to a terminal on the south side of Lancaster Sound. From there it would be piped south to Chesterfield (or wherever the port is situated) for onward shipment, either by tanker or by pipeline, to Canada South.

There are other advantages but these are enough to show what some of the benefits might be. The extension of steel 600 miles northward up the west coast of the bay would also surely stimulate growth and development along that littoral. The whole project would be a boon to the native population by providing employment on a wide variety of tasks in the various construction projects and in the operation of the facilities when completed.

All this activity would benefit Churchill and both ports should stimulate trade and growth, not only for western and central Canada but the Northwest Territories as well.

It[']s not too far-fetched, surely, to think of steel being extended even further north. Fury & Hecla Strait would not be the obstacle it appears for there are islands (Elder & Ormonde) in its eastern end which could serve as stepping stones for bridging. Steel could also go north up the Boothia peninsula. Developments like these would open up the north and would surely be in the Canadian tradition of pushing back frontiers.

There may be some who would scoff at the suggestions contained here. I know you won't. Its cost would be high but then so would the rewards. With the Alaskan pipeline to Valdez now reputed to have escalated to 3 billion dollars, with the off-shore tanker terminal at Prudhoe estimated to cost a like amount, we are truly living in a world where enormous sums of money are the order of the day. Of course it all depends upon whose money is involved, but the transportation problem facing the Americans is enormous.

From a strictly Canadian viewpoint it[']s time we did some homework on this matter of Arctic transportation. With Panarctic seeking oil in the islands nobody, to my knowledge, has really grappled with the problem of getting it out once it[']s found. "Roads to Resources" was a political slogan and not much else a few years back. The ideas outlined here could be a plan for such roads with some substance to them.

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TEXT FOR AN ADDRESS ON THE
SUBJECT OF A NEW PORT TO BE
BUILT ON HUDSON BAY.

PREPARED FOR DELIVERY AT THE
CHATEAU CHAMPLAIN, MONTREAL,
TUESDAY, MARCH 14, 1972.

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A NEW DEEP WATER PORT ON HUDSON BAY

--oo0oo--

Mr. Chairman and Gentlemen

It now becomes my job to provide you with the background to this intriguing proposal. Hopefully, I will be equal to this task for it appears we have here the germ of an idea that could be important to Canada. What we are glimpsing, it seems to me, is something which is not only Arctic or sub-Arctic in scope but could, instead, be national -- even international -- in significance and impact.

The views I express this morning will be my own but I am secure in the knowledge that they are, for the most part, endorsed by all members of the Great Plains Committee.

I have not met anyone with whom I have discussed this proposal for a new port who didn't share, in varying degree, a measure of enthusiasm for what we have in mind. The invariable reaction seems to be that here is something which merits at the very least a good hard look. Here is something which could meet many needs, something that could give new meaning, new thrust, to northern growth and development.

Speaking for myself, my role is to prosel[ytise] for I truly believe in this recommendation to create a deep water port, airport, rail link, pipeline terminus and community to serve Western Canada and the Northwest Territories. I stress that I am not pretending that such an idea is unique nor do I claim any proprietary rights to the suggestion. Like so many things in life it is simply a revelation of the obvious.

This morning I hope you will take note of certain basic facts which I will be putting to you. The first of these is that speaking environmentally, speaking about ice conditions, we are involved here not with the Arctic but with sub-Arctic conditions. Because of this the challenge, and I speak in a sailorly context mind, is markedly less demanding.

A. P. Low, commenting on the feasibility of navigation in Hudson … [remainder of section missing]

<u>Origin of the Recommendation</u>

This proposal was the concept of Capt. Thomas Pullen, Canada's representative on the Manhattan. It was brought to the attention of the group by Mr. Richard Rohmer, Q.C.

He was, of course, referring then to Churchill or Port Nelson, the matter of the terminus being then still undecided. What he said still holds true but newer possibilities require new initiatives for truly the Hudson Bay Route still remains a dream unfulfilled.

Only a week ago we read in the papers of the annoyance and impatience of the western farmers at the inability of our national transportation systems to handle their grain shipments for export. It seems this is not a new situation for in 1906 we read of the inability of the railways of the West to handle the wheat crop harvested in the fall of that year. By the end of February, 1907, less than one-third of the crop had been shipped to the Lakehead, and farmers found themselves pressed to meet crop loans while thousands of bushels of salable grain lay in snowbanks on the ground.

In all this early agitation for a port on Hudson Bay it is interesting to read that an Ontario Member of Parliament of the day said, and I quote: "the sympathy of the East goes out with the aspirations of the West.... It is a national route, a national outlet we want....... and it will greatly enhance the wealth of the Canadian nation as a whole." Unquote. Hopefully such a broad-minded attitude to national progress will always prevail.

So interest, especially amongst Westerners, in an outlet to tide water on Hudson Bay goes back many years. The end result was, of course, the creation of the Port of Churchill, joined to Canada South by rail in 1929 and opened for shipping in 1931. But, in my view, it has never really lived up to expectations.

Moving on now 40 years brings us to the successful voyages of that giant icebreaking tanker Manhattan through the Northwest Passage in 1969, and to Pond Inlet in the eastern Arctic in 1970. Canadians became so worked up about sovereignty then that they overlooked the message for Canada that was to be learned from these achievements. In the minds of those of us who were present at the time, and whose interest is ice navigation, it simply confirmed what we had always felt, that giant ships, by virtue of their enormous weight and the resulting inertia, make remarkably efficient icebreakers. And, happy to relate, because they are so commodious such vessels can haul prodigious tonnages. Taken together these two facts must signify a break-through in Arctic transportation. Or they should do. It strikes me as strange that these lessons take so long to sink in.

The chief beneficiary of that $50 million icebreaking tanker experiment was not its sponsor, Humble Oil, but Canadian Northern development. One example of this is, of course, the reason we are here to-day. In our eastern Arctic, and especially in Hudson Bay and Hudson Strait, it must be obvious that at long last we have available to us the means for an integrated approach to those inseparable twins -- resource development and transportation.

An ability to transport cargoes virtually all year has been impossible hitherto. It might be said that as a consequence northern transportation has suffered. Not so, really, for the tonnages have in the past been quite small. In fact the requirement to move bulk cargoes is only now appearing on the scene just about the same time that the capability to do so is becoming practicable. Now, as the tempo of exploration and discovery accelerates, such an attractive possibility lies within our grasp if only we have the wit and determination to take hold. From the viewpoint of feasibility, the manner in which we avail ourselves of this new state of affairs is surely limited only by our ingenuity and vision of the future.

At this point I should talk briefly about ice because ice is what it[']s all about. There are some here who, I believe, would like to have some inkling of this in order to grasp the problems involved. You, who are experts, will appreciate that it is difficult to be both succinct and meaningful on this topic without running the risk of indulging in misleading and wishy-washy generalities. The source for most of what I will say comes from the Chapter on ice by Margaret Larnder in this excellent work on Hudson Bay. (Science, History & Hudson Bay - Vol 1)

Ice coverage in the Bay is usually at its maximum from January to April but it is never 100% complete. The shearing effects of winds, tides and currents produce stresses that fracture the ice, separating floes from each other either driving them apart, thus creating stretches of open water, or causing them to override so that they are crushed and broken into a maze of ridges and hummocks.

Winds during the winter are predominantly from the north, northwest or west. Accordingly, what is known as a flaw lead (a band of open water in other words) develops along the west side of the bay and has been observed to extend from Roes Welcome Sound to the north of our harbour site as far south as Churchill.

Indeed, Roes Welcome Sound is another area where stretches of open water and moving fields of unconsolidated ice usually persist all winter. High tides and strong currents keep this ice in motion. Whether this could be a factor in making access to Northport somewhat easier by conventional shipping remains to be seen.

Also, in Hudson Strait itself, high tides and strong currents keep the fields of heavy ice in motion throughout the winter so that, except for a narrow shelf along the coasts, the ice never forms a solid cover although it has been considered too heavy for navigation by conventional shipping.

In what we call [‘]bad ice years’, conditions in Hudson Bay may present problems. Delayed break-up, or an exceptional period of prevailing winds from the east or south, may hold fields of winter ice in the northern part of the bay. Instead of following the direct track to Churchill, which runs diagonally from the western entrance of Hudson Strait southwest to Churchill, conventional ships may be forced to follow devious routes around or through heavy ice fields south of Southampton Island to reach open water off the west coast -- the same open water I mentioned earlier which is usually to be found there -- that so-called flaw lead.

Of course, all the ice is gone by late summer, most of it having melted ‘in situ.’ Some of it is carried out of the Strait by wind and current.

I have attempted to show that the ice cover is not 100% in either the Bay or the Strait. I have touched on the fact that conditions are ‘looser’ in the Strait and across the top of the Bay on the route to, and in the direction of, Northport. I have suggested that there are somewhat ‘looser’ conditions along the west coast of the Bay where Northport would be located. So much for ice cover, what about ice thickness?

Ice in river estuaries may continue to grow in thickness throughout the winter by accretions of freshwater ice on the bottom as well as on the top. At or near river mouths it may reach a final thickness of some 8 feet.

Sea ice in the main body of the Bay forms initially to a <u>maximum</u> thickness of <u>about</u> 6 feet. I should think 4 feet would be a representative average thickness. But rafting and ridging causes floes to pile up on each other. Here they freeze together considerably increasing the thickness of the ice cover and producing a very rough and uneven surface, crisscrossed by pressure ridges that may rise from 6 to 20 feet above the general ice level. The underwater thickness, i.e. the downward projections of these ridges, may be from four to five times as great as those extending above the water. Therefore, although Hudson Bay ice is never more than one year old, it can become very heavy and rugged by the end of the winter.

To the uninitiated these sound like pretty formidable conditions. For conventional ships, and ice-strengthened ships including all our icebreakers, they <u>are</u> formidable, indeed they are insurmountable. But in the selection of Northport we have the most direct route with a saving of 200 miles compared with Churchill, we would hope to traverse that part of the Strait and the Bay where we would experience and exploit the maximum amount of what I referred to as 'jostling room' and, lastly, we are by no stretch of the imagination talking about 'conventional' ships.

The question "How much ice can an icebreaker break?" is easier to ask than it is to answer. The simplest response is the least helpful: "It depends."

Pack ice, the sort of stuff that moves about in Hudson Strait during the winter, for example, has that 'jostling room.' It was under these conditions in the Northwest Passage that <u>Manhattan</u> broke asunder floes more than 24 feet thick. But should this sort of ice come under pressure because of strong winds a ship could be held motionless as happened to <u>Manhattan</u> in Baffin Bay during her second voyage. No risk -- just annoyance at having to wait for nature to relax her grip. The reason for this was simply that the tanker lacked the power to cope with conditions.

Fast ice, that is ice which freezes in a solid sheet in bays and estuaries, is a different obstacle. It is usually difficult for a ship to overcome because there is nowhere for the ice she breaks to go other than under her hull or on top of the unbroken ice on either side. In both cases tremendous amounts of power and a good hull form are required to be successful. That is why <u>Manhattan</u> was stopped dead in less than 3 feet of fast ice in Pond Inlet. Our Canadian icebreakers were even less effective.

Given the right design and strength, the two ingredients essential for success in ice are thrust and inertia. Thrust is the horsepower developed by a ship's propellers. And mass is the quantitative measure of inertia. What is needed, then, is the best mix of horsepower and displacement for the area of operations. <u>Manhattan</u>, at 155,000 tons and 43,000 shaft horsepower had about the right mass but far too little thrust. Our <u>Louis S. St. Laurent</u>, at 9,000 tons and 24,000 shp lacks both mass and power. For Northport service I would envi[s]age 150,000 tons or so and about 120,000 shp. But this is properly a matter for Naval Architects -- Canadian Naval Architects please, not Finns or Germans or even Americans.

Therefore, let me stress at this point that the sort of capability, the sort of bulk carrier I am thinking about, <u>must</u> be designed and built as near to true icebreaker standards as we have ever been before. Such a step has never yet been attempted but it[']s perfectly feasible. When it is I truly hope it will be an all-Canadian endeavour. It will not be enough that she be big, or carry large tonnages, for these confer no advantages in ice. Indeed, quite the reverse if we are thinking of tankers. No, such vessels must be, and there's no problem in doing this, impervious to ice damage and at the same time able to defeat the pack on their own - unaided. They must be their own icebreakers. This is the most important fact concerning the suggestion to deploy giant ships in high latitudes. The Manhattan showed, by what she accomplished, that it is perfectly feasible to do this.

What I have in mind would dispense with the need for the so-called escorting icebreaker. That class of ship would not match our icebreaking bulk carrier. The only thing that could, would be another icebreaking bulk carrier. No icebreaker captain would dare hazard his command by placing her ahead of an icebreaking behemoth. All those to whom I have spoken about this have made the point with understandable fervor. Not only would it be extremely dangerous it would also be utterly unnecessary.

The role of the Government icebreaker, then, has obviously been changed insofar as the big icebreaking bulk carrier is concerned. It has been changed but by no means diminished. There will be occasions when ice conditions become particularly severe, albeit only temporarily, but when an icebreaker might make the difference between 'go' and 'no go' for a bulk carrier. Novel tactics were evolved for this sort of a situation during the Manhattan voyages by her accompanying Canadian icebreakers.

And so, armed with the knowledge that we have access to most areas of the eastern Arctic, and all of the sub-Arctic, by this new development, I was asked by our Chairman to look into the possibility of moving iron ore from Mary River in North Baffin into Western Canada via Churchill. It is in the context of large ships that when one examines Churchill as a port that its inadequacies become apparent. Yet it is the only sub-Arctic port in the east connected by rail to Canada South. If one accepts the premise that the bigger the ship the better her ability to defeat ice, and here I include of course the necessary strength, power and design to go with it, then I would say to you that such a vessel would be able to get to Churchill at any time of the year but, on account of just that capability, she would run aground 12 miles off the harbour entrance because of her excessive draft. Or, to put it another way, a vessel small enough to get into Churchill and use it as a port would never be able to get there except during the present summer navigation season.

But Churchill suffers from more than just shoal water as if that wasn't critically important. There are powerful currents, especially in the harbour entrance. The harbour itself is small and maneuvering room is restricted even for ships of modest size. Problems exist from fresh water ice carried down the

Churchill River and accumulating in the harbour at freeze-up just when ships are hurrying to load and get out.

Port facilities are dedicated almost exclusively to the grain trade. There would be little room for expansion were large tonnages of other commodities to invade the port. Churchill, in my view, will never be much more than what it is now -- a grain exporting facility during the summer for ships of 15,000 tons or so. But, on the other hand, we feel that if what we visualize should come to pass the effect on the economy of Churchill as a whole is bound to be beneficial.

The next step, then, was to seek another port site. Any of the recommendations I have seen for improving the Port of Churchill, at great expense, have contemplated doing so for ships with laden drafts of 34 feet or less. The vessels I am talking about would draw 75 feet. There are no suitable sites to be found to the south and so my attention was focussed on the littoral far to the north of Churchill.

What I wanted was at least 90 feet of water, room to accommodate the comings and goings of ships 1,200 feet long, deep water approaches from seaward and maximum natural protection from wind-driven ice. One such site is to be found off the settlement of Chesterfield Inlet -- hence Northport. There may be other sites, better sites, but one thing I feel certain about, there are none any nearer to Churchill that meet my requirements than this one. Actually, I would prefer to know Northport as Promise Harbour. A nearby island is called Promise Island. In my opinion, one not shared by all my colleagues, surely a more fitting name.

Let me add that 150,000 ton icebreaking bulk carriers would not be Northport's only customers. All ships currently using Churchill in the summertime could use it. Thin-skinned ships of any size and of any type could also use it during the same period. Ice-strengthened ships of any size and type would be able to call there over a longer period. And then, when conditions were at their worst the big icebreaking bulk carrier would hack her way through at will. There seems no reason why other ice-strengthened vessels could not exploit this situation and follow in her wake. So the number, the size and the type of ship which could use the facility seems unlimited -- such versatility has never been envisaged for Churchill.

Hopefully, I have made a case for year-round shipping to a new port on the west side of Hudson Bay. One aspect I have not dwelt on is the subject of the connecting railroad. It has been estimated that the cost per mile for this 600 mile extension would be $540,000 or a total of $324 million. Comparable costs, for resource-type railroads actually constructed or under construction, are the Quebec Cartier Mine Extension at $500,000 per mile, the Alberta Resource Railroad at $400,000 and, finally, the Great Slave Lake Railroad at $495,000. As to its feasibility, something which is causing doubt in the minds of a few people, I am informed that the terrain is not unsuitable. A sometime Chief Engineer of the C.N.R. told me that that organization was once in favour of extending the railroad north beyond Churchill, how far I don't know, and that a survey at that time indicated the terrain was not unsuitable.

Mr. Chairman, I should now like to offer the following selection of roles, a selection that is by no means all-embracing, that we see Promise Harbour (or is it Northport?) playing as a major transportation and industrial community.

Western Canada and the Northwest Territories would have year-round access to tidewater on the east and have it, please note, without being beholden to Ontario and Quebec interests. The savings in distance would be substantial. Edmonton, for instance, is closer to Liverpool, England, via this port than it is via Montreal by 1,200 miles.

The disadvantage of having the St. Lawrence Seaway closed to traffic for several months every winter would be eliminated.

Northport, with rail connections to Canada South, would establish a land bridge between European or Atlantic markets on the one hand, and Japanese and Far Eastern markets on the other, which would be approximately one-half the current land bridge distance between the Pacific and the Atlantic.

Western farmers would, after all these years, be able to despatch grain overseas all year. Not only could grain be shipped 12 months of the year but Churchill could be used either as an alternative during the summer navigation season or in addition to Northport. Grain storage facilities at Churchill would continue to be fully used.

Movement from Western Canada would be facilitated for potash, coal, pulp and paper products, sulphur and any and all other commodities produced there and destined for markets in the Eastern United States, Europe and elsewhere.

Such a facility would surely also attract a wide range of imports.

Northport could serve as the southern terminus for the very large resource-carrying aircraft transporting oil from the Arctic Islands. From Northport the product would continue its journey to market either by tanker or by pipeline.

As a pipeline terminal for oil derived from the Athabas[c]an tar sands deposit a few hundred miles to the southwest for overseas delivery or for movement to Canada South by tanker.

As a pipeline terminal for oil and gas from the Mackenzie Delta region. The distance from there to Northport is less than it is from the Delta to Edmonton and it might be the case that the terrain is also less forbidding. This is an option that pipeline interests have not investigated.

It might also even serve as a pipeline terminal for gas and oil originating on the North Slope providing, as it does, access to tidewater for delivery to East Coast markets.

There would be access to world markets, year-round, for any and all mineral, oil and gas discoveries which may be made in future years in the continental area to the north and northwest of Northport.

A pipeline could be run south from Northport to serve the midwest and Chicago area of the continent. In other words this port would serve as a staging point in a whole new pipeline network.

If it becomes possible to pipeline under Parry Channel far to the north (and I have my doubts) then such a line could terminate at Northport for onward delivery by tanker or the product could continue in the line to Chicago already referred to.

It could serve as a port for tankers with oil and LNG embarked at a port on Ellesmere or any of the other Arctic Islands.

Ores from deposits in the Ungava area could be landed for onward delivery by rail to Canada South and the continental rail network. And, of course, that iron ore from North Baffin, that started this all off in the first place, could be got to Western Canada.

We feel this proposal has the potential of creating a major industrial and, in the words of latter-day gobbledy-gook experts, truly an inter-modal transportation complex. We do not think this is a visionary scheme. But it will require men of vision if something worthwhile is to be done about it.

On the wall is a diagram which shows one form this place might take. It is, you will note, a corridor sort of layout, a corridor joining the four functions, port, airport, the industrial complex-cum-railroad depot and, of course, the town site.

The port would be designed to afford all-round protection from pack ice. As there is not sufficient natural protection a man-made harbour will have to be provided but this should not be beyond the wit of man to achieve. A nuclear generating station discharging warm circulating water into the harbour could assist in keeping the locally formed ice from creating problems for ships attempting to maneuver there.

The airport, covering 15,000 acres, would have three runways each 15,000 feet long and 400 feet wide to accept the giant aircraft which I mentioned earlier. The industrial complex would occupy 1,500 acres or so for the storage, processing and warehousing of various commodities. I think there is little point in becoming involved in details for what is involved here is a conceptual approach.

Adverting briefly again to costs, one would have to include a sum to up-grade the rail line which runs south from Churchill for I don't suppose it would be able to handle the heavy traffic that would result from all this. There may be a tendency to quail at the cost of what we propose but if Quebec can embark on a power project at an estimated cost of $6 billion we should keep in mind that we are looking at a fraction of that cost for something which in the long run could have far more meaning for Canada.

One more point, before I wind this up, and it is the need, in my view anyway, for a transhipment port so that the expensive icebreaking bulk carriers would be employed in those areas for which they were designed to operate. I should think a facility in the Canso Area. This would mean that the Great Lakes market would be open to lake vessels -- for example iron ore.

Mr. Chairman, I will dwell no longer on this. I believe, I certainly hope, enough has been said to stimulate useful discussion. Let me close by repeating the theme of the 1970 Arctic Transportation Conference held at Yellowknife. It says it all. I only hope that we are going to get a little leadership, a little action, from those who have the responsibility. The theme went like this: "Transportation plays a crucial role in the development of a country. The building of the C.P.R. helped unite Canada. What this generation does in the Arctic can have equally important and long-lasting results."

Doc. 10: T.C. Pullen, Report on the Feasibility of Shipping Lead/Zinc Concentrates From Strathcona Sound to Europe, Prepared for Watts, Griffis & McOuat Limited, 26 February 1973.

HBC Archives H2-141-1-4 (E 346/1/24)

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REPORT ON THE FEASIBILITY

OF

SHIPPING LEAD/ZINC CONCENTRATES
FROM STRATHCONA SOUND TO EUROPE

Prepared For

Watts, Griffis & McOuat Limited
Suite 911, 159 Bay Street,
Toronto, Canada

by

Northern Associates (Registered)
of Ottawa & Montreal

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February 26, 1973

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INTRODUCTION

The intent of this report is to examine and define those factors governing marine operations between Strathcona Sound, on the Brodeur Peninsula of north Baffin, and Europe, to conclude whether they are feasible and to obtain some assessment of the size, number and ice-capability of the vessels needed for the task.

From a mariner's viewpoint, the location of the ore body and the plan to load the product at tidewater in Strathcona Sound is propitious. As a general rule in those latitudes, ice conditions become progressively more difficult the further west one goes. It would be a far more difficult undertaking to contemplate shipping operations to Melville Island. It would be only a little less difficult to reach Bathurst Island on a scheduled basis during the summer. Strathcona Sound is, therefore, ideally located and certainly more so than is Little Cornwallis Island. As will be seen in the Section on ICE CONDITIONS, Strathcona Sound experiences only First-year ice which is in large measure the explanation for this satisfactory state of affairs.

Bathymetrically, Strathcona Sound is well situated for the waters there, and between there and Europe, are by arctic standards well known, well charted and well travelled. This is an important consideration. The Canadian Hydrographic Service has more commitments for surveys than it can handle. If Strathcona Sound, or the approaches thereto, were an unknown quantity hydrographically, the likelihood of having surveys carried out there would be remote. Under such circumstances, marine underwriters would be understandably hesitant to see operations attempted there. Rates imposed would reflect this apprehension.

This report examines the total route situation and takes into account the several alternatives. Mileages are included plus the matter of voyage cycles. This last, of course, relates directly to the number of deliveries it would be possible to make and the size of vessel required.

Ice conditions are explained as well as the meteorological conditions to be expected. Both of these influence to a varying degree the feasibility of marine operations -- especially the former.

Notwithstanding the foregoing the factor which will henceforth govern arctic marine operations for commercial purposes will be the Government's Arctic Shipping Pollution Prevention Regulations. The impact of these have been taken into account in the preparation of this report.

Recently the Ministry of Transport circulated a proposed change to the regulations. Consideration is being given to an extension of the dates between which ships may operate into the various zones if they have icebreaker escort. The degree of extension depends upon the number of ships being convoyed. Such a proposal is sensible but with the paucity of arctic icebreakers in relation to commitments it would be extremely unwise to rely upon the availability of such escort when needed. This aspect is dealt with in more detail under the heading of ICEBREAKERS.

In general, it is clear that operations into Strathcona Sound are perfectly feasible. For the most part it is a matter of ship size and ice-capability.

For example, a Type "E" vessel, i.e. one with no ice-strengthening, is permitted by the rules to operate into Strathcona Sound (Zone 13) between August 15 and September 20. During this period it might be possible for such a ship to call at Strathcona twice. Accordingly, it would seem that one 75,000 dwt vessel could handle the commitment. But first a cautionary note. It would take only one year when ice conditions were bad, when there was a delay in break-up and with heavy floes littering Baffin Bay in areas usually clear of ice during the summer, to render any scheme to use unstrengthened ships, of whatever size, useless. Such thin-skinned vessels need only brush against one heavy floe to suffer heavy damage, damage that might require docking, delaying if not frustrating completely the whole plan. For this reason it is not intended to give consideration to the use of unstrengthened bulk carriers.

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SUMMARY AND CONCLUSIONS

The new Arctic Shipping Pollution Prevention Regulations now control arctic shipping operations. They define the ice-capabilities of vessels with inevitable cost implications to operators, they establish various zones and lay down the dates between which the various types and classes of vessel may operate into those zones. Thus is established the number of voyages that are possible during the season and therefore the number and/or size of the ships needed to remove the required tonnage.

Shipping operations between Strathcona Sound and Europe are feasible. The former place, in an arctic context, is very well located for such traffic.

The tonnage to be moved (150,000 tons) is small enough that its removal would be practicable during the so-called navigation season (August - October).

The length of this navigation season depends upon the number and ice-worthiness of the vessels to be used in this service, the prevailing ice conditions in any particular year (for they vary widely and unpredictably from year to year) and the availability or not of icebreaker assistance.

Strathcona Sound is well placed for the ice regime there, and between there and open water in the North Atlantic, is preponderantly one year old -- no more.

The duration of the navigation season will vary from year to year but, on the average, will probably last for 15 weeks for a Type "A" vessel (Lloyds Ice Class 1*).

To ensure the total tonnage requirement can be removed the most ice-worthy vessels should be used. However, they would obviously be more costly than other less capable ones. It is a matter of trade-offs and an economic examination of this aspect, and others, would seem to be needed to strike the right balance between minimum costs with maximum capabilities.

An unescorted Type "A" vessel should be able to complete at least 5 deliveries to Europe each season -- possibly 6.

A Type "A" vessel with icebreaker escort should be able to make 9 deliveries direct to Europe. Such escort would only be needed between Strathcona Sound and open water in Baffin Bay.

Unstrengthened ships (Type "E") could be used during the period between August 15 and September 20 -- but see the cautionary note in the INTRODUCTION.

Bathymetrically speaking there are no problems. The waters are deep and well charted for the entire route. No additional hydrographic effort is required.

There are no navigational hazards and no additional navigational aids would seem to be required.

Environmentally the chief threat to shipping would be the combination of fog, bergy bits and growlers lurking in the Baffin Bay/Davis Strait portion of the route and also in the vicinity of Cape Farewell.

Canadian icebreakers are so few in number and already unable to meet commitments that planning by commercial interests should be based on the concept of unescorted shipping. An exception is that it is reasonable to expect a degree of icebreaker assistance at the start of the season to break the first ship into Strathcona Sound.

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ASSUMPTIONS

The following assumptions serve as a background to this Report:

The requirement is to move 150,000 tons of lead/zinc concentrates each year.

The destination: Europe through Europort (Rotterdam)

Year-round navigation into the arctic is not contemplated. Removal of the product would be undertaken during the so-called "summer navigation season" when conditions are most favourable for shipping operations.

During the "closed season" for navigation, the product would be stockpiled at site in Strathcona Sound.

A suitable loading facility, assuring ships sufficient water depth plus protection from wind-driven pack ice, would be available in Strathcona Sound.

Government icebreaker support would be available to assist ships during "bad" ice years when the pack is slow to clear during the summer navigation season, also at "break-up" and at "freeze-up" in order to gain the longest possible navigation season.

The moisture content of the product would not inhibit handling and loading in low temperatures.

Transhipment does not fall within the scope of this study nor the economics of transportation costs.

Note: Nautical miles are used throughout.

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ROUTES AND DISTANCES

Introduction

The route between Rotterdam (Europort) and Strathcona Sound can be divided conveniently as follows:

The Ocean Passage Extending from Rotterdam to Davis Strait (66° 42' North, 55° 00' West). See Figure 1.

Baffin Bay This extends from the foregoing position east of Cape Dyer to 74° 25' North, 77° 37' West in the approaches to Lancaster Sound. See Figure 2.

Lancaster Sound to Strathcona Sound From the foregoing position east of Cape Dyer to Strathcona Sound. See Figure 3.

The Ocean Passage -- 2,370 miles

This is the open water portion of the route and is by far the greatest part representing 74% of the total. There is deep water throughout capable of accepting any size of vessel. It passes through some notoriously stormy waters in the vicinity of Iceland but during the time of year when ships would be operating through this region the weather conditions would be considerably more benign than during the winter. The matter of navigation would be routine [page missing?] and no more different or difficult than for any other ocean passage.

The segment between Europe and the vicinity of Cape Farewell on Greenland's southern tip (1,720 miles) is icefree and ships would be capable of proceeding at their best speed subject only to prevailing wind, sea and swell conditions. Between Cape Farewell and Davis Strait scattered ice floes would be encountered together with icebergs, bergy bits and growlers. All of these represent a danger to vessels especially in reduced visibility.

Fog is prevalent throughout the area at this time of the year. The combination of fog and ice should compel a prudent master to proceed most carefully at a time when the presence of open water would seem to be a good opportunity to make up for lost time. This could be especially tempting on the passage from Strathcona if heavy ice had caused delays in Baffin Bay and elsewhere.

Baffin Bay -- 695 miles

This part of the route lies between Davis Strait and Lancaster Sound and all of it traverses waters which can be ice-infested. It represents 21% of the total. Figure 2 portrays a number of route options depending upon the prevailing ice conditions and the time of the year.

Option "A" favours the west Greenland coast….

This would be the route for ships to take during a bad ice year for they would then hope to avoid the worst of the Baffin Bay pack. In addition, it is almost always the route to follow early in the season for the same reason. Should there be open water in the bay this is where it would be encountered which is this option's chief advantage.

In ice navigation and shiphandling the shortest way to one's destination is by no means via the most direct route. A disadvantage of Option "A" is that it is by far the longest route and it also passes through waters where the largest number of icebergs in Baffin Bay, or anywhere else for that matter, is to be found. As a factor which might affect shipping this last point is more apparent than real. However, wherever there are bergs there are bergy bits and growlers and it is these one must avoid.

Option "B" follows the trail of Option "A" northward from Davis Strait to the latitude of Disko Island where it swings northwesterly across the bay to the entrance of Lancaster Sound. This would be the route to take by ice-strengthened ships in an average ice year. Unstrengthened vessels would have to take Option "A", or await better conditions or hope for icebreaker escort.

Option "B" seems unnecessarily long but it is shorter than the preceding option by about 150 miles. It also avoids some of the worst glacial ice concentrations.

Option "C" is clearly the ideal route for it is direct. However, ice conditions in the bay seldom permit ships of the type and size needed for this service to follow it either alone or even with icebreaker escort. In a good ice year all of Baffin Bay can be clear of ice by late September permitting ships to go direct but this should not be counted on. This option is 100 miles shorter than "B".

Note A route via Foxe Basin might occur to someone as a possible alternative and as a means of avoiding Baffin Bay although it would be substantially longer than any of the three options discussed above. It lies westward from Admiralty Inlet, south via Prince Regent Inlet, the Gulf of Boothia thence by way of Fury & Hecla Strait, Foxe Basin, Hudson Strait and into the Labrador Sea.

The shallowest part occurs in the eastern approaches to Fury & Hecla but notwithstanding this a ship drawing 40 feet could negotiate this route. However, the heavy pack ice which is jammed into the Gulf of Boothia must preclude any further consideration of this alternative.

A minor variation in routes should here be mentioned. This is the passage which lies between Bylot Island and north Baffin by way of Pond Inlet, Eclipse Sound and Navy Board Inlet. The waters throughout are deep and there would be no limitation on ship size.

No saving in distance is achieved by this alternative when compared with any of the foregoing three options.

In any event the ice conditions in Eclipse Sound are such that there would be few occasions indeed when it would be advantageous for a ship to take this inside passage. Accordingly, for the purposes of this examination, no further consideration will be given to the Pond Inlet alternative.

Lancaster Sound to Strathcona Sound -- 165 miles

The shortest leg of the whole route -- 5% of the total. Throughout the waters are deep and capable of accepting any size of vessel all the way into the Sound. Canadian Chart # 7982 -- Strathcona & Adams Sounds shows two landing sites. Water depths appear to be ideal for a loading site. There are no navigational hazards.

[Page missing]

Distances -- Summary

	Passage Distance	Voyage Distance	% of Total Route
Europe -- Davis Strait	2,370	4,740	74
Baffin Bay			
via Option "A" 780)			
)			
via Option "B" 665)	695	1,390	21
)			
via Option "C" 640)			
Lancaster Sound to	165	330	5
Strathcona Sound	----------	--------	-------
Totals	3,230	6,460	100
		(nautical miles)	

Note The mileage figure for the Baffin Bay leg is a mean of the three options.

Open water would be assured for the Europe to Davis Strait section. Ice would be encountered on the other two sections in varying degree, depending upon the time of the year, the particular area involved and the prevailing ice conditions for that year.

Because of the need to maneuver around icebergs and the pack it is really not feasible to give an accurate mileage figure for the Baffin Bay, Lancaster Sound, Admiralty Inlet and Strathcona Sound portions so those given are approximations.

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SHIPPING IN THE ARCTIC -- IMPACT OF THE ARCTIC SHIPPING POLLUTION PREVENTION REGULATIONS

It is not practical to discuss ice conditions along the route to Strathcona Sound without considering certain key factors. The first is the impact of the Arctic Shipping Pollution Prevention Regulations (hereafter ASPPR) on marine operations into Canadian arctic waters. The second is the type of vessel to be involved in such operations. The third is the need to determine that part of the total route from Europe where ice conditions will be most difficult.

The one governing factor which now dominates all plans for arctic shipping is the Government's ASPPR which were recently passed into law. The routes to be followed by ships and the duration of the shipping season there no longer depend on the capability of a particular vessel as decided upon by her owners, or on the skill or lack of it in the masters in charge or even on whim. All must now be in accord with these new rules. The last two factors noted above are really a product of the first -- the ASPPR.

The Canadian arctic and sub-arctic have been divided by the ASPPR into 16 zones (see Appendix 1) which finds Strathcona Sound in Zone 13. Provided vessels destined for that place hug the Greenland side of Baffin Bay they should be able to get within 250 miles of their destination without entering any zone. The mileage to be covered in Zone 13, which in turn will govern the length of the season and type of vessel, represents less than 8% of the total distance from Europe.

Zone 13 extends as far west as Resolute Bay where the ice regime is rather more severe than that which prevails east of Admiralty Inlet. Assuming the shipping dates for Zone 13 were arrived at on the basis of the worst ice conditions likely to be met through the zone it is possible that in the less arduous parts an application for some extension of dates might be looked on with favour by the Ministry of Transport. This could materially increase the number of deliveries.

The ASPPR lay down the dates that various types of vessel are permitted to be in Zone 13, and all other zones too, each year. See Appendix 2. In all there are five vessel types, "A" to "E" inclusive. These can be compared with the more familiar Lloyds ice classifications as follows:

Type "E"	Lloyds 100A1	Unstrengthened
Type "D"	Lloyds Ice Class 3	Strengthening only for light ice conditions
Type "C"	Lloyds Ice Class 2	Strengthening only for intermediate ice conditions

Type "B"	Lloyds Ice Class 1	Strengthening for ships intended to navigate in severe ice conditions
Type "A"	Lloyds Ice Class 1*	Strengthening for ships intended to navigate in extreme ice conditions

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It should be appreciated that the terms describing ice capabilities above are relative only and are based on conditions in the Baltic which are not comparable with those met in the arctic.

Accordingly, for the purposes of this study, the Type "A" will be taken as the most suitable compromise between the lesser ice performance of Types "B" and above and the greater, and therefore more costly, Arctic Class. Table 1 shows the performance to be expected from the five vessel types and at this stage tends to confirm the desirability of considering only the Type "A" vessel.

There is a great variation in ice conditions to be found in the straits and sounds through which ships must pass to attain Strathcona Sound. Leaving aside the ASPPR, the typical duration of the navigation season for icebreakers, ice-strengthened and unstrengthened vessels moving to and from Strathcona are shown in Diagram 1. From this it is clear that the place where ice imposes the greatest restriction on all types of ship is Admiralty Inlet which, of course, also includes Strathcona Sound. Therefore, Admiralty Inlet permits only a 28 week season for icebreakers, 14 weeks for ice-strengthened vessels and approximately 8 weeks for unstrengthened ones.

The data presented in Diagram 1 can be condensed further by reducing the number of areas from five to three. This has been done in Table 1 with the result that it is possible to show the normal period of time a particular location is navigable according to vessel type. It is on the basis of these data in Table 1 that the statements can be made in the Summary below.

Summary

Ice conditions in Strathcona Sound and Admiralty Inlet impose the greatest limitation on the length of the navigation season for all types of vessel than is the case for any other part of the route. If a Type "A" vessel is used to penetrate Strathcona Sound and Admiralty Inlet the ice there will permit such an unescorted entry from July 21 to November 12 (see Table 1). On the other hand, since these areas are in Zone 13, the ASPPR will permit entry from June 25 until October 22. While it may be legally possible for a Type "A" vessel to enter those places on June 25 she may discover that nature will not co-operate until July 21. However, at the other end of the season, nature would seem to permit a Type "A" vessel to operate in these two areas until November 14 whereas the ASPPR restrict a ship to October 22.

The upshot is that the length of the season into Strathcona and Admiralty Inlet, for a Type "A" vessel, lasts from July 21 until October 22. Accordingly, the season can be taken to be 94 days.

It will be noted that in VOYAGE CYCLING, mention is made that six voyages might be optimistic and the possibility of only five was included. The discrepancy between the requirements of the ASPPR and the length of season derived from Table 1 is another reason for opting for five rather than six deliveries for a Type "A" vessel.

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TABLE 1

NORMAL ACCESSIBILITY DURING THE "OPEN WATER" PERIOD ACCORDING TO AREA AND TYPE OF VESSEL

AREA	TYPE OF VESSEL	LENGTH OF NAVIGATION SEASON	TOTAL (weeks)
Baffin Bay	Icebreaker	May 1 to March 21	40
&	Ice-strengthened	July 14 to January 21	25
Davis Strait	Unstrengthened	August 1 to November 21	15
Lancaster Sound	Icebreaker	May 1 to February 28	40
	Ice-strengthened	June 1 to December 14	26
	Unstrengthened	July 21 to October 21	12
Admiralty Inlet	Icebreaker	July 1 to January 31	28
&	Ice-strengthened	July 21 to November 14	15
Strathcona Sound	Unstrengthened	August 14 to October 14	8

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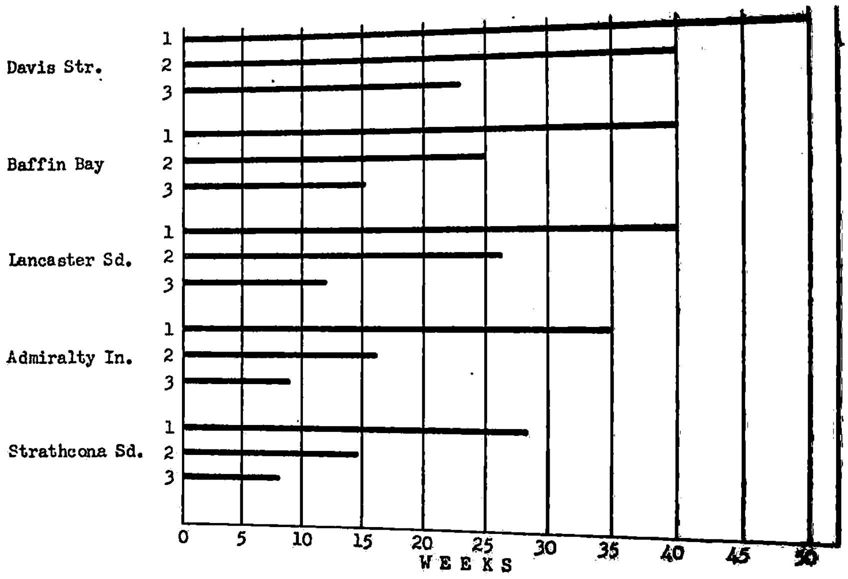
DIAGRAM 1

Typical Duration of the Shipping Season for Icebreakers[1]
Ice-Strengthened Vessels[2] and Unstrengthened Vessels[3]



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ICE CONDITIONS

The route between Europe and Strathcona Sound has been divided into three sections which have already been described. The ice conditions and concentrations for each, as they affect navigation for a Type "A" vessel, between July 15 and November 1, are described below. Maps of ice concentrations are included for those potentially ice-encumbered sections of the route.

The Ocean Passage -- Europe to Davis Strait

Ice conditions in the north Atlantic would not prevent a Type "A" vessel from attaining the entrance to Davis Strait at this time of the year. Either of the routes shown on Figure 1 between Rotterdam and Davis Strait could be used.

Caution would have to be exercised between Cape Farewell and Davis Strait because the current which sweeps around the cape, and northward up the west Greenland coast, carries with it quantities of heavy "storis" from east Greenland during the summer break-up period. This type of ice is one which all ships would want to avoid and this could be easily accomplished by standing well south of Cape Farewell[.]

… It can be concluded, without any reservation and for all types of ship, that the Ocean Passage section of the route presents no problems insofar as sea ice is concerned and this is especially so during the period July 15 to November 1.

Baffin Bay -- Davis Strait to Lancaster Sound

Ice conditions here can hinder a Type "A" vessel attempting to pass through this area between the dates already mentioned. No hard and fast rules can be established because the types of ice and the degree of concentration vary from week to week as well as from year to year. One factor which influences the ice, and which remains relatively constant, is current -- see Figure 4.

Generally, the ice conditions in the eastern and western parts of Davis Strait, and to some extent in the eastern and western parts of Baffin Bay, are very different due primarily to currents. The warmer one which moves north along the west Greenland coast normally keeps this part of the strait, and also the adjacent part of the bay, free of ice. Figure 5 indicates the effect of this current on the ice concentrations for mid-July in a typical year.

Even though the mid-July concentrations along the west Greenland coast are small and passage for shipping, particularly a Type "A" vessel, appear to be relatively easy, numerous icebergs are distributed throughout this area. A typical iceberg population for mid-summer is shown in Figure 6.

Bergs are not only visually impressive but they also make good radar targets so they can be sidestepped with ease. Bergy Bits and Growlers, on the other hand, are far more hazardous, especially the latter, for they float low in the water making extremely poor visual and radar targets. Wave action rounds off their corners making them even more difficult to detect with radar. Growlers can weigh several hundred tons, enough to inflict serious, if not fatal, damage to the hull of a ship unfortunate enough to strike one in heavy weather.

As shown in Figure 5 the ice concentrations on the Canadian side of Davis Strait and Baffin Bay in mid-July do not favour the transit of a Type "A" vessel.

The ice conditions in the bay in mid-July are generally more concentrated than those described for Davis Strait and as for the previous instance the eastern parts of the bay support a much lighter ice cover than does the Canadian sector.

… No map is supplied to describe ice concentrations likely to be encountered by a vessel moving through the Baffin Bay section and the Lancaster Sound - Strathcona Sound section in mid-September. No map is necessary because normally no ice exists at this time along the routes outlined above and shown in Figure 1. Occasionally, during a "bad" ice year, some ice may remain along the Baffin coast during mid-September but the remaining areas of both sections will be almost totally free of ice.

By the end of the legal navigation season (the end of October) the ice concentrations in the Baffin Bay section would usually appear as shown in Figure 7. As in the previous instance the route along the west Greenland coast is the more favourable one through Davis Strait and Baffin Bay at this time of the year. Although the northern part of the bay, according to Figure 7, supports concentrations up to ten tenths (i.e. 100% ice cover) the majority of this ice is less than 10 inches thick as it has only begun to grow.

Based on the concentrations shown in Figures 5 and 7, plus other evidence, it can be concluded that the best route for ships attempting to pass through the Baffin Bay section should parallel the west coast of Greenland from Cape Farewell to Cape York during the early and later stages of the navigation season. The passage across Baffin Bay to Lancaster Sound, from the vicinity of Cape York, is normally more difficult than the passage north. At the beginning and at the end of the navigation season a ship may be obliged to use Option "A" as shown on Figure 2. The route designated as Option "B" can be used a few weeks after the beginning and before the close of navigation while Option "C" route can only be used in the latter part of the season if it happens to be a typical one.

Lancaster Sound to Strathcona Sound

This, the third section of the route, will pose the greatest problems for a Type "A" vessel as far as the effect of ice is concerned. Such a vessel would have no major problem crossing Lancaster Sound to the entrance to Admiralty Inlet during the third week in July. However, the ice cover in the inlet as well as in Strathcona Sound will likely be solid and unmoving as is shown in Figure 5. But this solid ice cover will be in an advanced state of decay and the ice will be rotten. Rotten ice is defined as ice where the puddles have melted through to the sea. While it may be termed rotten the ice between the holes may be as much as four feet thick. The ice thickness curve (Diagram 2) gives the average rate of growth and decay for ice in the Strathcona Sound area.

A Type "A" vessel attempting to penetrate this solid but rotten ice cover in the inlet in the latter part of July would have problems. These would be compounded in Strathcona Sound. However, break-up and subsequent clearing of these two areas is normally completed by mid-August. From then until the beginning of October the areas are easily accessible to such a vessel.

After October 1 new ice begins to form. Due to the protected situation there it will form first in the sound. Ships attempting to enter would have to combat this newly formed ice cover from the beginning of October until the close of navigation at the end of that month. Although conditions during October are not the best a Type "A" vessel would still be able to operate in this section although there could be occasional delays on account of unfavourable ice conditions.

It is concluded that a Type "A" vessel would be able to pass through Lancaster Sound during the navigation season stipulated above without undue difficulty. However, such a vessel could be held up occasionally for short periods as she attempts to enter Admiralty Inlet and Strathcona Sound near the beginning and at the end of the navigation season. No difficulties attributable to ice would be experienced during the middle part of the navigation season for any of these locations.

Summary and Conclusions

The navigation season for an unescorted Type "A" vessel from Europe to Strathcona Sound extends from July 21 until October 22. Ice conditions in

Admiralty Inlet and Strathcona Sound could delay a ship for brief periods at the start and at the close of the season.

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VOYAGE CYCLING

To determine the duration of each voyage between Strathcona Sound and Europe, and therefore the number of voyages it might be possible to complete during the navigation season, the following factors should be taken into account:

> Ship speed in open water -- Davis Strait to Rotterdam and return -- 15 knots
>
> Ship speed through ice-laden waters -- Davis Strait to Strathcona Sound and return -- 12 knots
>
> Loading and unloading times -- 2 days each.

Accordingly, a voyage cycle would work out as follows:

Loading time at Strathcona Sound	2 days
Passage time to Davis Strait	3 days
Passage time to Europe from Davis Strait	6½ days
Unloading time at Rotterdam	2 days
Passage time to Davis Strait	6½ days
Passage time to Strathcona Sound from Davis Strait	3 days

Total (one complete cycle)	23 days

To achieve the maximum possible number of deliveries the first ship destined for Strathcona Sound at the beginning of the season should be stationed at the outer limit of Zone 13 ready to enter that zone as soon as the Arctic Shipping Regulations would permit. For a Type A vessel this would be

June 24. It is one day's steaming, assuming she enters Zone 13 early on June 25, to reach Strathcona Sound. These dates vary for other types - see Table 2.

The regulations permit a Type A vessel to operate in Zone 13 between June 25 and October 22, a period of 120 days. One ship should be able to make 6 deliveries during this period on the basis of a 23 day voyage cycle and assuming she arrives for the first load on June 26. She should be back for subsequent loads as follows:

July 19
August 11
September 3
September 26
October 19

The Regulations require a Type A vessel to be clear of Zone 13 on October 22. On the basis of the foregoing examination the ship would be two thirds of her way to Davis Strait, clear of Zone 13 with a day in hand.

It remains a matter of opinion whether such a ship could be relied upon to make six deliveries on the basis of the speeds and cargo-handling times used. At the beginning of the season the first two voyages into Strathcona would have to be undertaken in the face of some formidable quantities of ice despite the fact that it would be in the process of ablation and break-up. There could be substantial delays. On the other hand, the September and October voyages should meet easy conditions and an opportunity to shorten the 23 day cycle by a considerable margin.

Table 2 shows that the other vessel types achieve fewer deliveries with Type "E", a ship with no ice-capability, managing to complete only two deliveries.

As indicated elsewhere in the text, only Type "A" vessels will be considered in this study.

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ICEBREAKERS

The true icebreaker does not exist as a commercial vessel. The icebreaking tanker Manhattan (155,000 tons & 43,000 shaft horsepower) probably came nearest to meeting this definition but she was really a test vehicle created for a specific purpose. All icebreakers are Government owned and operated, they are immensely strongly built of high quality materials and possess extraordinarily powerful engines and great endurance -- or they should do. Because of these attributes they are also costly ships to build and operate.

The need to consider the movement of commercial bulk cargoes may in a few instances justify the construction of pure icebreaking bulk carriers. This would envisage high tonnages (5 million tons or more) and virtually an all-year operation. However, such is not the requirement for Strathcona Sound.

Canadian and American icebreakers were designed for summertime operations in the arctic, nothing more, and hence their contribution to shipping operations there are governed by this fact. They have little capability should they wish to extend the present navigation season by even a small amount. For this to become possible very much larger and far more powerful icebreakers would be required.

To convey an idea of the capabilities and limitations of these vessels the John A. Macdonald, the icebreaker which accompanied Manhattan through the Northwest Passage, displaces only 9,000 tons and develops 15,000 shp. Canada's newest and largest icebreaker, the Louis S. St. Laurent, displaces 14,000 tons and develops 24,000 shp (27,000 for short periods). The latter vessel, despite all this power, can break only three feet of fast ice in the continuous mode. In fast ice four feet thick she must resort to backing and ramming tactics. Not very impressive especially when it is realized that First-year ice can attain a thickness of approximately seven feet.

Earlier in this report reference was made to a proposal recently put out by the Ministry of Transport concerning an amendment to the Arctic Shipping Pollution Prevention Regulations. This suggests that ice-strengthened ships (e.g. Type "A") could, with icebreaker support, operate in the various zones between the dates that apply to the icebreaker. For instance, a Type "A" vessel operating to Strathcona Sound could enter Zone 13 June 10 (15 days earlier) and depart for the last time on December 31 (70 days later)[,] a period of 204 days. This represents a very substantial extension of the season -- from 94 days to 204 days during which total period nine voyages could be undertaken.

Attractive as this may sound the foregoing is predicated on the availability of an Arctic Class 3 Icebreaker -- i.e. a vessel with the capability of the Louis S. St. Laurent already described. The assured availability of this ship to meet the special needs of this one commercial operation, with numberless competing commitments of various sorts, is unlikely to say the least. No planner would rely on having a shipping operation dependent upon such flimsy possibilities.

Clearly, with the quickening pace of arctic development, there is a need for a substantial increase in the Government's arctic icebreaking fleet, both in the number of ships and in their capabilities. New construction is needed to replace the older ships of the fleet. The recent announcement of a plan to build four new icebreakers will not meet the need for these ships will not be arctic-capable.

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BARGES AND PRIME MOVERS

One of the riskiest operations in the high arctic is one which envisages tugs trying to tow barges through ice. It is totally impractical. However, if a prime mover (euphemism for a tug in the pusher role) were to be designed to be thoroughly ice-capable and able to lock into, and become an integral part of, an equally ice-capable barge, there could be merit in this method.

A major advantage to such a concept would be the ability to over-winter one or more of these barges at site, stockpiling the product directly into them during the closed navigation season. Thus would one handling process be avoided. Such an arrangement would be very attractive were the moisture content such that the product would freeze if stored ashore. Breaking it loose so that it might be handled and loaded into a ship could be expensive and time-consuming. The erection and heating of storage sheds to prevent this could be equally expensive.

By over-wintering, barges could also serve as fuel caches and storage dumps for the mining operation[,] lessening or removing altogether the need for resupply by air during the winter.

Critics of this method allege that the capital cost of creating such very special ice-strengthened barges (to meet Government standards and the rigours of heavy ice) plus the cost of at least one prime mover would be high. Indeed, high enough to be nearly the same as the capital cost of an equivalent ice-capable ship of similar capacity. Only shallow water, they say, which would deny access by ships would justify adopting the barge and prime mover mode. This remains to be proven.

Despite this type of criticism expressed above there are advantages to the barge method and this concept should be examined if only to establish comparative costs before such an alternative is dismissed as [too] expensive or impractical.

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APPENDIX 3.

DEFINITIONS

Note: All definitions, except that for STORIS, come from the World Meteorological Office publication WMO Sea-Ice Nomenclature (No. 259 TP 145 -- 1970)

BERGY BIT

A large piece of floating glacier ice, generally showing less than 5 metres above sea-level but more than 1 metre and normally about 100-300 square metres in area.

GROWLER

A small piece of ice, smaller than a BERGY BIT or FLOEBERG, often transparent but appearing green or almost black in colour, extending less than 1 metre above the sea surface and normally occupying an area of about 20 square metres.

HUMMOCK

A hillock of broken ice which has been forced upwards by pressure. May be fresh or weathered.

HUMMOCKED ICE

Sea ice piled haphazardly one piece over another to form an uneven surface. When weathered, has the appearance of smooth hillocks.

HUMMOCKING

The pressure process by which sea ice is forced into HUMMOCKS. When the floes rotate in the process it is called screwing.

ICEBERG

A massive piece of ice greatly varying in shape, more than 5 metres above sea-level, which has broken away from a glacier, and which may be afloat or aground. ICEBERGS may be described as tabular, dome-shaped, sloping, pinnacled, weathered or glacier bergs.

RAFTED ICE

Type of deformed ice formed by one piece of ice overriding another.

RAFTING

Pressure processes whereby one piece of ice overrides another. Most common in new and young ice.

RIDGE

A line or wall of broken ice forced up by pressure. May be fresh or weathered.

RIDGED ICE

Ice piled haphazardly one piece over another in the form of ridges or walls. Usually found in first-year ice.

STORIS

The Scandinavian name for the pack of heavy ice floes which drifts from the Arctic Ocean along the east coast of Greenland, around Kap Farvel (Cape Farewell), and northward along the west coast of Greenland where it melts. (POLAR OPERATIONS - Macdonald - U.S. Naval Institute)

Doc. 11: T.C. Pullen, Polar Icebreaker: Operational Requirements and Characteristics, 7 January 1974.

HBC Archives H2-141-2-2 (E 346/1/61)[1]

P O L A R   I C E B R E A K E R

OPERATIONAL REQUIREMENTS

and

CHARACTERISTICS

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January 7, 1974

INTRODUCTION

The purpose of this document is to state the missions, required capabilities and characteristics of a new Canadian Polar Class Icebreaker to meet operational requirements in the Arctic.

2. While a statement of operational requirements, the required capabilities are kept within the bounds of technical feasibility and Canadian industrial capacity. It is not a technical specification, but an outline of parameters from which detailed designs and specifications can be developed.

[1] *Editors' note:* See the original file for a memorandum from A.H.G. Storrs, Director, Marine Operations, Department of Transport, to Captain Pullen, dated 19 February 1970, providing "general remarks on some of the considerations that should be taken into account in preparing the statement of operational characteristics for a polar icebreaker."

MISSIONS

3. The primary mission is to support shipping including resource exploration support shipping, and anticipated resource (i.e. oil, ore and gas) marine transportation. Present indications are that the initial concentration of Arctic traffic will be distributed east of the Prince of Wales/McClure Strait, however, it is desirable that this ship have at least an eight to ten month capability for passage through the North West Passage.

The large bulk or LNG carriers envisaged will be so designed that in normal circumstances, they will be capable of negotiating the ice independently.

It is not intended to provide close escort and the functions of the icebreakers therefore are:

- a) "to prevent" marine disaster, and
- b) to maintain the flow of marine transportation, by providing icebreaker assistance capable of:
  - (i) preventing beset ships from being carried by ice into shallow water or other dangerous situations.
  - (ii) releasing ships that are beset
  - (iii) assisting ships that have sustained damage to a port of refuge or to open water.

4. Secondary missions are:

- a) to provide a policing function, ensuring compliance with Canadian Regulations.
- b) Search and Rescue.
- c) Pollution control.
- d) To provide a vehicle for hydrographic and marine science investigations on a limited scale in otherwise inaccessible areas.
- e) To contribute to the provision of environmental intelligence on the route.
- f) to provide emergency medical assistance to ships on the route and remote settlements in the area.
- g) To provide emergency logistic support to remote areas.

ICEBREAKER CAPABILITY

5. Performance in ice must be the primary criterion in the design. Considering ice conditions on the route, the minimum acceptable ice performance to enable the missions to be carried out on a year-round basis is as follows:

   a) To be capable of maintaining not less than 3 knots in consolidated pack ice up to 8 feet in thickness.
   b) To be capable of progress by ramming through consolidated Polar Ice (multi-year ice) of a thickness up to 25 feet.

6. It is expected the requirement of 5(a) above will be the controlling factor determining Shaft Horsepower/Displacement requirements; and 5(b) will influence the choice of scantlings.

DIMENSIONS AND POWER

7. To achieve the required icebreaking capability it is estimated the ship must be of about 25,000 tons displacement with a total shaft horsepower of about 100,000.

8. Approximate dimensions to be in the order of:

   a) Waterline length 500 ft.
   b) Maximum beam (W.L.) 95 ft.
   c) Maximum draught 45 ft.
   d) Block co-efficient .5.

ENDURANCE

9. Considering the mode of operations in the Arctic on a year-round basis, and the difficulty of providing fuel in the area, maximum endurance consistent with other design factors must be sought. This will influence the choice of propulsion system and space for fuel tanks.

10. A free-running steaming endurance of 20,000 miles at economical speed, still having 20% fuel remaining, is considered a minimum.

11. Assuming gas turbine-electric or diesel-electric propulsion and an all purpose underway consumption rate of 0.5 lbs./SHP/hr. it is estimated fuel consumption would be of the following order:

a) Free-running at economical speed (13-14 knots) ...100 tons/day.

b) Icebreaking using max. continuous power.............500 tons/day.
(full = SHP 100,000 = $\frac{.5 \times 100{,}000 \times 24}{2240}$ = consumption 535 tons/day

If max. continuous is 93½% of full power = 500 tons/day.

c) Standing by, stopped, or at anchor......................... 30 tons/day.

12. Fuel required to provide a 20,000 mile free-running endurance at economical speed (13-14 knots) would be about 4,400 tons. To have a 20% reserve remaining, tank capacity would have to be not less than 8,000 tons; that is about 32% of the loaded displacement. However, the greater part of this ship's dead weight is expected to be bunkers.

13. If on task operations during periods of complete heavy ice cover involves 1/3 of the time breaking through ice at maximum continuous power and 2/3 of time standing by stopped, fuel consumption would average about 5,600 tons per month per icebreaker. Sustained operations would, therefore, require a sizeable refuelling facility in the area.

The foregoing obviously will not apply in the event of nuclear propulsion.

HEEL, TRIM AND BALLAST SYSTEMS

14. For achieving optimum performance in ice, it must be possible to impart a continuous rolling motion, change the trim, and adjust the draught as loading alters due to fuel and stores consumption. An adequate metacentric height must also be preserved to ensure stability when riding up on ice in the ramming mode.

In making continuous progress through heavy consolidated pack ice, a rolling motion to maintain a film of lubricating water between shell and ice is an important element in reducing friction. When using the ramming technique, heeling and trimming are important to overcome static friction when backing down.

15. Heeling arrangements should enable a 13 to 14 degree roll each side for optimum effect, and must not be less than 10 degrees. The period for a

complete roll should be about 4 minutes, and must not be more than 6 minutes.

16. Trimming tanks should enable a change of trim of at least 6 feet in the loaded condition without using peak and other ballast tanks.

17. Ballast tanks should have the maximum capacity consistent with other design factors. It is appreciated it will not always be possible to compensate for all fuel consumed between successive replenishments. But, if possible, ballast tanks should at least ensure positive stability in the ramming icebreaking mode with fuel nearly exhausted and without ballasting fuel tanks.

STABILIZERS

18. A ship designed for optimum performance in ice, with very round bilge sections, very little flat vertical section aft, a large metacentric height and a smooth bottom, is inevitably an extremely heavy roller in the open sea. The ship's natural roll period is short and the motion can be violent. Strains on rigging and other gear can be severe: and the motion can be very exhausting for the crew. A means of reducing the rolling when on open-sea passages must therefore be provided.

19. A system is required which will dampen the roll by at least 60 to 70 percent. The system should also be as simple as possible, with a minimum maintenance requirement. This suggests a passive flume tank system.

20. As stabilization will not be required when in ice, the flume tank system should, if possible, be designed to use the same tanks as the heeling system.

SHIP CONTROL

21. Good manoeuverability and quick response to rudder and engine orders are essential. Control positions providing direct control of both rudder and engines must be located in the wheelhouse and on each bridge-wing accompanied by appropriate tell-tale indicators.
The bridge should be designed to give maximum possible all-round visibility from each control position. (A wheelhouse study has been completed).

22. A triple-screw propulsion system is envisaged and to achieve optimum handling qualities it is considered that power distribution for a total of 100,000 SHP will be either 1:1:1 or 1:1.5:1 (2/7:3/7:2/7).

ICEBREAKING BOW

23. For optimum icebreaking performance, the configuration of the bow is one of the most important aspects of the design. While the bows in existing icebreakers have given satisfactory performance, the conditions under which the proposed new ship will have to operate are somewhat different. The ship will be larger than existing icebreakers, and she will spend a large portion of her service in complete consolidated heavy ice cover. When breaking through such ice it is not just broken and pushed aside, but must be forced under or over the adjacent ice, or slide down the ship's side on edge, or escape under the ship as she progresses. The manner in which this is accomplished largely depends on the bow design while to a lesser degree, hull form generally contributes to overall icebreaking efficiency.

24. It is therefore considered that it is not sufficient merely to enlarge or adapt an existing bow design. There is a requirement for an in-depth investigation including model tests, of this aspect to define an optimum bow design and hull form. This study has been defined, detailed and is in progress.

AVIATION

25. A shipborne helicopter capability is required primarily for tactical ice reconnaissance. In addition it is needed for personnel and stores transfers; for rescue work; and as a means of keeping ships on the route under surveillance.

Helicopters

26. Two types of helicopters are required:

a) A small twin-engine machine capable of carrying two ice observers in addition to the pilot for local ice reconnaissance to a radius of 25 miles. It must be able to scramble at short notice with a minimum of effort. It must provide good all-round visibility for the ice observers; be float equipped for landings on ice, land or water; and have survival gear appropriate to the environment as an integral part of the aircraft's equipment.

b) A large twin-engine machine for medium-range ice reconnaissance to a radius of 100 miles, carrying two ice observers in addition to the aircrew.* This machine must also be capable of the airlift and rescue tasks. It must have the following features:
   i) An all-weather capability to permit operations during darkness and in low visibility.
   ii) Power folding of the rotors to permit hangaring.
   iii) Slings and slinging arrangements for cargo that cannot be stowed inside the aircraft.
   iv) A winch for landing and recovering people and equipment when conditions prevent touching down.
   v) Illumination for night operations.
   vi) Emergency flotation equipment.
   vii) Survival gear appropriate to the environment and stowed as an integral part of the aircraft's equipment.

<u>Aircraft Establishment</u>

27. To enable the intensity of flying and availability required for operations, the ship's aircraft establishment must consist of <u>two of the small helicopters and one of the large helicopters</u>. In addition, the ship's flight-deck must be of sufficient size and strength to receive the largest shore-based rotary wing aircraft likely to be in service.

* Note: The minimum 200 mile range would place such an aircraft within still air range of at least one of the existing Arctic fuelling sites from any position on the Northwest Passage Route between Davis Strait and Point Barrow, Alaska.

<u>Aviation Fuel</u>

28. It is estimated the large shipborne helicopter will be able to accumulate up to 1,000 hours flying time, and each of the small helicopters 1,200 hours, before shore maintenance overhauls are required. With a full establishment of aircraft aboard, this would enable the large machine to be airborne about 15% of the time, and one of the small ones about 36% of the time, during a nine-

month deployment. Ideally, the ship's aviation fuel capacity should cater to this without replenishment.

29. The large helicopter is expected to consume about 135 gallons per hour; and the small helicopters 22 gallons per hour each. A total of 187,800 imperial gallon of useable helicopter fuel would, therefore, be required. Assuming JP-5 fuel (SG .803 at 60°F) this is about 673 tons. Allowing for tanks filled to 95% and a margin for tank stripping, the minimum tank capacity required is about 32,000 cubic feet.

<u>Flight Deck</u>

30. The flight-deck must have sufficient area and be strong enough to permit unobstructed flying operations by both the ship-borne and large shore-based helicopters. Its design should take into account the point loading at gross weights, plus the normal growth factors to be expected for such machines as the "Chinook", "Pathfinder" and the "Skycrane". In addition the following factors must be considered:

a) An accident on deck creates a serious risk of fire and explosion. The design must therefore be such as to direct spilled fuel over the ship's side and not forward into the hangar. Moderate camber and adequate drainage are necessary; and there must be no sheer to the deck.
b) Comprehensive deck lighting for night operations.
c) Location of the cargo hatch and dimensions of the flight-deck should be such as to permit flying operations by the smaller helicopters while cargo is being ranged on deck.
d) Heating arrangements in the flight-deck to expedite melting and removal of snow and ice.
e) Standard flight-deck facilities such as firefighting, fuelling, tie-down points, breakdown guard rails, safety nets, etc., must be included.
f) A shelter should be provided for flight-deck personnel during flying operations with the hangar door(s) closed.
g) An enclosed control position with good visibility over the flight-deck and its air approaches is required. It must have both internal and helicopter-frequency communications.

Hangar

31. The hangar must be large enough to accommodate the Unit Establishment of helicopters when all aircraft are embarked. For ease and simplicity of operations it is to be forward of, and on the same level as, the flight-deck.

32. In addition to the main door(s) to the flight-deck, it must have adequate access and escape doors.

33. It must have adequate insulation; heating and ventilation; customary services such as electrical power, compressed air, fresh water, tie-down points, etc. For engine changes there must be sufficient overhead clearance and suitable lifting arrangements. Stowage for spare gear must be provided.

34. Firefighting facilities appropriate to the stowage of three helicopters and ancillary equipment are essential.

Workshop

35. An aircraft workshop is required, adjacent to the hangar. Its layout, furnishings and facilities must be appropriate to the needs of periodic inspections and emergency repairs.

Aircraft Control

36. Arctic helicopter operations, especially during periods when storms, darkness and low temperatures can combine to create hazardous flying conditions, demand a high standard of aircraft control. To carry out efficient flying operations in support of the icebreaker, aircrew must be secure in the knowledge that the ship is in communication and aware of the aircraft's location.

37. Air control arrangements must, as far as possible, enable the ship to track its airborne helicopters, provide informative control and assured homing. [Equipment] required to achieve this include:

a) Reliable ship/air voice radio communication.
b) Appropriate ship's radar equipment (S and X bands).
c) Radar transponders or radar beacons in the helicopters.

d) Ship radio beacon for use of D/F in the helicopters.
e) Ship D/F on aircraft voice radio frequency.
f) A rotating visual beacon in the ship, installed to give all-round coverage with a high-intensity light.
g) A simple air plot on the ship's bridge.

NOTE: These requirements in no way obviate the need for appropriate navigational systems in the aircraft.

<u>BOATS AND OVER ICE VEHICLES</u>

<u>Boats</u>

38. In addition to the lifesaving requirements of the SOLAS Convention and the Steamship Inspection Service Regulations, boats are required for the following functions:

a) The movement of people and cargo between ships and between ship and shore when helicopters cannot be justified for the task, or are not available.
b) Hydrography.
c) Sounding ahead of the ship. (A feasibility study for a forward looking ship borne sounder has been initiated).
d) Diving.

39. To meet these needs the following are required:

a) One 50 foot landing craft.
b) One 36 foot Sounding Boat.
c) (Both to be handled by crane).

<u>Over ice Vehicles</u>

40. The ship will spend a large portion of her service in complete ice cover where boats cannot be used. In these circumstances there is a need for over ice vehicles for movement of people and cargo when aircraft cannot be used. The following, or similar vehicles, would meet this need:

a) A minimum of two small tracked vehicles ("Ski-doo" type) with trailers.
b) One large tracked vehicle ("Bombardier" type). Stowage to be plumbed by crane.
c) ACV [air-cushion vehicle or hovercraft] of the SRN6 class?

Boat and Vehicle Shop

41. A workshop and stowage for boat and vehicle equipment, engine servicing, battery charging, etc., must be provided.

ICE AND METEOROLOGICAL OFFICE

42. An important task is to contribute to environmental intelligence on the route. Ice and weather information is required for both tactical purposes and future planning. This involves the recording and reporting of observed data; reception of reports from other observers; reception of broadcast ice and weather reports and forecasts from central authorities; and correlation of all this information.

43. The requirement is for a ship's environmental intelligence office where these functions can be performed. It should be located adjacent to the bridge for easy access by the command. It should have:

a) Indicators from remote-reading sensors.
b) Radio, RATT [Radio automatic teletype] and FAX trans/receivers for Ice and Met. Communications.
c) A large plotting table.
d) Office arrangements for recording, filing, reference material, etc.

44. Space requirements for the Ice/Met Office are of the order of 15 feet by 10 feet.

HYDROGRAPHIC AND MARINE SCIENCE LABS

45. A secondary mission of the ship is to undertake hydrographic and marine science investigations on a limited scale in otherwise inaccessible areas. While some of this can be done using the ship's normal facilities and reporting of new hydrographic information is of course a continuous normal duty of CG Ships, special teams will be embarked from time to time for these investigations. On these occasions, space for plotting and instrumentation will be required in addition to usual navigational facilities. When not in use for this purpose, this space could also be used for navigational training of embarked cadets.

46. The requirement is for a modest plotting room adjacent to the bridge. Dimensions should be of the order of 15 feet by 10 feet.

47. Special laboratories for marine science are not considered necessary.

NAVIGATIONAL EQUIPMENT

48. The following are the main navigational equipments considered necessary. In addition, other items to complete a standard outfit for piloting, dead reckoning and celestial navigation must, of course, be provided.

a) A minimum of two radar sets, one X-Band and one S-Band.
b) Two complete Echo Sounders.
c) Two Master Gyro Compasses.
d) Loran A.
e) Transit Satellite Navigation System.
f) Decca Navigator.

49. Special area is required in the choice of equipment to ensure optimum performance under the variety of environmental conditions which will be encountered. Design features of equipment, and layout in the ship, must cater to the needs of user techniques in Arctic navigation. A high degree of dependability is required and alternative power supplies must be provided for some [equipment] to ensure continuous availability. Maintenance requirements must be minimal.

COMMUNICATIONS EQUIPMENT

50. In addition to the communications facilities installed in the latest Canadian Government Icebreaker, the following features should be included:

a) Cryptographic facilities to enable passing classified messages between the ship and shore authorities.
b) Tape recorders for the automatic logging of voice radio circuits.
c) An operations talk-back intercom system between Bridge, Radio Office, Ice and Met Office, Hydrographic Room, Flight-deck Control Position, Machinery Control Room and Master's cabin. The system should have an executive over-ride feature at the Bridge position.

d) A remote control unit for helicopter-frequency voice radio in the Flight-deck Control Position, as well as on the Bridge. (See para 30(g).)

e) Radio, RATT and FAX trans/receivers for Ice and Met. communications in the ice and Meteorological Office. (See para 43(b).)

COMPLEMENT

51. The design and selection of [equipment] for the ship must have an eye to maximum practical use of automated systems so that crew requirements can be kept to a minimum. The ship will be deployed for on-task duty in the Arctic at least nine months of each calendar year: November through July. The remaining months will be used for maintenance and leave. For the on-task periods a form of crew rotation will be required.

52. It is, of course, impossible to determine a precise complement before other factors, notably the propulsion system, have been established. However, it is estimated the crew will be of the following order:

DECK	ENGINE ROOM	STEWARDS
Master 'A'++	Chief Engineer 'A'+	Purser 'A'-
Chief Officer 'A'	Senior Engineer 'A'	Ass't Purser 'C'+
1st Officer 'B'	1st Engineer 'B'	Chief Steward 'C'+
2nd Officer 'B'	2nd Engineer 'B'	Chief Cook 'C'
3rd Officer 'B'	3rd Engineer 'B'	2nd Cook 'C'+
3 Ass't Watchkeeping Officers 'C'+	3 Ass't Watchkeeping Officers 'C'+	1 Ship's Clerk 'D'
Medical Officer 'B'	1 ET_2 'C'	1 Storekeeper 'D'+
Medical Ass't 'C'	9 ET_1 'D'+	8 Stewards 'D'
1 Radio Officer 'B'		
2 Radio Officers 'C'+	8 Mechanics 2 'D'	MET. OBSERVERS
2 Helicopter Pilots 'B'	6 Mechanics 1'D'	
2 Flight Engineer 'C'		2 in "C" cabins
1 Electronic Technician "C"+		
1 Boatswain 'C'		
1 Bosun's Mate 'C'		
1 Carpenter 'C'		

10 Leading Hands 'D'+
12 Seamen 'D'-

Dormitory, with all facilities, for 32 2nd year cadets.

12 - "D" cabins with 1 Pullman type extra berth for 3rd year cadets.

In addition to the foregoing there should be at least spare cabins as follows:

Code "A" - 1
Code "B" - 4
Code "C" - 8
Code "D" - 8

Accommodation Code

A. Day cabin, night cabin, office and complete W.C. facilities.

B. Day cabin, night cabin, complete W.C. facilities.

C. Single cabin with washroom and shower (Consideration to be given to convertible berth).

D. Single berth cabin with wash hand basin, sharing adjoining washroom and shower with one other similar cabin.

NOTE:

Cabins with the same coding will in some instances also reflect rank, by virtue of size, locations and appointments as for example the "A" cabins of the Master and the Purser or the "B" cabin of the First Officer vis-a-vis the "B" cabin of the Third Officer and so on down to and including the "D" cabins.

ACCOMMODATION

53. A habitability study contract is being carried out by DRB, the results of which will, to CG approval be incorporated in the final design.

Amenities should include the following:

- Theatre for sixty (60) with stage and sound systems, projection room etc. suitable for filmed and live entertainment.
- Gymnasium with provision for individual and team competitive sports and usual exercise machines.
- Sauna and swimming pool.
- Hobby room including dark room, wood and metal working tools, crafts etc.

- Well stocked library and writing room.

Habitability

58. All living spaces must be designed with a view to maximum ease and comfort, consistent with utility. The location of cabins, mess rooms and recreation spaces should avoid areas of excessive noise and heat. Air conditioning should be capable of maintaining normal room temperatures both in the Arctic cold (down to -60°F) and in the Tropics, should the ship be required to make a Panama Canal passage. Insulation must be adequate to avoid condensation and icing inside accommodation spaces. The layout must be such that, as far as possible, there is convenient access to all parts of the ship without having to go outside.

Amenities

There should be at least 4 lounge/recreation rooms.

Consideration is to be given to reception of live television via satellite.

Facilities for amateur radio enthusiasts.

There should be an equipped classroom close to the cadets dorm if practical.

In addition to the offices provided in senior cabins there shall be a ship's office and engineer's office.

The medical office shall be adjacent to the ship's hospital and surgery together with both ward and isolation type patient accommodation.

The surgery is to be fully equipped in a manner superior to that existing for commercial passenger liners.

Separate dining rooms to be provided as follows:

- Master and Senior Officers.
- Officers general including 3rd year cadets.
- Petty Officer.
- Crew.

The dormitory housed cadets will use a cafeteria dining room adjacent to the dormitory and which can also be used as a games and general purpose room where 2nd year cadets are not carried.

In addition to 2nd year cadets, P.O.'s and crews catering will be cafeteria style.

Galleys, including cafeteria serving, pantries, ready use reach in or walk in refrigerators should be on one deck with provision stores and refrigeration space immediately below - though not necessarily the next deck down - and with necessary dumb waiter and elevator communication.

All dining rooms and accommodation should be above the main deck, priority given to accommodation.

PROVISIONS AND STORES

60. As far as possible, the ship should be self-sufficient for provisions and stores during her Arctic deployments. Although it is expected limited quantities of fresh provisions can, from time to time, be included in communication flights to the operating area; the capacities of refrigerated provision store rooms, dry provision stores, and general stores must be adequate to permit provisioning and storing for a period of 9 months.

CARGO SPACE

61. A limited cargo capacity is required to provide emergency logistic support to remote areas and for occasional transportation of special equipment. However, the ship is not intended as a cargo carrier for Arctic resupply purposes.

62. The requirement is for a cargo capacity of 200 tons weight, at a stowage factor of 100 cubic feet per ton; (i.e.) a cubic capacity of 20,000 cubic feet.

Hatch Dimensions

63. Hatch dimensions should be not less than 14 feet by 12 feet.

Cargo Path

64. As much of the cargo carried would probably be landed by helicopter, it is important there be an easy cargo path to the flight-deck. If possible, the cargo space should therefore be under the flight-deck, with a flush hatch.

Cranes

65. The ship should be provided with cranes, rather than booms and derricks. Assuming the cargo space can be located under the flight-deck, two cranes are required, one each side. They should be able to plumb the cargo

hatch, barges alongside on their respective sides, work boat and large tracked vehicle deck stowages. They can thus serve multiple purposes; cargo handling, lifting of aircraft, and lowering and hoisting of the landing craft, sounding boat and large tracked vehicle. In their stowed positions they must, of course, be clear of the flight deck. The type of crane selected should have an enclosed heated operator position and, as far as possible, working parts protected from the elements. Each crane must have a <u>SWL of 35 tons</u>.

<u>SHIP'S HOSPITAL</u>

66. Sick Bay arrangements are required to serve the needs of the ship's company, for providing emergency medical assistance to ships on the NW Passage route, emergency medical assistance to settlements in the operating area, and treatment of survivors from any SAR incident. The following should be included:

a) An examining room.
b) Operating room.
c) Dispensary.
d) X-Ray room.
e) Dark room.
f) Hospital ward (10 berths) with adjacent washroom (sinks, shower, toilet). Provision to be made for isolation of certain patients as required.
g) Medical stores space.

<u>OTHER SPECIAL FEATURES</u>

<u>Environmental Protection</u>

67. Considering the area of operations, the ship and her equipment must be capable of functioning efficiently in air temperatures down to -60°F and in wind velocities up to 100 knots. The following therefore require special attention:

a) Insulation and heating of tanks and piping systems including ballast, heeling and stabilizer systems, domestic and sanitary water systems, fire mains, etc.
b) Protection of antennae against wind, cold, icing and condensation. Radar aerials, in particular, will require special

arrangements, (eg) electrically transparent domes, heating of scanner motors, wave guide heating, etc.

c) Upper deck machinery.
d) Insulation, heating and ventilation of accommodation and internal work spaces.

Fire Protection

68. Fire on board ship during an Arctic Winter, should it get out of control, is a most serious threat to survival. Men compelled to take to the ice in such an emergency could quickly perish. To meet this danger, ship design and layout, fire detection and alarm systems, and fire-fighting facilities, become especially important. The ship should have the highest practical degree of fire zone sub-division; means of isolating corresponding sections of the ventilation system; a comprehensive fire detection and alarm system; good access routes; and a full range of fire-fighting equipment, including smothering arrangements in high-risk areas.

Illumination

69. For night operations the following special lighting arrangements are required:

a) A mercury-vapour type headlight on each bow to illuminate ice in the grain of the ship. To be an integral part of the hull and placed to prevent reflected light from interfering with vision from the bridge.
b) Two searchlights on the upper bridge, remotely controlled from the wheelhouse, providing all-round coverage.
c) Floodlighting alongside the ship to illuminate all approaches to gangways and the loading positions for landing craft and tracked vehicles.

Towing Winch

70. To extricate ships which have become beset or disabled a towing capability is needed; one which permits variations in the length of tow depending upon prevailing ice conditions and its influence on the vessel being towed. A self-rendering towing winch, protected from the weather, is a requirement.

71. Because of high freeboards, bulbous bows, raked stems and the size of modern ships, it is impossible to achieve a suitable lead for towing at short stay. A towing notch in the stern, commonly found in icebreakers, is therefore not required.

Small Arms Stowage

72. Small arms are required:

a) For self-protection of parties away from the ship in helicopters, tracked vehicles and on foot.

b) To have an armed presence to ensure compliance with Canadian Regulations and to assist in the preservation of Law and Order, should the occasion demand.

73. For self-protection, 10 rifles or carbines are required. For the policing function, an armed party of up to 10 may be required; and they should be equipped with a minimum of 4 automatic pistols, 6 automatic carbines, and related [accoutrements].

74. Therefore secure stowages for a total of 16 rifles or carbines, and 4 pistols, are required. In addition a secure small arms ammunition stowage must be provided.

Diving

75. To permit examination of propellers, rudders and other underwater fittings, of own ship and of ships being supported, a free-swimming diving capability to a depth of 15 fathoms is required. Such a capability may also be needed on occasions for the examination of terminal facilities. A full outfit of underwater tools, including cutting torches, is required. In addition to standard diving equipment, a recompression chamber must be included.

Waste Disposal

76. As the ship will on occasions spend several days standing by stopped in ice, special arrangements must be made for sewage and garbage disposal. Normal methods of overboard discharge are not acceptable and although ship generated sewage may be legally discharged in Arctic waters it is considered that H.M. Ships particularly Coast Guard, should where practical, set examples.

Consideration to be given either to adequately treated discharges overboard or incineration.

POWER AND DISPLACEMENT REQUIREMENTS - POLAR ICEBREAKER

References:

(a) "Predicting Icebreaking Capabilities of Icebreakers" (May 1969) (US Coast Guard Naval Engineering Report No.2, CG-316-2 promulgated 12 Jan 70 - limited distribution.)

(b) "Prediction of Icebreaker Capability" by CDR. R.M. White, USCG - paper to Royal Institution of Naval Architects (1969).

(c) "Application of Nuclear Power to Icebreakers" by Messrs. Lank and Oakley - paper to Society of Naval Architects and Marine Engineers, New York (Jun 1959).

Introduction

1. The purpose of this paper is to determine the approximate Shaft Horsepower and Displacement needed in the Polar Icebreaker to enable the required icebreaking capability.

Required Capability

2. As stated, the minimum acceptable ice performance for the missions to be carried out on a year-round basis is as follows:

"(a) To be capable of maintaining continuous progress in consolidated pack ice up to 8 feet in thickness.
(b) To be capable of progress by ramming through consolidated Polar Ice (Multi-year Ice) of a thickness up to 25 feet."

3. The problem can thus be divided into two modes of icebreaking, each influenced in its own way by ship characteristics. The two modes are the "Continuous Mode" and the "Ramming Mode".

Primary Factors

4. There is a general lack of detailed full-scale data covering the performance of icebreakers of different horsepower, displacement, beam and hull form. However there is sufficient information to conclude:

(a) The primary characteristics which determine capabilities in the "Continuous Mode" are Shaft Horsepower and Beam.
(b) The primary characteristics which determine performance in the "Ramming Mode" are Displacement and Impact Velocity.
(c) The shape of the hull causes perturbations in icebreaking capability which are small relative to the effects produced by variation of the primary characteristics. Nevertheless, refinements in the hull form of conventional icebreakers may result in reductions of over 20% in power required for the continuous mode, and greater maximum capability in the ramming mode. The most important of the hull form changes which give promise of improved capability is in the bow configuration.

5. The Shaft Horsepower needed will therefore be governed by the required continuous-mode icebreaking capability. The Displacement needed will be controlled by the required ramming-mode capability.

Prediction Methods

6. Reference (a) makes a thorough comparative analysis of a number of theoretical and semi-empirical methods of predicting icebreaking capabilities. It is the most up-to-date and authoritative work on the subject which has come to hand and is based on Russian and American studies, model tests and experience. It concludes:

(a) The "KASHTELJAN" Method is the most rational available for predicting continuous-mode icebreaking capabilities.
(b) The "WHITE" Method is the best for ramming-mode predictions.

7. This reference also includes the results of tests in a Wind Class Icebreaker (USCGC STATEN ISLAND) in the Bering Sea, 10-24 Feb 69, and a number of graphs showing predictions for several icebreakers using the various prediction formulae and techniques.

KASHTELJAN Predictions For LENIN, Continuous Mode

8. On page 215 of reference (a) continuous-mode predictions for the LENIN, using various theoretical techniques, are given in graph form. Near-zero-speed Resistance in Metric Tons is plotted against Ice Thickness in Meters; and this gives the Thrust required in that ship for continuous-mode

breaking of various thicknesses of standard monolithic ice, (ie) homogeneous ice of a tensile failure stress of 235 pounds per square inch.

9. As beam is one of the primary factors affecting continuous-mode performance, and the beam of the LENIN is the same as that of the envisaged Polar Icebreaker (90 feet), these curves should be a good basis for comparison if one assumes similar hull efficiency.

10. The KASHTELJAN Curve for LENIN indicates that the Thrust required for continuous-mode operations varies as t^2, where t is ice thickness. Near the upper limit of the plotted curve, a thrust of 400 Metric Tons is required to break through an ice thickness of 1.725 Meters (5.65 Feet).

11. Extrapolation. Extending the curve upwards on the basis of Thrust $\propto t^2$, (ie) $T = 400\ (t/5.65)^2$, the following values can be found, indicating the approximate thrust required for continuous-mode operation at near-zero speed for various ice thicknesses. (Table 1.)

(TABLE 1)

Ice Thickness (t) (Feet)	Thrust Required (T) (Metric Tons)
6.0	451.1
.2	481.7
.4	513.2
.6	545.8
.8	579.4
7.0	614.0
.2	649.6
.4	686.2
.6	723.7
.8	762.4
8.0	801.9

Thrust and Horsepower

12. The prediction methods for the continuous mode examined in reference (a) relate Resistance, and consequently Thrust, to Ice Thickness. There is therefore a need to establish a meaningful relationship between Maximum Thrust Available and installed Shaft Horsepower before estimates of required power can be made.

13. Icebreaker propellers are normally designed to give maximum thrust at near-zero speed, (ie) to provide maximum bollard pull. However a large increase in power will not return a correspondingly large increase in thrust. The

gain in thrust with increased power is limited by the amount of propeller disk area which can be provided and other factors.

14. The Maximum Available Thrust in five existing icebreakers, taken from reference (b) for WIND, GLACIER and LENIN, and from [Department of Transport] design data for the MACDONALD and ST.LAURENT, compared to the respective installed shaft horsepowers, is as follows:

	WIND	MACDONALD	GLACIER	ST. LAURENT	LENIN
Thrust, max available (lbs)	270,000	369,600	455,000	510,720	730,000
Shaft Horsepower	10,000	16,000	21,000	24,000	39,200
Thrust/SHP (lbs)	27.0	23.1	21.7	21.3	18.6

15. Employing a data curve fit of this information in a least square manner, the relationship between Thrust and Shaft Horsepower is given by the equation $T = 22.34418\ SHP^{0.73326}$, where T is maximum available thrust in Metric Tons and SHP is in thousands.

16. Though other factors may have an influence, this information about existing icebreakers can be used as a basis for estimating the maximum thrust which can be expected at higher installed powers. Indeed it appears to be the only method readily available and should be sufficiently realistic for planning purposes. The following table (Table 2) gives the results of upward extrapolation:

Max Thrust (Metric Tons)	Thrust/SHP (lbs.)	Shaft Horsepower (Thousands)
400	17.3	51.1
450	16.5	60.0
500	15.9	69.2
550	15.4	78.8
600	14.9	88.8
650	14.5	99.0
700	14.1	109.5
750	13.7	120.3
800	13.4	131.4

Ice Thickness and Shaft Horsepower, Continuous Mode

17. Using the results of the extrapolated KASHTELJAN predictions for the LENIN (Table 1), and the projected maximum thrust to be expected at higher installed horsepowers (Table 2), the following gives the estimated installed shaft horsepower required for continuous-mode operations in various ice thicknesses for a ship with a 90-foot beam and a hull efficiency similar to that of the LENIN.

(TABLE 3)

Ice Thickness (Feet)	Shaft Horsepower (Thousands)	Ice Thickness (Feet)	Shaft Horsepower (Thousands)
6.0	60.2	7.0	91.6
.2	65.8	.2	98.9
.4	71.7	.4	106.6
.6	78.0	.6	114.6
.8	80.9	.8	123.1
		8.0	131.8

Conclusion Concerning Shaft Horsepower

18. Based on the above information it can be seen the Shaft Horsepower required for continuous-mode operation in an ice thickness of 8 feet is about 131,800. This assumes a hull efficiency similar to that of the LENIN. It also assumes a Thrust/SHP ratio determined by mathematical analysis of data about existing icebreakers and its extrapolation to higher installed powers.

19. In para 4(c) above it was stated refinements in hull form may result in reductions of over 20% in power required for the continuous mode. This statement originates from reference (a); but, though undoubtedly well founded, the magnitude of the possible reduction must be a subjective assessment. However if it is assumed that full benefits from hull design improvements, notably in the bow configuration, can be realized; and these result in a 20% reduction in required power; then the installed Shaft Horsepower can be reduced to about 105,400.

20. It is also conceivable that efforts in propeller design could achieve a slightly better Thrust/SHP ratio than that estimated in Table 2. Finding Thrust/SHP at higher powers on the basis of data from existing icebreakers, though statistically plausible and the best means available for this appreciation, may be subject to some error. It is a large extrapolation.

21. Considering these additional factors, and assuming improved hull and propeller designs can result in a combined reduction of 24% in necessary

power, it is concluded the minimum installed Shaft Horsepower required for the Polar Icebreaker is 100,000.

22. This is a conservative estimate. It allows for the full benefits which can reasonably be expected to accrue from design improvements. Anything less would make it unlikely the ship could achieve the required continuous-mode icebreaking performance.

WHITE Predictions, Ramming Mode

23. The ramming-mode predictions by the recommended "White" Method, given in reference (a), correlate Ice Thickness with Impact Velocity and Displacement. For the LENIN the prediction formula for standard ice (tensile failure stress of 235 psi) can be reduced to

$\underline{H = 0.11465\ v^{0.5}\ w^{0.4225}}$ where H = Ice Thickness (Feet)
V = Impact Velocity (Knots)
W = Displacement (Tons)

24. Displacement and Impact Velocity are the main arguments. A number of other factors such as beam/draft ratio, waterplane coefficient, block coefficient, dynamic friction coefficient, spread angle and bow angle are included in the full prediction formula; but variations in these factors make only slight differences in the result. Moreover, the combined subsidiary factors for LENIN approximate the mean for existing icebreakers; and, of course, these factors for the envisaged icebreaker cannot be known. The simplified formula for LENIN, in which the several subsidiary factors are included in the numerical constant, can therefore be used for assessing ramming-mode performance in icebreakers of various sizes without error of practical significance. Using the simplified formula, Ice Thickness predictions can be expected to be accurate to plus/minus 2 per cent.

25. The following table, based on the formula for LENIN, shows Ice Thickness (in feet) which can be broken in the ramming mode at various Displacements and Impact Velocities.

(TABLE 4)

Displacement (Tons)	8	Impact 9	Velocity 10	(Knots) 11	12
13,000	17.7	18.8	19.8	20.8	21.7
14,000	18.3	19.4	20.5	21.5	22.4
15,000	18.8	20.0	21.1	22.1	23.1
16,000	19.4	20.5	21.7	22.7	23.7
17,000	19.9	21.1	22.2	23.3	24.3
18,000	20.4	21.6	22.8	23.9	24.9
19,000	20.8	22.1	23.3	24.4	25.2
20,000	21.3	22.6	23.8	25.0	26.1
21,000	21.7	23.0	24.2	25.5	26.6
22,000	22.2	23.5	24.8	26.0	27.1
23,000	22.6	23.9	25.2	26.5	27.6
24,000	22.9	24.4	25.7	26.9	28.1
25,000	23.4	24.8	26.1	27.4	28.6

26. By the same ramming-mode formula for the LENIN, the following table shows the Impact Velocity required at various Displacements to break an Ice Thickness of 25 Feet.

(TABLE 5)

Displacement (Tons)	Impact Velocity (Knots)
18,000	12.1
19,000	11.5
20,000	11.0
21,000	10.6
22,000	10.2
23,000	9.8
24,000	9.5
25,000	9.1

Impact Velocity

27. In order to obtain the necessary kinetic energy to break ice in the ramming mode, both Speed and Displacement are required; and Tables 4 and 5 show the relationship of these factors. The greater the displacement, the lesser is the impact velocity required to break a given ice thickness; and, within the quantitative limits considered, the greater the impact velocity the less the required displacement. Before an assessment of the displacement needed for the required ramming-mode performance can be made, it is therefore necessary to consider Impact Velocities.

28. The following factors have an influence:

(a) The Horsepower/Displacement ratio, or Thrust/Displacement ratio, which indicate relative ability to accelerate.

(b) The length of charging run.

(c) The presence of broken and brash ice in the charging path.

(d) Limitations imposed by the ship's structural strength.

29. Comparison of acceleration data for the WIND, GLACIER and LENIN given on page 129 of reference (c) indicates that the distance required to reach a given speed from dead stop in open water varies directly as Displacement/Thrust. The LENIN can reach a speed of <u>6 knots in 85 feet</u> and her Displacement/Thrust (tons) ratio is 49.

30. With the enormous thrust required for continuous-mode operations in the envisaged Polar Icebreaker (circa 800 tons), her ability to accelerate will be better than that of the LENIN because her Displacement/Thrust ratio will be smaller. On this basis, it seems clear she will be able to reach any practical impact velocity is less than a ship's length, even with considerable brash ice in the charging path. The controlling factor in the choice of maximum impact velocity, and hence the required displacement, is therefore <u>structural strength</u>.

<u>Scantlings</u>

31. The calculation of scantlings is beyond the scope of this paper. However it is pertinent that <u>impact loading per unit area</u> varies approximately as <u>Displacement x Velocity</u>^{2}. Considering this in relation to the values in Table 5, loading will be less at slower impact velocities even though displacement will have to be greater. For example, at a displacement of 25,000 tons and an impact velocity of 9 knots, the impact loading per unit area would be some 22% less than with a displacement of 18,000 and an impact velocity of 12 knots.

32. It may also be useful to consider the impact loading involved in terms of equivalent impact velocities in existing icebreakers. At a displacement of 25,000 tons and an impact velocity of 9 knots, the impact loading per unit area would be approximately the same as in the MACDONALD charging at

$$\left[\frac{25{,}000 \times 9^2}{8900} \right]^{0.5} = \underline{15.1 \text{ knots}},$$

and in the ST.LAURENT charging at

$$\left[\frac{25{,}000 \times 9^2}{13{,}300}\right]^{0.5} = \underline{12.35 \text{ knots}}.$$

33. Whether these impact velocities are possible in the MACDONALD and ST.LAURENT against a hard ice ridge without sustaining structural damage is not known, but it seems unlikely. Greater strength than in these icebreakers is probably needed.

34. Relative strength of the shell plating varies approximately as the yield strength of the material, the square of the plate thickness, and inversely as the square of frame spacing. The 16-inch frame spacing in the MACDONALD and ST.LAURENT is probably the minimum which would permit proper access for erection and welding, so this cannot be improved. Additional strength would therefore have to be found by using plating of higher yield strength and/or increased thickness.

35. Assuming that 9 knots is the maximum safe impact velocity in the ST.LAURENT, which has a maximum ice belt shell plating thickness of 2 inches; and using steel plate of the same yield strength and with the same frame spacing; the shell plate thickness needed in the Polar Icebreaker at 25,000 tons displacement for an impact velocity of 9 knots would be approximately

$$\left[\frac{25{,}000 \times 2^2}{13{,}300}\right]^{0.5} = \underline{2.74 \text{ inches}}.$$

At 18,000 tons and 12 knots, it would be approximately

$$\left[\frac{18{,}000 \times 12^2 \times 2^2}{13{,}300 \times 9^2}\right]^{0.5} = \underline{3.10 \text{ inches}}.$$

36. These approximations are in no sense technical specifications, but are intended merely to illustrate the rough dimensions of the problem. In addition to increased shell plating, frames and their back-up support would also need additional strength.

Conclusion Concerning Displacement

37. Table 5 above gives a series of options showing combinations of Displacement and Impact Velocity which can achieve the required ramming-mode performance.

38. It has been shown that the structural strength which can be provided will be the controlling factor in the choice of an appropriate option. Also an approximate indication of the scantlings involved has been given.

39. The difficulties of ship construction using heavier or higher-strength steel plate than in present-day Canadian Icebreakers will undoubtedly require special equipment (rollers, shapers, etc.), and possibly new techniques. In the interests of cost, timing, and for maximum Canadian content, it is important these special needs be kept to a minimum.

40. Considering these factors, the least demanding option should be selected. It is therefore concluded the Displacement should be 25,000 tons.

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PROPULSION SYSTEMS - POLAR ICEBREAKER

Introduction

The purpose of this section is to examine the options available to meet the propulsion requirements in the Polar Icebreaker. Various systems will be compared and, finally, a system which best meets the requirements will be recommended.

Requirements

The basic requirement is for a propulsion system which, in a 25,000 displacement ship, can produce a maximum continuous shaft horsepower of 100,000 on three screws: 50,000 SHP on the centre screw, and 25,000 on each wing screw. In addition the following factors must be included in the comparison criteria:

(a) Fuel consumption.
(b) Maintenance, overhaul requirements and life cycle.
(c) Manning requirements including numbers and professional qualifications.
(d) Control and response characteristics.

(e) Ability to withstand shock.
(f) Weight and space requirements.
(g) Safety.
(h) Availability and Canadian content.
(i) Capital and Operating costs.

The intensity of operations will have an important influence on the demands made on the machinery. For this analysis it is assumed the ship will be deployed in the Arctic for 9 months of each calendar year and may be required to operate at maximum continuous power for up to 1/3 of the on-task time.

Endurance is very important because of the difficulty and expense of providing refuelling facilities in the area. The maximum possible endurance, consistent with other design factors, should therefore be sought. For purposes of comparing the machinery options a model in which the combined fuel capacity and machinery weights are 40% of the displacement; (is) 10,000 tons, will be used.

<u>Systems</u>

Because of the shock loading on propellers inherent in icebreaker operations and the need for quick response, both ahead and astern, it is considered the transmission system must be electric. Various prime movers with generators, control equipment and electric motors will therefore be considered. Options are as follows:

(a) Diesel - Electric.
(b) Gas Turbine - Electric.
(c) Dual Diesel and Gas Turbine (CODAG)
(d) Conventional Steam Turbine - Electric.
(e) Nuclear Steam Turbine - Electric.

Doc. 12: T.C. Pullen, Memorandum to Strathcona Mineral Services Ltd., Being an opinion as to the feasibility of commercial shipping operations originating in the Coronation Gulf area of the Arctic, 18 April 1975.

HBC Archives H2-141-2-2 (E 346/1/59)

April 18, 1975

Memorandum to Strathcona Mineral Services Ltd.
Suite 401, 44 Victoria Street
Toronto, Canada

prepared by

Captain T.C. Pullen
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Ottawa, Canada

Being an opinion as to the feasibility of commercial shipping operations originating in the Coronation Gulf area of the arctic.

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Introduction

Should mineral development in the Bathurst Inlet/Kent Peninsula region of Coronation Gulf prove feasible then it is necessary beforehand to have an opinion whether the product could be delivered to market by sea. Market, in this instance, could be in the east, Europe and North America East Coast, or in the west, Japan and North America West Coast, or both.

Writer's Qualifications

As Commanding Officer of the icebreaker, HMCS Labrador, the writer has firsthand knowledge of conditions, as they might influence shipping operations, between Baffin Bay and King William Island including the approaches to James Ross Strait. This includes the first circumnavigation of Somerset Island, sounding of Peel Sound and the first hydrographic survey of Bellot Strait and its approaches.

In addition, a survey of conditions between Point Barrow, Alaska, and Coronation Gulf was carried out onboard the CCGS Camsell and of ice conditions in the Bering Sea onboard the U.S. icebreaker, Glacier.

Caution

This Memorandum has been prepared at very short notice. For that reason it has had to deal with generalities rather than specifics. If anything, it errs on the side of prudence for in addition it deals with a region which hitherto has attracted little commercial interest.

Coronation Gulf has been, and is, a transit area, one through which over the years ships have picked their way en route to somewhere else. These are, for the most part, ships coming from the west making for Cambridge Bay and Spence Bay with supplies. Occasionally ships use this route when attempting the Northwest Passage and in this case they are heading for Bellot Strait or Peel Sound.

By arctic standards, bathymetric knowledge of the area is good, especially along the main shipping channels. It is skimpy, though, in locations where ships have until now had no reason to venture, e.g. close in to the north shore of the Kent Peninsula. But even then there are sufficient data to indicate that the bathymetry would not prevent access by commercial ships to selected locations there.

Assumptions

The following assumptions have been made:

a) The amount of cargo to be shipped would be not less than 200,000 tons and not more than 300,000 tons.

b) Because of the foregoing, such tonnage would be shipped during the so-called summer navigation season when conditions are most favourable - i.e. July to October inclusive.

c) Ships would head west (through Dolphin & Union Strait and onwards) or east (through Dease Strait, into Queen Maud Gulf and onwards).

d) Ships used in this service would be ice-strengthened.

e) Icebreaker assistance during 'heavy or bad' ice years, at break-up and at freeze-up would be available.

f) Ships envisaged for this service would be suitable in all respects (power, maneuverability, strength) and be handled by people with experience.

<u>Government Regulations</u>

Anyone contemplating shipping operations in the arctic must be aware at the outset of the <u>Arctic Shipping Pollution Prevention Regulations</u> (hereafter <u>ASPPR</u>). The whole of the Canadian arctic has been divided into 16 Zones. Coronation Gulf is in Zone 11. For each Zone the duration of the permitted navigation season there is laid down for all classes of vessel, from the unstrengthened type through the varying degrees of ice-strengthening to the most powerful of icebreakers -- Arctic Class 10.

One must, then, always look at the problem of moving cargoes out of the Coronation Gulf area within the framework of these rules. In addition, one must also take into account the dates between which navigation is permitted for a particular class or type of ship for those other Zones through which they must pass to reach their destination or open water where the rules do not apply.

Moving westward from Zone 11 (Coronation Gulf) one passes through Zone 12 before reaching Alaskan waters. As Zone 12 is less restrictive than Zone 11, the latter is the governing zone. To the eastward, however, the situation is not so straightforward. To reach open water in Baffin Bay one must move from Zone 11 through Zones 7, 6 and 13 in that order. Zone 6 becomes the governing zone. For example, assuming a Type 'A' vessel, Zone 6's navigation season is from August 15 to October 15 (2 months) whereas for Zone 11 it is from July 10 to October 31, nearly 4 months.

<u>Additional Factors influencing Shipping Operations</u>

<u>Bathymetry</u> Canadian Charts # 7082 and 7083 should be examined in conjunction with this Memorandum bearing in mind, always, that the soundings are given in fathoms - multiply by six to get feet.

The main body of Coronation Gulf has adequate water depths for shipping.

To the west, in Amundsen Gulf and the Beaufort Sea, there are no restrictions on shipping caused by shallow water. For westbound traffic originating in Coronation Gulf, or for traffic inbound from the west, the ruling waterway is Dolphin & Union Strait where the maximum depth is 45 feet. This should permit the use of ships with a loaded draft of 35 feet or a little more.

Dolphin & Union Strait experiences strong currents but not sufficiently so to interfere with operations during the ice-free summer period. Tidal range is less than six feet.

For eastbound traffic, the situation is less hopeful. There are two possible routes out of Queen Maud Gulf. One is by way of Victoria Strait, up the west side of King William Island, into Larsen Sound thence to Bellot Strait or north up Peel Sound. The other is by way of James Ross Strait, up the east side of King William Island. This latter route has a maximum depth of only 17 feet which effectively disqualifies it for ships suitable for the trade being considered. Victoria Strait could be a useable route but at the moment it is inadequately surveyed. What soundings are available indicate that a deep water channel can probably be delineated but at the present time the risk is too great.

Summing up, therefore, ships operating to the westward would be required to draw no more than 36 feet or so of water to be able safely to negotiate Dolphin & Union Strait. To the eastward it would be hoped that the Canadian Hydrographic Service will be able to prove a safe deep water channel through Victoria Strait before too long. James Ross Strait would only be useful for ships in ballast provided they drew no more than 13 feet or so, an unlikely possibility or, on the other hand, to consider the possibility of using ice-capable barges and powerful ice-capable pushers.

<u>Ice Conditions</u>

All the foregoing remarks on bathymetry do not take ice into account. In narrow channels, or where it is important not to stray too far from the recommended track, ice athwart a ship's desired course can cause delays or even pose a threat should a vessel stray too far in an attempt to do an end-run.

In an average ice year the period a ship is permitted to operate in a particular zone by the <u>ASPPR</u> should assure her reasonably easy conditions. In a good ice year, that is one when ice conditions are very much lighter or easier than usual, then shipping operations benefit. Higher speeds become possible and the season can also be extended somewhat. In a bad year, the opposite holds, delays are frequent, there is a risk of damage to hulls by impatient or inept shiphandlers and icebreaker assistance would be necessary.

Ice conditions vary from year to year. It is not possible to forecast what a particular summer season will be like for there are so many variables and man has not yet succeeded in anticipating what nature is going to do.

Virtually the whole area of interest and which is being examined in this Memorandum, is subject only to winter ice, or first-year ice, the product of one winter's freezing. Old ice, or multi-year ice, is encountered if at all only in the Beaufort Sea on the run to Point Barrow, Alaska, or in Larsen Sound north of King William Island on the run towards Peel Sound or Bellot Strait in Boothia.

It is the movement of the heavy pack in the Arctic Ocean down onto Point Barrow which signals the end of the navigation season in the western arctic. Ships operating in Coronation Gulf, 1,400 miles to the east, and which intend to escape to the westward before this happens, would have to be on their toes not to become trapped by this movement of very heavy ice.

Insofar as the eastward route is concerned, assuming that it can even be considered, the chief difficulty from ice would occur when heavy pack is driven down M'Clintock Channel onto the west coast of Boothia, effectively sealing off Peel Sound and Bellot Strait from ships in Victoria Strait.

Summing up, the ASPPR spell out the length of time different classes of ship may operate in the various zones, based on the ice conditions known to prevail in those zones. It remains to be seen whether sufficient lift can be provided to remove the tonnage within those constraints.

Vessels

It would be tempting to employ unstrengthened ships in such a trade but the ASPPR, see TABLE below, lay down that entry to Zone 6 (which embraces Prince Regent Inlet, Peel Sound, Bellot Strait, Franklin Strait and Larsen Sound) is barred to such vessels all year. However, unstrengthened ships may operate westward out of Coronation Gulf from mid-July to the end of September, a period of 11 weeks.

Until more is known about vessel size, capacity, speed, destinations and so forth, it is impossible to work out voyage cycles or even to arrive at the number and size of ships needed for the job.

The use of tug and barge in ice is totally impractical. On the other hand, if one were to consider using a prime mover in the form of a powerful ice-capable pusher, able to lock into an equally ice-capable barge, much could be achieved.

One advantage over ships would be the ability to over-winter a number of such barges at site, stockpiling the product directly into them during the closed navigation season. In this way one handling process could be eliminated. There are other advantages which occur to one. Barges could serve as fuel caches and storage dumps, lessening the need or removing it altogether, of the need for winter resupply by air.

In locations where shallow water poses problems, as is very definitely the case with James Ross Strait, the use of ice-capable pushers and barges becomes attractive. This is an alternative that merits consideration.

Conclusion

The Government's Pollution Prevention Regulations (ASPPR) spell out in precise terms the periods during which ships of varying ice capabilities may operate in the arctic. Also defined are the powering and structural requirements for vessels seeking to be classed in the different ice categories.

To ship cargoes westward the ruling depth is 45 feet which should not represent much, if any, of a constraint. To ship eastward is more challenging. One of the two possible routes is limited by a maximum of 17 feet of water, the other is known to be dangerous on account of shoals and has yet to be completely surveyed. … [final page missing]

Doc. 13: T.C. Pullen, Winter Drilling Operations in the Beaufort Sea—Being an Opinion as to the Practicality of such an Undertaking, 23 November 1976.

HBC Archives H2-141-5-6 (E 346/7/8a)

Winter Drilling Operations
in the Beaufort Sea --- Being an
Opinion as to the Practicality
of such an Undertaking.

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It is understood that CANMAR-DOME propose to carry out winter drilling operations in the inshore area of the Beaufort Sea making use of the fast ice there for the purpose. Such a plan has merit when taking account of the fact that a belt of fast ice forms every year along the coast extending from the shoreline out to the region of the ten fathom line. If summertime drilling activities could be extended in time by adopting this plan then such a step would make for better use of costly facilities which otherwise would lie idle for many months.

What is offered here is an opinion that has been asked for at short notice and from afar. It is an opinion based on a general outline of what is proposed.

Vessels

In addition to the drill-ship there would be available for support purposes, and especially icebreaking duties, four so-called icebreakers (originally designated supply boats) each of which displaces 3,000 tons and develops 7,000 shaft horsepower.

Comment While they are not icebreakers in the true sense of the term they are, that notwithstanding, formidable vessels for icebreaking duties as envisaged. The fact that four of them will be available is a significant factor.

Success would seem to be assured provided they are there when needed and would be skilfully handled.

Deployment

The four 'icebreakers' would be deployed to Herschel Island in the autumn there to await freeze-up and formation of the fast ice. When the ice had reached the desired thickness, about two feet, the drill-ship conducted by two or three 'icebreakers' would proceed to the desired drilling location in a water depth of between 30 and 60 feet. The lower limit (30 feet) would be governed by the draft of the drill-ship (approximately 23 feet) and the upper limit (60 feet) by the edge of the fast ice to seaward which, as has already been stated, would lie probably in the vicinity of the ten fathom line.

The selection of a minimum depth of 30 feet would be to assure a safety margin for the drill-ship of seven feet in the event of sea and swell at break-up and in open water. A prudent move.

Comment Reaching the desired drilling location through the fast ice, two feet thick, should pose no problem to the 'icebreakers'. At that time, first-year ridges should not be insurmountable. No attempt should be made to cope with multi-year ridges, if there are any. The whole concept should be predicated on first-year ice only.

It is assumed that the convoy (drill-ship and escorting 'icebreakers') would approach the fast ice from seaward at right angles, penetrating it to the desired location where they would stay for the winter. Hopefully, the timing of this would be such that the track made through the growing fast ice could re-freeze before a storm with accompanying seas had a chance to break up the weakened ice at this location. It would also be important to locate the drilling site as far as possible in from the seaward edge of the fast ice.

Maintaining an Ice-free Zone

Once the drill-ship has been planted in position it is proposed to break open a circular area of 1,000 feet in diameter around her and to remove therefrom all the broken ice. To achieve this it is intended to use the propeller wash from the 'icebreakers' to drive the ice debris under the adjoining edge of the fast ice.

Comment It is likely, however, that instead of the ice being forced under the undisturbed ice, the fragments will simply circulate within the confines of this man-made polyna though some may be flung up on top of the fast ice. Whatever happens, however, it should be possible to clean out the area if that is considered essential, but different techniques might be needed to accomplish this.

It is also reported that once the drilling business is under way there would have to be an area of open water 100 feet in extent all around the drill-ship. Beyond this, up to 500 feet, would be another zone where the sea water would be refreezing, after having been cleared of broken ice, and that when it grew to a thickness of two feet, it would be re-broken and removed by one means or another. This would be a process which would be repeated continually throughout the winter. There is no reason why this could not be done.

Movement of the Fast Ice as a Threat to the Drill-ship

Should the fast ice start to move, but no more than 100 feet, then such movement could be accommodated by the 100 foot open water zone around the drill-ship already referred to. Drilling operations would not be jeopardized. Should the fast ice advance more than 100 feet, but less than 500, then the icebreaking capabilities of the 'icebreakers' should be equal to the task of protecting the drillship. Finally, should the ice advance more than 500 feet, then the drill-ship would be obliged to suspend operations and move off site. In such circumstances, the 'icebreakers' would be required to break a path back onto location as soon as possible after ice movement has ceased.

Comment The technique described above is perfectly feasible.

Maintaining an Ice-free Zone around the Drill-ship

It is hoped to use a canopy of some sort, possibly on a barge-type structure, though much lighter and less complicated, and by this means employ the hot waste air from the drilling motors to prevent ice from forming either beneath the barge or within 100 feet of the drill-ship.

Comment To make helpful comment on this sort of a technique is not easy. One wonders whether it would, or could, work. Whether sufficient waste heat would be generated to cope with the prevailing low ambient temperatures and wind chill to prevent, even inhibit, ice formation and growth would have to be determined. I have my doubts. The use of bubbling techniques, a proven success in other applications, seems a better approach to keeping an area clear of ice. But bubblers are best suited to still water. A modified system, with the bubbler just below the surface, could be a partial answer and certainly worth a try.

Fast Ice Movement

Once the ice has become set, by February say, CANMAR-DOME consider it unlikely it will make any significant move, almost certainly not more than 100 feet and between February and May no more than 50 feet, both of which statements mean the drill-ship would not be involved with the ice surrounding the man-made polyna.

Comment Unless the site selected was in an exposed fast ice location, for instance to seaward of Pullen Island off the Delta, rather than in a sheltered location, Mackenzie Bay say, and unless there were unforeseen circumstances (high tides, unexpected tidal cracks, working too close to the seaward edge of the fast ice, effect of the driving pack on the fast ice) it seems reasonable to draw the same conclusion. Uninterrupted drilling operations should be assured. But generalizations are dangerous and it cannot be too strongly emphasized that site selection would be of critical importance.

Possibility of Drilling Two Holes in a Winter

It is being suggested that if the aforementioned technique proves successful, consideration might be given to moving off to a second drill site. This scenario would see the first drilling operation taking place between November and February, followed by a move to a new drilling site in March and drilling until May.

Comment There is a risk here of trying to take on too much and ending up with nothing. There would be a push to start too soon with the first drilling operation before the fast ice had established itself and encountering difficulties with failures in the ice. It would be better to demonstrate this new technique by attempting one drilling operation and until this has been proven, with all the lessons learned and applied, then only should a second well be attempted in a subsequent winter.

Conclusions

Those who have generated this proposal to make more efficient use of drill-ships and 'icebreakers/supply boats' during the off-season (winter) have endeavoured to think of everything and come up with a sound and workable plan. From the information made available to me, and in the short time available to assess it from afar, what is proposed seems feasible and I would endorse it.

I would repeat my caution about trying to undertake two drilling operations in one winter. A situation could arise where the 'icebreakers' might become engaged in a struggle against heavy ice to protect the drill-ship on account of unexpected ice movements, early break-up or whatever, and be damaged in the process. Availability of these valuable craft for the ensuing summer operations is of extreme importance and such a risk would not seem to be worth it.

While every eventuality may have been anticipated, there will always be circumstances which arise that have not been thought of and which call for bold, swift and effective measures. Those with the knowledge and authority to make crucial decisions would need to be on or near the scene of operations full-time.

[Signed: T.C. Pullen.]
T.C. Pullen

1306 Chattaway Avenue
Ottawa, Canada — November 23, 1976

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Doc. 14: T.C. Pullen, Report to The Polar Gas Project on Plans for the Shipment of Pipe and General Cargo to the High Arctic and Baker Lake, 22 April 1977.

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April 22, 1977

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R E P O R T

to

THE POLAR GAS PROJECT

on

PLANS FOR THE SHIPMENT OF PIPE AND GENERAL CARGO TO THE HIGH ARCTIC AND BAKER LAKE

prepared by

Captain T.C. Pullen
Ottawa, Canada

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1 -- Introduction

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This report has been written following the meeting held in the offices of the Polar Gas Project in Toronto, March 31, 1977, and subsequently summarized in the Memorandum dated April 7. The writer was asked to give his views in writing and this, then, is the result. I trust it will be of help.

If, indeed, cargo is to be landed over beaches at certain selected sites, then before such events it will be necessary to deal with a number of matters some of which are listed hereunder:

i) Surveys of the sea approaches to the beaches including the setting up of suitable ranges.

ii) Checking of beach gradients.

iii) Compilation of local tidal ranges and the ...times of high and low water.

iv) Current studies and their influence on local ice after break-up.

v) Underwater surveys by divers to detect bottom hazards and identify safe approach courses to the beaches.

With the exception of Chesterfield Inlet, the writer has a personal knowledge of most of the locations discussed in this report and hopes that the information given here will contribute to successful planning of the projected sealift operation.

Copies of both the reports mentioned on page 32 were obtained.

T.C. Pullen

Ottawa, Canada April 22, 1977

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2 -- Summary

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a. Spence Bay, on the west side of Boothia, is not an option.

b. Lord Mayor Bay, on Boothia's east side, is the preferred choice over Spence Bay.

c. The ice conditions en route to, and in, Lord Mayor Bay should not pose too much of a challenge to suitable icebreaking vessels.

d. Allen Bay, on Cornwallis Island, is not recommended as the major cargo transfer point.

e. Radstock Bay seems the best choice for the main cargo transfer activity with nearby Maxwell Bay running it a close second.

f. Given the fulfilment of certain requirements, all the proposed stockpiling sites are considered accessible.

g. In the case of Chesterfield Inlet, hydrographers who have surveyed it report that the Bowell Islands cargo transfer point would be acceptable only under certain conditions, and failing this a site within 10 miles of the entrance should be considered.

h. A brief review of the impact of the Arctic Shipping Pollution Prevention Regulations, some exemptions therefrom, and their application to Allen, Aston and Radstock Bays. Reference to Marine Underwriters and, finally, some remarks on past experience and forthcoming needs.

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3 -- Lord Mayor Bay versus Spence Bay as an Unloading Site

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a. Introduction It is understood that the tonnage earmarked, for whichever of the above sites is selected, will amount to 268,000 tons of which 188,000 will be pipe. This represents 18.5% of the total high arctic requirement. What follows, then, is an examination of the two choices in an attempt to show which is the better.

b. Spence Bay -- Comment

Access to Spence Bay is governed by the least depth of water en route which, from the eastern arctic, occurs in James Ross Strait (17 feet) and, from the western arctic, in Simpson Strait (24 feet -- probably less). To reach James Ross Strait from the north and east, vessels have the option of going by way of Peel Sound or Bellot Strait/Prince Regent Inlet. The saving in distance between these two options is 60 miles with Bellot/Prince Regent Inlet being the shorter.

c. There are no limitations of depth on either route for the purposes envisaged by Polar Gas. For instance, the minimum depth of water in Bellot Strait is 72 feet (22^{m}).

d. The Canadian Hydrographic Service confirm the aforementioned ruling depth for James Ross Strait, emphasizing that the soundings shown on the charts are of a reconnaissance nature only, with all that that implies -- see cautions and warnings printed on most arctic charts. Even if a first class survey was undertaken the view is that it would likely confirm the 17 foot least depth.

e. From the Pilot of Arctic Canada, Volume III, Second Edition, page 203: "The only recorded depths in the strait are those in that part which forms the channel between Matty Island and the Boothia Peninsula. These depths are very uneven and vary from 30 fathoms ($54^{m}9$) to 3 fathoms ($5^{m}5$); several isolated shoals exist in this sector." Underlining is for emphasis.

f. And on page 207: "The depths in ...... James Ross Strait are very uneven and vary from 25 fathoms ($45^{m}7$) at its southern entrance to about 10 fathoms ($18^{m}3$) in its northern part. Depths of 3 fathoms ($5^{m}5$) occur in several places in this part of the strait. Possible reefs or shoals are thought to extend for as much as 2 miles offshore from both sides of the strait thereby <u>narrowing</u> its navigable portion to about 1.7 miles in width."

g. Generally speaking the adjacent coastlines are low and devoid of prominent features so that fixing a vessel's position, either visually or by radar, would be a chancy business.

h. The writer has some personal knowledge of the area having taken HMCS Labrador, naval icebreaker -- 7,000 tons, 10,000 shaft horsepower -- to the northern entrance to James Ross Strait in 1957 to enable three United States Coastguard vessels to complete the Northwest Passage. However, because the ship was drawing 30 feet it was not prudent to proceed further south into the strait in shoaling conditions in what were then totally unsounded and uncharted waters.

i. Fog, too, is a factor which must always be taken into account there and also in Larsen Sound to the north. The combination of fog, heavy ice, low-lying land and shoal water impose a heavy burden on mariners attempting to navigate there.

j. The ice regime is well documented and need not be commented on except to note that conditions vary always from year to year. The likelihood is that over five years consecutively there will be one, possibly more, years when ice conditions at the southern end of McClintock Channel and Larsen Sound will be so heavy as to create severe problems for vessels attempting to scoot from behind the lee of Prince of Wales Island to reach the shelter of King William Island.

k. It is safe to conclude, therefore, that because of severe depth restrictions in James Ross Strait (17 feet) the use of Spence Bay becomes impractical. An alternative, Victoria Strait and Simpson Strait, also become impractical on account of depth restrictions and navigational difficulties in the latter.

<u>Lord Mayor Bay</u> – <u>Comment</u>

l. Nothing is known of the bathymetry of Lord Mayor Bay and, according to the Canadian Hydrographic Service which was queried on the subject, no surveying there is planned at the moment. The nearest soundings terminate at Victoria Harbour 27 miles or so to the northeast of the landing site in the bay.

m. It was visited first, and named by, Captain John Ross R.N., in 1829 when he passed the winter of 1829-30 in the ship Victory in nearby Felix Harbour.

n. The geomorphology* of Lord Mayor Bay, and especially that part in the northeast corner of interest to Polar Gas, appears promising. This can be inferred from photographs (see sample) and from remarks made by a colleague who for years was stationed at Spence Bay and travelled extensively in the area including Lord Mayor Bay, a traditional hunting area for the natives of Spence Bay.

o. The rugged coastline, and the off-lying islets, are steep-to, indicating deep water and, according to my source, there never was evidence of rafted ice in the bay -- a further indication of shoal-free water.

p. The saving in distance from Lancaster Sound by favouring Lord Mayor Bay over Spence Bay would be as much as 160 miles. If such a saving is gained by reducing the icebreaking mileage it becomes even more significant.

q. Ice conditions in Lord Mayor Bay and environs are covered elsewhere in this report.

r. Lord Mayor Bay is apparently as 'environmentally sensitive' as Spence Bay according to my source for it is, and has always been, a traditional hunting area.

s. In conclusion, then, Lord Mayor Bay must be the preferred choice over Spence Bay or, to put it better, the Gulf of Boothia has to be selected over Larsen Sound and James Ross Strait. Because shoal water and other adverse factors deny access to Spence Bay from whatever approach there is no point in seeking an alternative landing site on that side of Boothia. Shepherd Bay might have been one possibility, there may be others, but it really is a futile exercise.

t. Turning then to east Boothia, Lord Mayor Bay is the obvious choice but first it will be necessary to investigate its bathymetry to confirm that conditions right up to, and including the landing beach, are favourable for what is needed by Polar Gas. Certainly it looks as though the orientation of the bay in relation to the overall lay of the land bordering the Gulf of Boothia, and also in relation to the behaviour there of winds, currents and ice movements, afford it a special, even favoured, status. Also to be taken into account is the protection to the bay from invading ice provided by the Astronomical Society Islands.

u. Wager Bay to the southeast could, at first glance, seem to be an alterative for it has deep water and good access from Hudson Strait. The Hudson Bay Company used to maintain a post there with an overland trail leading northwest to Chantrey Bay but the distances involved probably disqualify this as a possible choice.

v. Finally, then, Lord Mayor Bay remains as the best choice and accordingly efforts should be made to keep a close eye on the ice regime there, and along the route from the north. Probes by icebreakers during the summer (September) shipping season ought to be undertaken to round out our knowledge of shipping conditions.

* <u>Geomorphology</u> Synon[y]mous with ‘physiography’ to denote the full scientific interpretation of the origin of topographic features, or the purely physical attributes of scenery.

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4 -- <u>Ice Conditions in Lord Mayor Bay</u>

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a. Through the good offices of Ice Central in Ottawa ice data for Lord Mayor Bay covering ten years (1967 to 1976 inclusive) have been obtained. These are in tabular form, are shown overleaf and are self-explanatory.

b. When considering the ice regime for Lord Mayor Bay it is necessary also to take account of ice conditions confronting ships attempting to reach it from the north, namely Prince Regent Inlet and the Gulf of Boothia. Accordingly, these are summarized here being a paraphrased version of the <u>Pilot of Arctic Canada</u>, <u>Vol</u>. <u>I</u>, <u>2nd Edition</u>, to which this writer contributed. Important facts have been underlined for emphasis.

c. Page 148: "The passages leading south .... are covered in winter by a heavy sheet of rafted and hummocked ice. In Prince Regent Inlet the pack remains in motion throughout the winter ..... but unlike other areas, the ice clears from north to south .... Complete melting does not occur, and because of the prevalence of northerly winds, an area of very heavy old ice accumulates at the south end of the inlet (Committee Bay) where influx and melting tend to balance each other."

d. "The southern part of the area is covered in winter with consolidated ice, a large proportion of which is second and multi-year floes. The amount of this old ice decreases towards the north and is only a small percentage of the ice cover in the northern part of the Gulf of Boothia and Prince Regent Inlet.

e. "Break-up ..... begins in late June and progresses slowly southward, aided by a slight outflow into Lancaster Sound. The southward retreat of the ice edge reaches .... Bellot Strait by mid-August and Fury & Hecla by mid-September. The pack is, of course, moved about by the wind and may at a particular time be pressed against either the Boothia Peninsula or the Brodeur Peninsula creating a shore lead on the opposite side.

f. "The coastal area from Lord Mayor Bay (southeastward) to Pelly Bay, which is separated by a chain of islands and islets from the Gulf of Boothia, has its own ice regime for no intrusions are possible. A consolidated cover of first year ice forms each winter and melts 'in situ' each summer."

g. "Freeze-up begins first in Committee Bay in early September" and although "autumn storms may temporarily disrupt the ice cover, it quickly reforms ...."

Comment

h. From personal experience in the area (Prince Regent Inlet to Fury & Hecla Strait including the survey of Bellot Strait and a probe south to Thom Bay) the ice conditions are as described. At that time (mid-September) the route from Lancaster Sound down the west side to Bellot and beyond to Thom Bay was open water. Certainly, though, Committee Bay is a catch-basin for much old ice trapped there by winds with a northerly component which predominate. However, this is many miles away to the south and east of Lord Mayor Bay which enjoys a different set of circumstances.

i. While the moving pack after break-up can be shifted to and fro due to the vagaries of wind an approach to Lord Mayor Bay should be feasible within the context of icebreaking barges and powerful icebreaking pushers.

j. Lord Mayor Bay itself for the most part has its own ice regime which is usually first year ice.

k. Clearly, no attempt should be made to undertake cargo operations there until September. To rush nature will result in damage, delay and frustration. It is worth repeating that each year has its own ice conditions and it is risky to try and make predictions. Over a period of five years the ice conditions listed in the Table overleaf, summarizing the best, the average and the worst, will likely all be experienced.

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LORD MAYOR BAY -- CLIMATOLOGICAL ICE CONDITIONS -- 1967-1976

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	JULY 30	AUGUST 15	AUGUST 30	SEPT. 15	SEPT. 30	OCTOBER 15
1976	10/10 FY	10/10 FY	10/10 FY	2/10 FY	2/10 & 8/10ths in strips.	9+/10, 2/10ths of which was old ice, the balance, new ice.
1975	10/10 FY	Open Water in the bay. 8/10ths across its entrance	9+/10 FY	OW	9+/10 new ice	9+/10 new ice
1974	9/10 FY	5/10 in the bay 9+/10 in approaches of which 2/10ths was old ice	OW in bay 8 to 9/10ths in the approaches of which 2/10ths was old ice	OW in bay except 7-8/10ths FY and old ice in SRN half of the bay	OW except for 9+/10 old ice along the shore of the bay	9+/10 grey & grey white ice in the approaches to the bay & 9+/10 along the shore

1973	10/10 Old	OW lead 5 miles along shore otherwise 9+/10 including approaches	5/10 & 8/10ths in strips. 9/10ths in the approaches	9+/10 mostly old ice	9+/10 of which 20% was new & grey ice	OW
1972	10/10 FY	10/10 FY	10/10 FY	9+/10 FY	10/10 FY	10/10 FY
1971	10/10 of which 8/10 was old ice	9/10	5/10 in bay of which 3/1 was old ice. 4/10 in approaches	3/10 & heavier strips	6/10 of which 4/10 was new & grey ice	9+/10 new & grey with a trace of old ice
1970	10/10 FY	9/10 FY	9/10 FY	9+/10 FY	9+/10 FY	8/10 old ice
1969	10/10 of which 6/10 was old ice	OW in bay 9+/10 in the approaches	1-3/10 mostly old ice with 8-9/10 in the approaches	1-3/10 with new ice forming	OW except 7-9/10 in southern half of bay	New ice northern half of bay & 7-9/10 old ice in the southern half
1968	10/10 FY	10/10 FY	4/10 FY southern half & 9/10 in the remainder & the approaches	9/10 mostly FW except OW in most southerly part	9/10FY	9+/10 of which 6/10 was old ice - remainder new & young ice
1967	10/10 FY	10/10 FY	9+/10 mostly FY	Northern half 9/10 grey ice Southern half 3/10 FY		

<u>LEGEND</u>

FY .... First Year
OW .... Open Water
SRN .... Southern

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	JULY 30	AUGUST 15	AUGUST 30	SEPT. 15	SEPT. 30	OCTOBER 15
BEST CONDITIONS	9/10ths	Open water in the bay and 8/10ths in the approaches	Open water in the bay and 6-8/10ths in the approaches	Open water	Mostly Open water	Open water
AVERAGE CONDITIONS	10/10ths	9-10/10ths	7-9/10ths in the bay 8-9/10ths in the approaches	Quite variable	Quite variable	Quite variable but freeze-up underway
WORST CONDITIONS	10/10ths	10/10ths	10/10ths	9+/10ths	10/10ths	10/10ths Mostly old ice

From material supplied by ICE CENTRAL

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5 -- Allen Bay -- Comment as to its Suitability

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a. In the matter of major cargo operations (1½ million tons over 5 years), from unstrengthened vessels to shore or direct into icebreaking barges, there is not much to commend Allen Bay. Resolute Bay has been rejected already as a possible choice and some of the reasons for this apply equally to Allen Bay -- particularly its vulnerability to wind-driven invasions of pack ice.

b. From the standpoint of a mariner Allen Bay, while able to accommodate a large number of ships (something Resolute Bay cannot do), and with good water depths, is nonetheless exposed to pack ice originating in McDougall Sound and Viscount Melville Sound driving in from the west or southwest to endanger ships and frustrate cargo transfer operations. Like Resolute Bay, it also experiences different ice regimes than alternative and better sites further east which enjoy earlier break-up and later freeze-up.

c. About all that can be said in its favour is propinquity with the important airfield of Resolute plus the benefits which might accrue by having government icebreakers nearby, for they remain in the vicinity of Resolute Bay during the summer to assist annual sealift re-supply operations.

d. Notwithstanding the foregoing, there are regulatory and insurance factors which disqualify Allen Bay as a major cargo transfer site -- see Part 7.

e. The remarks above relating to Allen Bay's suitability insofar as an anchorage and water depths generally are derived from a study of the Field Sheet, # 4689, which was produced by the Canadian Hydrographic Service following a survey there in September, 1976. The Pilot of Arctic Canada, Volume III, Second Edition, page 264, is also not very encouraging for it states: "Allen Bay is reported to be difficult and dangerous to approach and affords no shelter."

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6 -- Radstock Bay & Other Alternatives

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a. Allen Bay, Resolute and Assistance Bays, all situated on Cornwallis Island, are not satisfactory as stockpiling sites. One must, then, look to Devon Island. To locate a suitable harbour there, one which can provide for the assured transfer of much material over a five year period, the following requirements must be met:

i) The bathymetry must be such as to accommodate ships of any draft and the area capable of providing plenty of berthing and anchoring space for a large number of vessels of all types.

ii) Maximum protection from wind-driven pack ice and room, too, inside the harbour for ships to seek shelter from ice which may appear from time to time.

iii) Protection from the prevailing winds.

iv) Suitable beaches for landing cargo and for the establishment of the needed structures and facilities.

v) Because ice concentrates mostly on the south side of Lancaster Sound, the harbour site must be located on its north shore.

vi) To avoid the risk posed by icebergs and multi-year floes blocking the harbour or interfering with cargo transfer operations, the harbour selected should be west of the 88th meridian beyond which the moving ice is not carried.

b. With the foregoing factors in mind an examination has been made of potential sites along the south coast of Devon Island. From west to east the following sites were considered and then rejected for one reason or another:

Erebus Bay (about to become a national historic site)
Gascoyne Inlet (too small & exposed)
Rigby Bay (small, shoal & exposed)
Graham Harbour)
Blanley Bay)
Stratton Inlet) too small or otherwise unsuitable
Burnett Inlet)
Powell Inlet)
Cuming Inlet)
* Croker Bay (too far east)
Dundas Harbour (too far east)

* Croker Bay could bear further examination provided it is not considered to be too far east. The surrounding land, however, because it is high and glacial, may disqualify it.

c. Two sites remain and in order of merit they are: Radstock Bay and Maxwell Bay.

d. <u>Radstock Bay</u> – <u>Comment</u>

It lies in the western end of Zone 13 (ASPPR) permitting a deep penetration of Lancaster Sound by Type "E" ships, yet it is not unrealistically located in that Zone as Resolute Bay is. If "E" type ships are permitted to go to

Resolute Bay, then it is not unreasonable to expect the same class of vessel to operate somewhat longer into Radstock Bay. The Arctic Pilot has this to say about the ice conditions in the two locations:

	Break-up	Freeze-up
Radstock Bay	Second week in July	Early November
Resolute Bay	Middle of August	Mid September

There is an inconsistency here in the Arctic Shipping Pollution Prevention Regulations which needs resolving.

e. The bay extends inland for 12 miles providing good, though not perfect, shelter for shipping. It is, however, better than all the other harbours, bays and inlets along the south Devon littoral. Radstock offers:

i) A bay which has been thoroughly surveyed and charted throughout.
ii) Good anchorages.
iii) Deep water throughout except for Palmer Shoal. It could, in effect, be an asset for it would serve to keep ice away from ships at anchor behind it.
iv) Suitable landing beaches and adjacent terrain.
v) Space for any number of vessels.

f. *The Pilot of Arctic Canada*, Volume III, Second Edition, page 279, states: "A strong wind from the south could force drifting ice into Radstock Bay from Barrow Strait, but the size of the bay is such as to allow vessels to retreat further into its upper reaches. A moderate west or north wind would probably blow the ice out. There is no record of the bay having been filled with ice during the navigation season, in fact there is evidence that this would be an infrequent occurrence."

g. An examination of the winds there show that most blow from a direction which should keep Radstock Bay clear of ice -- namely 73% of them during August, 86% of them in September and 91% in October. Further, the winds which blow from the vulnerable quarter, i.e. from the south and southeast, do so at a not very formidable rate, viz. force 2 to 3 in August, force 3 in September and force 3 to 4 in October. These data are based on Ministry of Transport figures obtained at the nearest weather recording station which is at Resolute and they represent average conditions. Typical wind conditions for the month of September are shown diagrammatically overleaf.

h. There are, on the average, 29 days during each year when winds exceed 34 knots in Resolute. This can be considered typical for the surrounding area, including Radstock, though local land features will have some effect. During September there is on the average one day when winds exceed 34 knots.

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…

i. Maxwell Bay -- Comment

This alternative enjoys the same Zone 13 advantages as Radstock Bay 30 miles to the west, including that favourable comparison with Resolute Bay in respect to break-up and freeze-up.

It has been thoroughly surveyed and the bathymetry is good, indeed excellent, for the waters are deep throughout -- see Field Sheet # 4488 (1973).

j. Maxwell is somewhat more exposed to the south than Radstock and possibly more vulnerable to invading ice moving under the effect of south or southeast winds. On the other hand, there is more space in the upper reaches to escape such ice invasions.

k. Nothing is known concerning beaches for the landing of cargo and this merits investigation.

l. Navigationally there are no problems. The approach to the bay, and the maneuvering room once inside, is all perfectly straightforward. High land provides first class radar control. The bottom in the several inlets is mud which is the best holding ground for vessels wishing to anchor.

m. In conclusion, it appears that Maxwell has everything that Radstock has, maybe even more, and is a desirable alternative.

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7 -- Stockpiling Sites -- Comment

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Aston Bay

a. Despite its exposed situation on the northeast corner of Somerset Island this site appears to be remarkably ice-free after break-up in August. This could be attributed, in part, to the lack of strong winds from directions (west through northwest to north) that could push ice into the bay in September.

b. Currents may, in fact, exert more influence on the movement and behaviour of the pack than winds. The east-setting current along the south side of Barrow Strait carries Viscount Melville Sound ice, and ice from other sources also, into Lancaster Sound although some is diverted south into Peel Sound. In years when there is a great deal of ice, the entrance to Peel Sound can be plugged and at such times Aston Bay, too, is likely to be jammed.

c. There is a photograph in Arctic Canada from the Air (Dunbar & Greenaway), page 162, which is significant. It shows Aston Bay on August 6 and it is virtually ice-free with only a few scattered floes drifting about.

d. On the other hand, however, Pressure Point, which lies ten miles north of the entrance to Aston Bay, has an ominous ring to it. Sometime in the past ice must have been piled against the coast at that location and possibly also in Aston Bay. But the circumstances which gave rise to the naming of that feature are not known and it could be misleading to infer too much from this.

e. There are no bathymetric data for the bay and obviously an hydrographic survey is needed to confirm what appears to be deep water capable of accepting vessels with the drafts being considered by Polar Gas. Canadian Chart # 7830 has depths of more than 700 feet off the entrance and it is not unreasonable to expect good navigable water depths right into the bay.

f. An examination of the local winds, based on data for Resolute 60 miles away, show that the best month for shipping is also a time for favourable winds. Page 171 of the Pilot of Arctic Canada, Volume 1, Second Edition, gives wind conditions for Resolute denoting that only 8% of the winds for September exceed 27 knots. 40% are 8 knots or less, 45% lie between 9 and 17 knots and 7% between 18 and 26 knots.

g. In conclusion, Aston Bay appears to be an acceptable choice as a stockpiling site despite what would seem to be its exposed location. In fact it is the only potential refuge along that part of the Somerset Island coast. There will be occasions when winds, currents and large quantities of ice will combine to plug the bay but this would seem to be the exception rather than the rule[.]

<u>Bellot Strait</u>/<u>Brentford Bay</u>

a. In seeking a stockpiling location here one should study the <u>Arctic Pilot, Volume II</u>, pp 299-309, to get a grasp of the special conditions which prevail there especially in the strait and the effect of its eight knot currents. As with all the other proposed stockpiling sites, there is really very little information on suitable choices in the <u>Arctic Pilots</u> or other publications.

b. The writer is familiar with Bellot Strait and its eastern and western approaches having surveyed it in 1957 to provide a deep-water escape route for ships trapped in the central arctic and unable to get out to the westward around Alaska. The only harbour that can be recommended as a result of this experience is Depot Bay near Fort Ross. The approaches from Brentford Bay, and Depot Bay itself, have been sounded and there is adequate water depth though in area it is small and vessels would need to anchor outside awaiting their turn to unload.

c. An on-the-spot investigation is needed to establish whether Depot Bay would serve the purpose. While it might be capable of handling small amounts of cargo, say 9,000 tons in one season, it could be that larger amounts, 95,000 tons, would create impossible congestion.

d. Port Kennedy cannot be recommended because of the threat posed by ice driven in from the strait by strong currents and winds. Hazard Inlet, according to the <u>Pilot</u> and as its name implies, is not promising but maybe this should be confirmed by an aggressive examination. Levesque Harbour is not a candidate for the adjoining terrain looks inhospitable to say the least -- see the photograph on page 148 of <u>Arctic Canada from the Air</u>.

Note: Depot Bay was named, and used, by Captain M'Clintock Royal Navy, in his ship "Fox" - 177 tons, during his Franklin search expedition of 1857-58. He also sought good shelter in Port Kennedy but the smallness of the "Fox" and the adverse opinion expressed in the Arctic Pilot, with which I share, gives rise to the comment in 'd' above.

Lord Mayor Bay -- See Part 3.

Brooman Peninsula (West) -- (Can. Chart # 7830)

a. For some time there has been talk of using Freemans Cove on the southeast corner of Bathurst Island but this is for a different purpose. As a deep-water terminal for VLICC's (Very Large Icebreaking Crude Carriers) this writer is uneasy about this choice and what hydrography that has been done there supports this view. At the entrance in particular there are shoals and lack of sea room.

b. The proposed plan to use Brooman Point (west side), 20 miles to the north, is in accord with this writer's view that a better VLICC port could be found near Markham Point.

c. In the bay formed by Markham and Brooman Points, and in which lies Wood Island, there are no hydrographic data making comment impossible. It is noted that the Canadian Hydrographic Service, for its 1977 programme, is planning to carry out work in Freemans Cover and also from Wellington Channel to Penny Strait. It would be most helpful if during these activities a reconnaissance probe could be made into the un-named bay between Brooman and Markham Points.

d. The bathymetry en route to Brooman Point up McDougall Sound, on both sides of Truro Island, is very deep and with plenty of sea room for vessels avoiding ice fields. Close to Brooman Point the chart indicates 60 feet (18m3) of water and a little further off there is 550 feet (177m).

e. This potential site is in Zone 6 of the ASPPR which presents no time limitations for Class III ships (August 1 to November 20) or to Class IV(July 20 to December 31).

f. It would be useful to have COMINCO's ice data for Little Cornwallis Island for the years the company has been active there.

g. Once the locally-formed ice in the Sound has dispersed ice-capable barges and thrusters should have little difficulty in delivering the scheduled tonnages. Some multi-year ice may trickle down from Crozier Strait but this should not disrupt operations for very long, if at all. The Brooman Peninsula (west side) seems a sound selection.

Richardson Bay (Melville Island)

a. Of all the proposed stockpiling sites this one represents the greatest challenge. The fact that Panarctic has already demonstrated that its operation on Melville Island can be supplied and supported by sea should be evidence that Polar Gas can do likewise using Arctic Class III or IV vessels.

b. A study of the ice conditions in Byam Martin Channel, Byam Channel and Austin Channel indicates that the further up the coast of Melville one goes the more difficult the ice conditions -- see page 151 of the Arctic Pilot, Volume I. In other words, Rea Point could be experiencing open water when Richardson Bay was still engulfed in fast ice. The Sea Ice Atlas of Arctic Canada, 1961-1968, (D.G. Lindsay, 1975) bears this out. Panarctic's experience of ice in Byam Channel would be helpful in arriving at a decision on the use of Richardson Bay. A particular watch should be kept on the latter place over the next few years to confirm whether or not there is a different ice regime.

c. There are no bathymetric data for the bay though soundings across the mouth show depths varying from 28 feet ($8^{m}6$) to 88 feet (27^{m}) -- See Can. Chart 7830.

d. Having in mind the ice capabilities of Arctic Class III or IV vessels, the choice of routes (east or west about Byam Martin Island depending upon ice conditions), and the proven record of shipping during the season, the Byam Channel littoral of Melville Island is a practical proposition. The one reservation the writer would offer, though, is the need to avoid selecting a site that will experience unnecessarily difficult ice conditions when a location further south along the coast might be preferable.

Byam Martin Island (East side)

a. A comparison of ice conditions around this island, using the Lindsay Ice Atlas, shows that for the eight years (1961-1968) the east experienced easier conditions for four of those years, the west side showed easier conditions for three years, and one year, 1966, could be considered a toss-up. There is no particular significance to all this except, possibly, to show that if one can get to Rea Point/Richardson Bay, then one can equally well reach the east coast of Byam Martin.

b. Having in mind the modest amount of cargo scheduled for the east Byam Martin site (9,000 tons of pipe during year 2, and 21,000 tons of general cargo the same year, plus 9,000 tons the following year), there is no particular problem with accessibility. This assumes, though, that the bathymetry inshore will be suitable and that satisfactory beaches can be found.

<u>Graham Moore Bay</u>

a. The particular location in this very large bay where the stockpile is to be is understood to be in the vicinity of Schomberg Point. No matter where, however, the prospects look good insofar as accessibility is concerned. A review of the ice conditions there, as shown in the Lindsay <u>Ice Atlas</u>, reveals the following:

1961 August 27. <u>Open water</u>.
1962 August 26 - September 5. <u>Open water</u>.
1963 August 26 - September 2. <u>Open water</u>.
1964 September 15 - 24. <u>Open water</u> in the southern approaches but for the remainder -- 10/10ths (9/10 multi-year & 1/10 first year).
1965 September 13- 22. <u>Once water lead</u> from the east to Playfair Point. In the bay proper 10/10ths first year ice.
1966 September 3-7. <u>Open water</u>.
1967 September 14 - 20. 8/10ths or more but all young ice -- 5 inches or so thick.
1968 September 4 - 14. <u>Open water</u>.

b. The bathymetry, what there is of it, looks good and there would appear to be ample water for shipping in the approaches from seaward, and in the bay itself. Investigations will have to be undertaken to establish a suitable landing site and prove the approaches to it.

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8 -- Chesterfield Inlet

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a. On April 19, discussions were held at the Canada Centre for Inland Waters, Burlington, Ontario, with the Hydrographer-in-Charge of the Chesterfield Inlet survey carried out in 1974 by the surveying vessel CCGS Narwhal. He indicated that navigation of the Inlet is a hazardous business but that this could be overcome in large measure if certain navigational aids were installed.

b. The tidal range along the Inlet varies at spring tides between 9 3/4 feet (3^m) and 19½ feet (6^m). On the basis of measurements and observations, it is estimated that currents approaching 10 knots are a possibility. A problem is the shelving nature of the shoreline along the Inlet. It is very low and gives a poor radar response making it impossible to determine where the shore ends and the water begins. The ruling depth from the entrance to Chesterfield Narrows is 16 fathoms (30^m) and from the Narrows it drops to 1½ fathoms (3^m).

c. Following the Narwhal's activities two reports were prepared by the Hydrographic Service -- the first is entitled Hudson Bay, Chesterfield Inlet, and Baker Lake - Sailing Directions Report - 1974, and the second is entitled Recommended Aids to Navigation Report Chesterfield Inlet Survey. Both are by B.M. Wright.

d. As to the matter of guides, who might be available now to take ships up the inlet, it was reported that there are only two living at the nearby settlement, one of whom is understood to have run a ship aground in the inlet not long ago. Such guides, for the purposes the Polar Gas Project has in mind, would be completely unsatisfactory. A special scheme seems called for to train the required number of capable, reliable and experienced pilots to meet this special need. Whether such talent can be recruited locally or have to be imported is not for this writer to say.

e. The Hydrographer-in-Charge pointed out that the proposed site on the Bowell Islands for cargo transfer was not a good choice for it is exposed to strong winds which blow across the low land to the southeast. The Narwhal found a far better and safer anchorage in the vicinity of Schooner Harbour 2

3/4 miles downstream on the north shore. See Can. Chart 5625 (corrected to March 10, 1977).

f. No attempts should be made to establish an alternative transfer site anywhere off the entrance to the Inlet, say in the vicinity of the settlement, on account of southeast gales which would endanger shipping. The recommended location is an anchorage 10 miles inside the inlet between Ellis and Moore Islands (see Can. Chart 5621) where protection is afforded for most conditions though even there swells from southeast gales are felt. The suggestion was made that good water might be found behind Ellis Island (not surveyed) where complete protection would be assured.

g. August is the ideal time for cargo operations because strong winds and gales start blowing early in September, especially from the northwest, with low visibility, snow, even blizzards, if <u>Narwhal</u>'s experience is any criterion.

h. The hydrographers stated that if Polar Gas would indicate the location of the Baker Lake stockpiling site they would undertake to investigate the bathymetry there for they will be carrying out additional work in Baker Lake this year.

i. In summary, then, the Hydrographer-in-Charge recommended that if the Bowell Islands (Schooner Harbour area preferably) are to be used as a cargo transfer point then the <u>minimum</u> requirements for safe transits by ships making up the inlet would be the use of <u>qualified pilots</u> plus the prior installation of <u>all</u> the navigational aids recommended by the Canadian Hydrographic Service in the report already referred to in paragraph (c) above. Failing these conditions, no attempt should be made to despatch vessels up the inlet, instead all inbound cargo should be transferred at Ellis Island.

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9 -- <u>General Remarks including Regulatory Considerations and Comment on Marine Insurance</u>

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a. <u>Allen Bay</u> In addition to the criticisms made in Part 5 concerning this place, there is one over-riding factor governing the situation, namely the

Arctic Shipping Pollution Prevention Regulations (hereafter ASPPR). Allen Bay lies in Zone 6 of the ASPPR. The boundary between Zone 6 and Zone 13 to the east is the 95th meridian of west longitude east of the bay, indeed it is east of Cape Martyr.

b. An examination of the ASPPR reveals that unstrengthened vessels (Type "E") are not permitted into Zone 6 at any time nor, indeed, are Type "D" vessels either. Discussions with the Regulations Branch of the Ministry of Transport confirm that there is no chance of the rules being amended to include Allen Bay in Zone 13. It seems the justification for the western boundary of Zone 13 being as far west as it is (to embrace all of Resolute Bay) is for reasons other than the ice conditions.

c. <u>Aston Bay</u> Not only does the 95th meridian of west longitude exclude Allen Bay, it also cuts through Aston Bay on the northwest corner of Somerset Island, placing all but the head of the bay, 6½ miles of it including the small unnamed island there, in Zone 6. The head of the bay, then, lies in Zone 13 but to get to it a vessel has to pass through Zone 6 which, for Type "D" and "E" ships, is forbidden.

d. <u>Exemptions</u> Any vessel carrying less than 16,000 cubic feet of oil (452.8 cubic metres) is exempt from the requirements of the ASPPR. If one could be assured that the rules would not be changed it would be possible to take advantage of this. The rules also have this interesting amendment: "Where ice conditions in .... a zone intended to be navigated by a ship (say Type "E") are no more severe than ice conditions .... in a zone of a higher number (Zone 14 for instance when we are interested in Zone 13), that ship may navigate ...... in .... Zone (13) during the period of time ... shown ..." (for Zone 14). For instance, if ice conditions in Zone 13, off Radstock Bay, are no more severe than the ice conditions in Zone 14, which happens to embrace the northern part of Hudson Bay, then a Type "E" ship could find her season extended beyond September 20 to October 31. Such an extension, it was explained, was subject always to the decision of a Pollution Prevention Officer.

e. <u>Radstock Bay</u> The duration of the shipping season in Zone 13, in which Radstock Bay lies, for Type "E" ships is August 15 to September 30 -- five weeks. Any request to have this extended for Type "E" ships, or any other type for that matter, would be turned down. Even if a Type "E" ship was being escorted by an icebreaker, the rules would still apply unmodified. It would seem, then, as was explained by the Regulations Branch, by keeping the fuel onboard below the minimum amount permitted by the rules, Type "E" ships could stay as long as was needed. On the other hand, a carefully prepared submission to have the rules modified to reflect the fact that Type "E" ships were being escorted by icebreakers might receive favourable consideration.

f. Marine Insurance According to the Regulations Branch, Lloyds, and the underwriting community generally, use the ASPPR as a basis for the establishment of premiums. Any move to start amending the rules would likely result in substantial increases in premiums or even withdrawal of cover altogether. It follows, then, that all other means should be sought to achieve what is needed (an extension of the season) rather than campaign to have the rules changed.

g. Looking Astern -- Looking Ahead It might be of some interest to make mention of the sealift which went into the construction of the Distant-Early-Warning Line twenty years ago. In three seasons, 1955 to 1957, 1,254,000 measurement tons of cargo were delivered to the arctic plus 10,304,000 barrels of POL products. An annual average of nearly 1 million tons. A total of 324 thin-skinned ships was involved.

h. For the Polar Gas Project it is clear a great deal of planning will be required for the sealift. Because of inexperienced masters and a shortage of ice pilots, ships may have to be escorted or even convoyed. Other matters will have to be taken into account. The list below is by no means complete:

- i The role of Coast Guard icebreakers in support of the sealift.
- ii Communications (Ship-to-Ship & Ship-to-Shore)
- iii Command & Control (Beachmasters, Harbour Masters & Officers in Charge of icebreakers and escorted shipping)
- iv Ice reconnaissance (Tactical & Strategical) for safe routing of shipping. Use of helicopters.
- v Weather forecasts for local operations (gale warnings)
- vi Medical including emergency first aid arrangements and airlift.

vii Repair facilities (holed barges, damaged rudders, propellers & underwater fittings)

viii Rescue services (downed helicopters, foundering vessels, fire, explosion)

ix Beach surveys (including swimming reconnaissance to mark and remove obstacles in the approaches)

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May 25, 1977

Memorandum to the POLAR GAS PROJECT

Being an Examination of Possible Additional Port Sites on the South Side of Barrow Strait and Lancaster Sound.

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ENCLOSURE (A) Section of CANADIAN CHART Number 7503 showing all the potential Port Sites, with mileages, etc.

REFERENCES (A) Pilot of Arctic Canada, Volume II Second Edition

(B) Report to the POLAR GAS PROJECT on Plans for the Shipment of Pipe & General Cargo prepared by Captain T.C. Pullen, dated April 22, 1977

(C) Arctic Canada from the Air, Dunbar & Greenaway, Queens Printer, 1956

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A. Introduction

For environmental reasons the preferred cargo-transfer site at Radstock Bay could become a 'non-starter'. Maxwell Bay, 30 miles further east, could be in the same category. Accordingly, it becomes prudent to look further afield for other possible sites. This Memorandum, then, looks at what might be available on the south side of Barrow Strait and Lancaster Sound. Re-introduced are two possibilities on the north side of the Sound which were referred to in Reference (B). Finally, in any overall consideration of port sites, Thule, Greenland, must be included.

Enclosure (A) depicts the sites examined in this Memorandum along the south side of Barrow Strait and Lancaster Sound. It also includes other information to give a general overview of the situation. Assuming Radstock Bay is the preferred location, a point immediately to seaward of that place has been established and is shown on Enclosure (A) as a red circle. From this point distances to the various sites have been measured to give the additional 'steaming distances' that would be required of the Arctic Class VII 'Pushers'.

B. Summary

To summarize, then, 8[1] sites were looked at of which only the following, in order of merit, can be considered as likely candidates:

Strathcona Sound
Baillarge Bay
Elwin Inlet
Croker Bay
Dundas Harbour
Thule, Greenland

C. Sites on Somerset Island

1. CUNNINGHAM INLET (Reference (A) -- page 277)

This is certainly an environmentally sensitive location for it is the calving site for many hundreds of white whales. This writer visited Cunningham Inlet in the Lindblad Explorer in 1974 to witness this annual affair. Notwithstanding the whales, though, the narrow entrance, shoals, and exposure to wind-driven floes from the north, render this inlet unsuitable for the purposes Polar Gas has in mind.

2. GARNIER BAY (Reference (A) -- page 277)

This bay is too small, it is vulnerable to northerly winds and there is shoal water inside. Unsuitable.

[1] These are in addition to those which were dealt with in Reference (B).

3. <u>PORT LEOPOLD</u> (Reference (A) -- page 275)

Reference (A) has this to say: "Northerly winds are reported to blow violently over the low neck of land to the north of the harbour so that shelter here is indifferent." Also "the first three weeks in September may be considered the navigable season .... but ice conditions in this harbour are reported to be difficult. From .... accounts of visits ...... in August and September, it appears .... the harbour may be found full of ice at any time during these months." See photograph on page 164 of Reference (C). <u>Unsuitable</u>.

4. <u>ASTON BAY</u> (Reference (B), pp 23 & 24)

Access must be by way of Zone 6 of the Arctic Shipping Pollution Prevention Regulations and is, therefore, '<u>off limits</u>' to Type "E" vessels.

<u>NOTE</u>:

There are two other potential sites on the east coast of Somerset Island, namely Elwin Bay and Batty Bay. They, too, lie in Zone 6 and in any event they are too small.

On the Brodeur Peninsula of Baffin Island there are three more sites, Port Neill, Port Bowen and Jackson Inlet. They too are in Zone 6 and are also too small.

D. <u>Baffin Island</u> -- <u>Borden Peninsula</u>

5. <u>ELWIN INLET</u> -- (Reference (A) -- page 264)

This inlet on the Brodeur Peninsula "is about 3 miles wide at its entrance" and "trends .... for about 15 miles." The shores are steep with heights of 2,000 feet. Reported to be very deep. This last fact could be a problem for with such depths anchoring becomes impossible. Certainly there is plenty of sea room for a large number of vessels. Whether the terrain at the head of the inlet lends itself to shore installations as envisaged remains to be seen. Reference (C) shows a photograph of the head of Elwin Inlet on page 117. Use of this place would involve 140 miles additional distance from the Radstock Bay reference point. <u>A possible site</u>.

6. BAILLARGE BAY -- (Reference (A) -- page 264)

The entrance is 2 miles wide and the bay extends for 12 miles. This writer has been in this place and been ashore at its head where conditions would be ideal for installations. Water depths good for anchoring. Mileage from Radstock Bay reference point 150. Definitely a possible site.

7. STRATHCONA SOUND -- (Reference (A) -- page 264)

This has become well known among arctic aficionados for it is the site of the loading port for Nanisivik Mines (lead/zinc). A berth has been built to accommodate ships up to 30,000 tons or so. Conditions in the sound would be suitable for another activity but it would have to be determined whether the parties now involved there (the mining company and government) would agree. Definitely a possibility. Mileage from Radstock Bay reference point is approximately 170 miles.

8. VICTOR BAY -- (Reference (A) -- page 265)

At first glance this too would seem to be an attractive choice but Reference (A) informs us that "temporary anchorage may be obtained near the head of Victor Bay in 12 fathoms but this place is exposed to northerly winds and ice. There are other disadvantages explained in the Arctic Pilot and so, with better selections available nearby, this location is not recommended at this time. Mileage from the Radstock Bay reference point is 160.

9. ADAM SOUND -- (Reference (A) -- page 265)

The long-established settlement of Arctic Bay, in the small bay of the same name which leads north off Adam Sound, presumably renders this as another 'non-starter'. There does not appear to be anything in the remainder of Adam Bay which would make it a better choice than either Elwin or Baillarge. It is 180 miles from the Radstock Bay reference point. Not recommended.

E. Notes

There are no further choices on the coast of the Borden Peninsula along the south side of Lancaster Sound. All of Bylot Island, for instance, is a game sanctuary (snow geese) and is, therefore, denied to all-comers. There are alternatives in some of the sounds and inlets to the south which lead off from Eclipse Sound but these have not been included here. The writer is familiar with Milne Inlet which is where the Mary River iron ore would be loaded should that project proceed.

Two of the possibilities covered in Reference (B) should be given more attention if Radstock and Maxwell appear uncertain. They are Dundas Harbour and Croker Bay. From a mariner's viewpoint both would serve for they have good shelter, deep water, and for the most part favourable ice conditions.

Thule, Greenland, which lies outside all control zones is a possibility although there would be administrative problems of some magnitude to settle first. From an ice point of view, certainly the easiest place of all for ships to reach.

T.C. Pullen

Ottawa, Ontario

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Memorandum to Stig Skarborn

May 12, 1977

Avoiding Multi-year Ice

Being the results of a discussion with Captain George Burdock, of the Canadian Coastguard, in Toronto on May 3, 1977.

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When considering year-round shipping operations in the high arctic, where there is a mixture of multi-year and first-year ice, the question arises whether large icebreaking bulk carriers would be capable of avoiding the heavier ice. If so, this would ease considerably the icebreaking task and reduce transit times. The region of chief concern is, of course, north of Parry Channel and particularly the route to King Christian Island.

Captain Burdock, an experienced icebreaker master, has operated in, and is familiar with, the ice conditions in those waters. While in command of an icebreaker he has probed northward to King Christian Island, and beyond to Thor Island, and between Amund Ringnes Island and the Grinnell Peninsula on Devon Island. He is also familiar with ice conditions in Belcher Channel and he navigated Penny Strait running aground when southbound in Queens Channel.

This officer stated that in his experience the distribution of multi-year ice floes within the overall pattern of fast ice was such that he was perfectly able to avoid the former. He agreed that an icebreaking bulk carrier, with high power, great strength and maneuverability, could do likewise.

Having regard to the ratio of multi-year ice to first-year ice along the routes to King Christian Island, then the former ice type can be sidestepped. In bad ice years, however, should the ratio of multi-year to first-year ice be greater than, say, 5/10ths then a ship of necessity would be committed to attacking multi-year floes and must be designed to succeed at that task. Should the amount of multi-year ice exceed 7/10ths then vessels may be called upon to resort to backing and charging tactics.

T.C. Pullen

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Final Revision May 1977

SPEED IN ICE -- NOTES

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Fog.

1. The combination of ice and fog along sections of the route from the Queen Elizabeth Islands to Eastern Canada will in effect slow traffic to the point where voyage times will be increased by a significant amount. The risks are too great for ships to ignore fog.

2. The International "Regulations for Preventing Collisions at Sea" have been in force for years. They are of signal importance to the correct handling of ships to avoid collision. One rule lays down that every vessel making way in conditions of restricted visibility such as fog, mist, falling snow or rain, must go at a moderate speed, having careful regard to the existing circumstances and conditions.

3. Many and varied are the unjustifiable excuses that have been offered, after a collision in fog, to plead that speed had been moderate at the time. Seldom has any of these been accepted. The essence of a moderate speed is caution in the existing circumstances. It is speed slow enough to avoid collision under the existing conditions of visibility. A long established idea in maritime law is that a ship, when proceeding in fog, should be able to come to a standstill within half the range of visibility ahead. Just how, one is entitled to ask, can one make such a judgment in a ship a thousand feet long if her bridge is in the stern?

4. The Rules continue: "Nothing .... shall exonerate any vessel ..... from the consequences of any neglect ..... to keep a proper look-out or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case. This is known as "the Rule of Good Seamanship" - a statement which speaks for itself and especially in this new arctic context.

5. Arctic marine traffic is growing and if icebreaking bulk carriers materialize the rules will have to be faithfully observed. While their intent is to prevent collision between ships, they are equally applicable to the arctic where

the chief risk is collision between ship and ice, a location where there is the heaviest concentration anywhere of floating glacial ice. The speed of ships in fog in iceberg-crowded waters will surely be something that will attract the closest scrutiny from the marine underwriters.

6. There will be instances, to give an example of the special problems arctic marine traffic will pose, when caution will be called for on the bridges of ships proceeding in fog in Baffin Bay where radars will indicate hundreds of echoes in the vicinity of a vessel. These would be icebergs but a situation could arise where two large ships on opposite courses could assume that the other was just another motionless iceberg. If they were on a closing course the result could be a collision with disastrous consequences. The use of true motion radar should meet this threat.

7. There is no excuse for proceeding at full speed in fog. A prudent, sensible master would go with caution and take no risk of endangering his ship. This is the conduct recommended for ships in fogbound but ice-free waters -- how much more important when traversing Baffin Bay in thick weather in the certain knowledge that ahead lurk more than 50,000 large bergs.

8. Radar, of course, is now indispensable for navigation in fog and it should be pointed out here that in the reformulation of the Rules for the Prevention of Collision at Sea in 1960, the following statement appears: "A vessel navigating with the aid of radar in restricted visibility must .... go at a moderate speed. Information obtained from the use of radar is one of the circumstances to be taken into account when determining moderate speed. In this regard it must be recognized that small vessels, small icebergs and similar floating objects may not be detected by radar."

9. The failure of radars to detect icebergs has been well documented and the following extract from The Use of Radar at Sea by Wylie is pertinent: "Icebergs with sloping faces may give specular reflection in an unfavourable direction and thus have a very small equivalent echoing area even though their actual size is large. Such icebergs will be very poor targets. Icebergs which have some faces nearly vertical and other faces sloping will change from good targets to very poor targets as the aspect changes. Growlers will be very poor targets because of their small size and their shape."

"Icebergs are often not detected at ranges as long as might be expected. Cases are often reported of bergs looming so large to the eye that it would seem almost impossible for them to escape detection by radar, and yet producing no echo until they are even closer. This is likely to be accounted for by the berg having smooth sloping sides and possibly also because of sub-refraction which often occurs in regions where ice is prevalent. The strength of reflection of radar waves from ice on the Grand Banks is 60 times less than from a ship of equivalent echoing area."

10. Having noted the poor performance of radar against ice under certain conditions it becomes necessary to point out that radar performance in fog is degraded even more -- to a great or less extent depending upon the amount of water vapour present in the atmosphere. To quote Wylie again: " .... the lower the visibility (the thicker the fog in other words) the ..... greater the reduction in ...... detection range. There is some reason to believe that polar fogs (at 32° F.) cause an appreciably greater reduction in detection range than fogs in temperate regions."

11. Summing up, then, not only do the Rules for the Prevention of Collision at Sea lay down just what ships should do in fog and low visibility generally, but in polar regions it is established that radar can be unreliable in detecting icebergs, bergy bits and especially growlers. The speeds recommended in the accompanying Table for large icebreaking bulk carriers take all the foregoing factors into account. In the final analysis it will be the master who decides how fast he is going to go. If he ignores the consequences of carrying on too fast in the presence of glacial ice and in fog he will, assuming he survives, have much to answer for in the event of a catastrophe.

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May 20, 1977

T A B L E - - SPEED IN ICE

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For an ARCTIC CLASS 10 vessel of 150,000 tons displacement, powering to satisfy the requirements of the Arctic Shipping Pollution Prevention Regulations, twin rudders, multi-screw arrangement and with the bridge forward.

Ice, as used in this context, is considered to be either, or both, hard (May/June) first-year sea ice six feet thick (1.8^{m}) and glacial ice which floats in an infinite variety of shapes and sizes. Sea ice which is thinner, or rotten, or both, presents less of a challenge. Accordingly, ships['] speeds can be greater than ... those given at the discretion of experienced ice masters. However, if the sea ice is thicker, or when in the presence of glacial ice, then greater care, with lower speeds, becomes the order of the day to lessen the chance of destructive impacts between ships and ice.

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<u>Ice Distribution</u>	<u>A</u> Clear Visibility Day or Night	<u>B</u> Fog or Whiteout
1. Nine to Ten Tenths Ice Cover	No restrictions on power. Speed in such ice conditions unlikely to build up to a dangerous level, i.e. in excess of <u>10 knots</u>. The risk here comes from forcing fragments into screws & rudders. High powers needed, of course, to permit the vessel to adjust course.	Risk of blundering into Multi-year floes unnecessarily, or into ridges or glacial ice that cannot be seen. On the other hand, 10/10ths ice acts as an effective brake when power is reduced or taken off. <u>Maximum speed 8 knots</u>.
2. Seven to Eight Tenths Ice Cover	Sufficient slack in these conditions for a powerful vessel to build up considerable speed imposing high impact loads on the hull & forcing heavy ice blocks into screws & rudders. <u>Maximum speed 12 knots</u>.	As for <u>A-2</u> plus the fact that a ship would be "flying blind" despite use of radars for ice interpretation. Little braking effect from the ice, ship more likely to carom unexpectedly & uncontrollably. <u>Maximum speed 12 knots</u> except in <u>Baffin Bay & Davis Strait</u> where it should be <u>8 knots</u>.
3. Four to Six Tenths Ice Cover	In these conditions there is sufficient water for a ship to reach dangerously high speeds with little difficulty & yet be unable to avoid all the ice. Risk here of high impact loads on hull & to	Being unable to see anything, and unable to identify dangerously heavy floes (bergy bits, growlers), in the grain of the ship, speed must be low even though there is sufficient open water to make

	screws & rudders. Shiphandling skill required. Maximum speed 14 knots.	up for lost time. Maximum speed 10 knots, 8 knots in Baffin Bay & Davis Strait.
4. One to Three Tenths Ice Cover	No restrictions on speed	Risk of unavoidable collisions with undetected icebergs, bergy bits & growlers too great despite radars. Maximum speed 10 knots in Baffin Bay & Davis Strait -- elsewhere 12 knots.

NOTE:

See also accompanying Memorandum entitled SPEED IN ICE -- NOTES dated 20 May, 1977.

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September 13, 1978

Report to the POLAR GAS PROJECT
on ice conditions in the Canadian Western
Arctic with particular reference to the
Selected Staging Sites.

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Introduction

This report deals with two tasks, the first being to collect historical data relating to sea ice conditions in the Canadian Western Arctic in waters bounded in the west by the Mackenzie Delta, in the east of Coronation Gulf and to the north by Prince of Wales Strait. Particular emphasis was to be placed on the role ice plays along the sea routes to the designated staging sites (see below) for the "Y" Line routeing of the Polar Gas Pipeline.

The second task was to provide a brief analysis of the ice regime as it would affect 'barge trains' operating from the Mackenzie Delta eastward to staging sites and also for similar ‘trains’ coming from Alaskan waters. Remarks were also to include suggestions for the management of cargo movements within the Western Arctic Region.

Staging Sites

The following staging sites form the basis of this report:

Mackenzie Delta (Tuktoyaktuk)

This is really more of a marshalling point than a staging site for it would receive considerable cargo down the Mackenzie and, in part, cargo from Alaskan waters to the west. Here convoys would be formed awaiting suitable times for a move to the remaining sites either under icebreaker escort or unescorted, depending upon ice conditions at the time.

Darnley Bay -- 250 nautical miles from Tuktoyaktuk.

Tinney Point -- 310 nm from Tuktoyaktuk.

Prince Albert Sound -- 430 nm from Tuktoyaktuk.

Peel Point -- 440 nm from Tuktoyaktuk. Hay Point is 340 nm from Tuktoyaktuk and is preferred to Peel Point.

Expediter Cove (Coppermine) -- 515 nm from Tuktoyaktuk.

Dolphin & Union Strait -- 455 nm from Tuktoyaktuk from vicinity of Camp Island.

TASK I -- Acquisition of Historical Data

Ice Central in Ottawa has supplied the following historical ice information:

Nine volumes of Ice Summary & Analyses, published by Environment Canada for the years 1964 to 1972 inclusive.

Each volume contains a series of weekly or fortnightly ice charts showing the progression of break-up, drift and formation of ice in the Arctic during the spring, summer and autumn months. Also presented is a series of charts showing the mean surface pressure and temperatures for the intervals between successive ice charts. The ice regime is compared to that of previous years and factors affecting movement of the ice are discussed. On the average there are 14 ice charts in each volume covering the period May 21 - October 22 by which time freeze-up is well underway.

Fortnightly and weekly ice charts for the years 1970 to 1977 inclusive for the months of August and September -- in all 66 ice charts.

Additional ice charts giving more details and for a longer period for the years 1968 (25), 1967 (28) and 1975 (20).

All this material accompanies this report.

The following material, in addition to the nine volumes of SUMMARY & ANALYSES referred to above, is in the writer's library should it be desired to extend the examination of historic ice data back further than 1964:

Aerial Sea Ice Observing and Reconnaissance- Canadian Western Arctic for the years 1957 - 1963 inclusive.

The 1960 Ice Season - Western Arctic

Ice Conditions in the Canadian Arctic during the Summer Shipping Season, 1963 (Hill, Cooper & Markham).

Sea Ice Distribution in Canadian Arctic Waters - Summer, 1962 (Markham & Hill).

Ice Thickness Data for Canadian Selected Stations as below:

Freeze-up 1967 - Break-up 1968
Freeze-up 1965 - Break-up 1966

Freeze-up 1964 - Break-up 1965
Freeze-up 1963 - Break-up 1964
Freeze-up 1962 - Break-up 1963
Freeze-up 1961 - Break-up 1962

Report of the Arctic Ice Observing and Forecasting Program - 1967.

Ice Thickness Data for Canadian (Arctic) Stations 1958-59.

Ice Central also has ice data going back before 1964 but these are on microfilm and the time required to examine these was neither available nor was it felt to be justifiable.

The number of years (15) which have been examined provides sufficient detail to get a feel for ice conditions during the summer season between Tuktoyaktuk and the Coppermine. Compared with the conditions to be found in Alaskan waters, the message this report has to pass is encouraging to say the least and is dealt with below.

--oo0oo--

TASK II -- Brief Analysis of the Western Arctic in Relation to Icebreaker Supported Shipping Operations to the Staging Sites

--oo0oo--

Alaska and Amundsen Gulf Compared

It is important to understand one salient feature of the overall ice situation in the western arctic, by which is meant the route from Icy Cape, 125 miles beyond Point Barrow, Alaska, eastward to Coronation Gulf, 1,200 miles distant. It is that the key to shipping, whether supported by icebreakers or going unescorted, is the stretch of coast from Point Barrow to the Yukon/Alaskan border. The best way to drive this home is to examine the ice map opposite.

This ice map is typical of the situation and shows conditions as they existed on August 6, 1970. The message is clear. Open water prevailed from west of Herschel Island as far east as the Boothia Peninsula. Unescorted shipping would have been able to get to all sites including Peel Point. But inbound shipping would first have had to get through the Alaskan portion of the route and, as the map shows, the ice conditions were anything but favourable though there is some open water close along the coast.

By the time shipping can be escorted by icebreaker(s) through the Alaskan section and delivered to the Mackenzie Delta, conditions in the latter area will be so far improved that it can either be sent on its way unescorted or, in a slow year, or a bad year for that area, a modicum of icebreaker escort would suffice.

Another conclusion can be drawn and that is the desirability of over-wintering vessels to permit advantage being taken of the earlier breaking-up and clearing of ice in the Canadian sector. Weeks could be gained by adopting such a course should Alaskan ice conditions happen to be bad. In addition, the risk of damage to vessels, being handled by inexperienced people, could be lessened.

1975 was one of the worst years for ice along the Alaskan littoral since records have been kept according to Sea Ice Consultants in Suitland, Maryland. It should, therefore, be interesting to examine the situation as it affected the Canadian Sector. The Americans experienced great difficulties in delivering essential cargo to Prudhoe Bay. In the final upshot much of it had to be returned and other arrangements made to get it in.

The polar pack, and the first-year ice, was packed onto the Alaskan coast at a number of so-called 'choke points' as far east as Barter Island. To have got shipping through this ice, comprised of ten tenths polar and first-year, would have called for an intensive icebreaker operation.

While conditions may have been difficult for Alaskan operations, matters were very satisfactory from Mackenzie Bay eastward beyond the Coppermine and Expediter Cove. Even Peel Point itself would have been accessible for approximately six weeks -- twelve weeks if Hay Point had been used instead (100 miles further south in Prince of Wales Strait). This would have been a situation where over-wintering vessels from the previous season would have paid big dividends.

Conditions in the Canadian sector were excellent once more for unescorted shipping. Icebreaker support would not have been necessary. Probably just as well, in the Polar Gas context, for all available icebreakers would have been hard at it getting barges from Icy Cape to Barter Island.

Shown opposite is an indication of the length of season in 1975 at the various sites, plus Dolphin & Union Strait, based on the Ice Summary & Analysis for 1975. People tend to generalize when they talk about ice years and whether they were good or bad. 1975 is a good example. For those concerned with Alaskan ice it was indeed a bad year but in the Canadian Sector conditions were excellent. It is not enough, then, to talk about such a large area as the 'Western Arctic' without specifying precisely where ice conditions were 'bad' or 'good' or 'average'.

An analysis of Alaskan ice conditions is not part of my task.

--oo0oo--

1 9 7 5

Place	Season	Duration (days)
at Tuktoyaktuk	July 18 - September 26	70
at Peel Point	August 8 - September 19	42 #
at Prince Albert Sound	August 1 - October 3	64
at Darnley Bay	July 25 - September 19	56
at Tinney Point	July 25 - September 26	63
at Expediter Cove	July 11 - October 10	91
in Dolphin & Union Strait	August 8 - October 31	84

Access to Hay Point could have been achieved between July 25± and October 17 ± (84 days). It is 95 miles down the strait from Peel Point.

Note: The duration of the season is approximate because the information is derived from ice maps drawn on a weekly or fortnightly basis.

--oo0oo--

Prince Albert Sound as an Example

An analysis of ice data for a typical site, in this case Prince Albert Sound, generates two shipping seasons, one for unstrengthened vessels and, by applying a 21 day addition, the seasons for icebreaker escorted shipping. A representative period of 6 years has been used for this calculation. The results are as follows:

	Unstrengthened	Icebreakers
1964	35 days	56 days
1965	42 days	63 days
1966	77 days	98 days
1967	21 days	42 days
1968	84 days	105 days
1975	64 days	85 days

Given:

Distance of 430 nm one way, a speed of 9 knots and an unloading time of 3 days, one complete cycle could be completed in 7 days. Assuming one barge can carry 6,700 tons then to deliver 184,400 tons will require 28 barge loads. The required tonnage, therefore, could be handled by 4 barges within a time frame of 49 days. 5 barges would reduce the time frame to 42 days on the basis of 30 shared deliveries. 6 barges would accomplish the task in 35 days or less.

The foregoing delivery times are less than the seasons for unstrengthened shipping, save for 1967, and even more so for icebreakers. Until figures are available for the other sites it is not possible to calculate whether the required tonnage could be handled but with a force of 25 to 30 barges, adequate seasons and icebreaker support there should be no difficulty.

Icebreakers -- Extending the Season

All the ice data that have been accumulated over the years for the Canadian Western Arctic take for granted, it would appear, that operations there are carried out by unstrengthened ships. Indeed, the only icebreaker committed to those waters is the CCGS Camsell. Her role is to lay buoys, check navigational aids, carry out hydrography and, from time to time, give assistance to vessels having difficulty in ice. For the amount of traffic that has been customary there, icebreaker services are necessary really only 'from time to time'. All cargo has, and is, carried in thin-skinned ships.

It is not easy, then, to be dogmatic about what influence on the shipping seasons would an icebreaker have. In the preceding section an arbitrary 21 day extension was adopted but there was some justification for this.

An examination of the detailed ice charts was undertaken and, for example, conditions indicated that in 1968 the presence of an icebreaker would have extended the season into Prince Albert Sound by 21 days; from 84 days to 105. The same holds true for the 1975 season there whereby the season would have been extended from 64 days to 85. That same year the season in Darnley Bay could have been lengthened by five weeks to a total of 91 days and at Tinney Point by 21 days to 84.

These are only a few examples, but the pattern is consistent and accordingly a blanket extension of 21 days on the face of it seems reasonable.

<u>The Polar Gas Project</u> -- <u>Need for Icebreaking Services</u>

The duration of the Polar Gas Sealift, four years consecutively, the very large tonnages involved, especially during the first two years, the number of barges involved and sites to be reached, makes it essential that in the Canadian sector ice does not frustrate the delivery schedule. The scale of the operation and the need to ensure deliveries on schedule, justifies the need for icebreakers.

Wherever in Prince of Wales Strait it is located, the staging site to serve Peel Point will experience probably the worst ice conditions of all the proposed sites. Heavy floes can, and will in a bad ice year in Parry Channel, be driven in at the north end of the strait from Viscount Melville Sound. Some will plug the entrance and others will cause problems further down the strait as they are borne there by winds and currents. To ensure access to the landing beach for the barges an icebreaker is necessary.

Another problem which will confront barge traffic over a 4 year period will be the ice bridge which sometimes forms from Banks Island across

Amundsen Gulf to Cape Parry/Cape Bathurst. If operations are to be started early in the season, or to ensure barges get through this ice en route from Tuk eastward to the other sites, then an icebreaker would be essential.

Prince Albert Sound, Darnley Bay, Tinney Point and Expediter Cove during 1964 shared a 35 day season for unescorted shipping. The problem then was they were isolated from Tuk and an icebreaker would have been needed to get traffic moving in good time.

The large number of craft involved in such an undertaking means inevitably that green hands will have to be recruited, people with little or no knowledge of ice seamanship. The availability of an icebreaker will reduce the risk of ice damage to vessels, inspire confidence in the crews, and ensure that those barges and other vessels which have to return to the westward before freeze-up at Barrow do get on their way. Marine underwriters would be favourably impressed if they knew that an icebreaker would be acting in support of the sealift vessels.

Command and control of such a widespread operation could best be handled from an icebreaker which would be capable of going anywhere in the area and which could have the needed facilities built into the vessel.

An icebreaker stationed at the eastern limit of the Alaskan ice would be in a good position to assist shipping struggling east to reach the western limit of Canada's responsibilities.

Finally, should vessels over-winter, the commencement of local operations could be substantially hastened were an icebreaker available to break the former out.

Regulatory Matters and Icebreakers

The Arctic Shipping Pollution Prevention Regulations lay down that Type 'E' Vessels, those which are not ice strengthened, are limited in time in certain areas of operation.

In the western arctic there are two Zones, 11 and 12, which govern the operations which Polar Gas has in mind. Type 'E' vessels may operate in Zone

11 from July 15 until September 30 and in Zone 12 from July 1 until October 20. See opposite.

Tuktoyaktuk and Darnley Bay lie within Zone 11 and the rest of the sites in Zone 12. If these rules are abided by they could impose a crippling limitation. The presence of an icebreaker would ensure that the maximum amount of cargo was delivered in the shortest time. Indeed, the presence of such a capability might cause the authorities to ease the restrictions somewhat on Type 'E' vessels if they are under escort.

Ships carrying less than 16,000 cu/ft of oil (452.8 cu/m) are exempt.

Over-wintering Challenger-type Icebreaker

The proposal to over-winter one Challenger-type icebreaker is most strongly endorsed for its ability to keep operations going during freeze-up. New ice begins to form in bays and inlets where the land provides sheltered conditions from wind and wave. If left undisturbed this ice grows quickly; a matter of inches overnight and in a few days the thickness is such that underpowered craft and unwieldy vessels must suspend operations for the winter. Icebreakers could break this new and young ice before it has a chance to solidify and thicken permitting activities to continue for a week or so. Even tugs, with their power, should also be able to contribute their share during the early stages of freeze-up.

The process of break-up also starts in bays and sounds. Open water forms at the mouths of rivers and streams because the fresh water run-off is the first to melt the sea ice. On page 214 of Arctic Canada from the Air (Dunbar & Greenaway) there is an aerial photograph of Prince Albert Sound taken in June which shows this process quite clearly. On page 214, Fig. 251, is evidence of the same process but even further advanced in Minto Inlet.

While this process of melting, rotting and ultimate dissolution of the fast ice in bays and inlets proceeds the ice to seaward remains firm. Thus an over-wintered icebreaker would be able to stir up the ice permitting less ice-capable craft nearby to start local operations weeks ahead of what would otherwise be practicable.

Finally, the over-wintering of an icebreaker could result in weeks of useful activity compared with one which would have to defeat the Alaskan ice to reach the Canadian sector. A bad ice year off Alaska could, then, have a serious impact on Canadian operations. There is also the risk that the icebreaker inbound from the west would not only suffer delays but be damaged in the process and be lost for the summer.

The ice map opposite shows typical freeze-up conditions taking place in Dolphin & Union Strait. Asterisks are used to indicate New Ice and Nilas -- in this case they denote 4 to 6 tenths ice. Ice Symbols used on Ice Maps are shown overleaf.

Over-wintering of Tugs

Over-wintering of tugs is also recommended and is positively feasible. Failure to do this would certainly shorten the time available for operations. Tugs are designed to have high powers but in an ice-breaking context they should also be built to permit a certain amount of this work without damage to shell plating and framing.

With five sites it is not possible for one large icebreaker to service more than one or two at break-up or freeze-up. Tugs at these other sites will have the task of delaying freeze-up and expediting break-up and should be moderately effective at this sort of work. Their over-wintering, then, becomes an essential part of the total operation.

If tugs are to over-winter at Tuk, say, then from the furthest site, Expediter Cove, it would take 2½ days at 8½ knots to make the run -- less for the other sites. If this tactic were adopted this time would be lost at the site(s) for ice-clearing operations. It should be possible to select suitable havens where these vessels could safely pass the winter at or adjacent to the sites for which they are responsible.

Barges for Fuel Storage

Using barges that over-winter for fuel storage makes a deal of sense. Provided the total amount is less than the maximum permitted by the Arctic Shipping Pollution Prevention Regulations (16,000 cubic feet or 452.8 cubic metres) there should be no difficulty except as noted below.

Notwithstanding the exemption, regulatory authorities may wish to satisfy themselves that the construction of the barges and the proposed over-wintering locations are in every way suitable.

If, on the other hand, the quantity of fuel it is proposed to store is in excess of the above quantity, then permission must be sought and construction of the barges will have to meet the technical specifications laid down in the rules.

<u>Harbour movements</u> -- <u>Before Break-up & After Freeze-up</u>

To what date might harbour movements (positioning barges and so forth) be feasible, and when may they be started in the spring? To answer this question an examination was made of ice charts prepared by Ice Forecasting Central for the months of June (2), July (4), August (5), September (4) and October (5). The year 1975 was used as being a typical year for this sort of an exercise. The earliest ice chart was for June 20 and the latest October 31. In addition some ice thickness data were examined for selected settlements near the Polar Gas sites. For instance Coppermine for Expediter Cove and Holman for Prince Albert Sound.

The results of this examination are of interest. It shows that (in 1975) local operations as envisaged by Polar Gas would have extended the season in Tu[k]toyaktuk harbour by 45 days. This was the largest increase. The smallest was for Deans Dundas Bay, serving Hay Point nearby and Peel Point. The increase here was reckoned to be 10 days.

TABLE

1975

	TUK	DARN	TIN	PR AL	PEEL*	EXP
Earliest date when local operations could be undertaken	Jun 20	July 18	July 18	July 10	July 18	July 1
Latest date when local operations could be undertaken	Oct 15	Oct 20	Oct 10	Oct 20	Oct 20	Oct 28
Total (days)	115	94	84	102	94	120
Season for Unstrengthened Ships	70	56	63	64	84	91
Increase	45	38	21	38	10	29

* Deans Dundas Bay used in this example

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Cargo via Mackenzie versus Point Barrow

The routeing of cargo from Point Barrow, Alaska, takes it close by Tuktoyaktuk even if it is not destined for that place in the first instance.

Deliveries to sites originating from Tuktoyaktuk will be underway before cargo inbound from Barrow because conditions in Amundsen Gulf, and especially in Tuk, are better and open earlier than those along the Alaskan coast.

If Tuk is to be used as a marshalling/staging point it must be remembered that it is a small harbour and there will unlikely be room for the sort of fleet Polar Gas will require, especially when Northern Transportation also bases its operations there too. Another site nearby should be ear-marked -- say in Liverpool Bay.

It is 480 miles from Point Barrow to Tuk, a gauntlet of ice through which ships must run. In 1975 shipping operations could have started from Tuk about July 20 with open water prospects to all sites. This would have been about five weeks earlier than ships could have negotiated the run from Barrow. But 1975 was a bad year off Alaska. In 1977 Tuk-based vessels would have had about a week in the way of a head start over the Barrow shipping.

It seems clear that in this respect Tuk-based operations will always be one jump ahead of inbound ships from Barrow.

Is One Challenger-Type Icebreaker Sufficient for Amundsen Gulf?

Yes. For the reasons already stated elsewhere in this report. More than one would be over-kill in an area where conditions do not justify it.

Tugs, maybe a selected number, would benefit if they were given a degree of ice-strengthening if they are to over-winter and be expected to extend operations by carrying out some icebreaking. Barges need not be ice-strengthened.

Ottawa, Canada T.C. Pullen

Doc. 15: T.C. Pullen, Memorandum to Don Gamble, The Arctic Pilot Project: Being Some Comments by T.C. Pullen on CARC's Submission dated March, 1980, to the Environmental Assessment Review Panel, 16 April 1980.

HBC Archives H2-141-1-6 (E 346/1/47)

April 16, 1980

Memorandum to Don Gamble

The Arctic Pilot Project

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Being Some Comments by T.C. Pullen on CARC's Submission dated March, 1980, to the Environmental Assessment Review Panel.

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Page 1 INTRODUCTION

para. 1 This opening endorsement by CARC of the Arctic Pilot Project (APP) turns out to be start point for pages of criticisms that follow. It is unique -- not seemingly so, among northern energy projects. It is "relatively small and flexible" (the latter being one of the great benefits which marine transportation bestows) not was unless the CARC verdict is in. Use of the past tense is a mistake at this stage of the paper. This project does offer exciting benefits in the pioneering of year-round navigation in the arctic and so forth.

para. 2 A paragraph full of generalities and one that cannot be permitted to stand as it is. What is being addressed here is CARC's view of the justification of the entire undertaking. In this writer's view the APP stands or falls on the ground of energy need -- domestic or national or continental. Energy self sufficiency might be a better way to express it. The generation of industrial benefits and other advantages are peripheral to aim of the exercise -- to move arctic energy to North American consumers.

"If it cannot be demonstrated that the APP meets Canadian energy priorities" then why are Panarctic, Petrocan, Melville Shipping and others making such an effort and spending so much money to achieve success? If a firm decision has been made to build the LNG ships abroad then this is news to this writer. A convincing case has to be made before this can be allowed to become fact.

Page 2

<u>para. 1</u> The key to arctic development has much more to it than marine systems which are "economically viable and environmentally acceptable" -- a tiresome and worn-out phrase that can mean anything or nothing. The key to arctic development would seem to be, firstly, is what is planned in fact practicable? The next statement in the CARC paper is nonsense and the sort of dangerous generality that weakens whatever case CARC has in what must be a fair, responsible, informed and unbiased approach to this whole affair. With particular reference to the movement of oil, CARC must learn first what the facts are before holding forth with such determined ignorance. The year-round movement of oil in the arctic would be just the opposite and one would have thought that CARC would have derived some comfort from this fact.

As to the settlement of 'aboriginal rights' (assuming there are any in an international waterway) the reader gets the impression, or this one does, that this matter is being used as a sort of "Captain's Cloak"[1] in case all other measure to halt or delay development fail.

Page 3

<u>First nine lines</u> I know all about the 1973 commitment "to achieve world excellence ......waters" having attended both meetings and chaired the latter one. An omission here from CARC's quotation was the stated aim that such "excellence" was to be achieved "within five years". We are two years past that

[1] An all-embracing Article in the Naval Discipline Act giving Captains of H.M. Ships unduly wide powers of punishment.

goal and there is precious little, if any, excellence around. So talk about "specific federal policies" having "reinforced these priorities" is meaningless.

An APP decision to go off-shore for its ships would seem to run counter to the 1977 policy to "develop a ship-building industry capable of responding to the demand for marine transportation in the Canadian arctic". If our government's northern policies which are "driving northern development today" are as referred to above then we are in trouble. To take the M/V Arctic as representing a marked achievement then prospects continue to be forlorn.

para. 1 A weak framework but "support" from CARC is not the answer. Until this writer has more experience of the EARP process he will not comment but to pretend that the Government of Canada has an effective arctic policy, or an effective arctic decision-making capability is untrue. See Edgar J. Dosman's paper: Arctic Seas - Marine Transportation & High Arctic Development, 18 Sept 1978.

Page 4 ENERGY CONSIDERATIONS

para. 2 Comment. It might be that money earned by exporting energy would help to offset the cost of importing energy from overseas if only in part until such time as Canadian consumers switch from oil to gas especially in the east. Surely to state that the project "is an energy export scheme" only is to dissemble just a mite?

Page 8

para. 1 To criticize APP on the ground that it is only an export scheme and then introduce the so-called advantages of an alternative, namely pipeline, is less than fair. The economy of scale, in the case of the POLAR GAS PROJECT, means that the volume of product moved is so great that the only market is in the U.S. and Canada merely serves as a support for the line to get there.

Page 10

para. 2 "Seasonal delays to avoid biologically important areas". This is a generalization. Biologists and scientists (when they can spare the time from killing polar bears with oil fuel) would have to get together with ship operators (arctic navigators not pale-faced quill-drivers from head office) and resolve this important issue to the satisfaction of both parties.

Page 13

para. 3, line 14 The "clearly more viable alternatives" are not made clear nor even mentioned. The only alternative for moving high arctic gas would be by pipeline and as already pointed out this means a U.S. market. It is not explained what is meant by "questionable reliability" -- is it for operational reasons? An unsatisfactory summary.

Page 22

line 1 et seq Surely this question has been addressed, in part, by the study carried out by Albery, Pullerits et al entitled "Marine Transportation of Oil & LNG from Arctic Islands to Southern Markets" prepared for Transport Canada's Strategic Studies Branch.

Page 28

para 3.1.1 "Corridor" is not a marine term and it is dangerous in that it conjures up a picture of long, straight passages. "Route" is a better term and it must be remembered that in the arctic routes never become fixed but vary infinitely according to the prevailing ice regime. Shipping "corridors" will not become established.

"Replicate"? A poor choice of word surely?

Page 29

para. 1 The number of transits is excessive. Discussed later.

Page 31

para. 1 penultimate sentence The routes shown on the map (FIGURE 1) do not represent the routes the ships will, or would like to, follow. They represent the routing use to which the computer was put. Any Ship Master who took his vessel into Melville Bay as shown should be removed from his command forthwith. Melville Bay accommodates 25,000 bergs and is constantly being fed more by the many glaciers located there. The use of the fast ice, then, by Greenlanders going between Cape York southeast towards Upernavik, would not be threatened nor would the ships operate as close to the Greenland coast as is shown in the vicinity of Disko Island.

Page 33

para. 1 One is constantly reading of the need to know more about the ice regime on a year-round basis, and about the weather, climatological factors generally, and the behaviour of animals. All this points to the need for an icebreaker capability permitting experts in all fields of endeavour to establish what the state of play is on a year-round basis. The only way this can be achieved is by ship, one with the endurance, size, strength and power to penetrate, and operate in or simply just loiter, to learn what the environment is all about. Only a Polar icebreaker can do this and Canada has shown little inclination to build one.

Page 33 (cont'd)

3.1.2.2 Ice Regime etc. This is a fair statement, and understandably so from the mariner's viewpoint, of how ships would want to route themselves. Use of the word 'hug' in relation to routing along the Greenland coast is unfortunate though it is a term I feel I introduced a while back. "Favour" is preferable

Page 34

Para. 1 This is a good paragraph and it is agreed there is no reason at all why ships should get too close to Greenland.

Para. 2 Icebergs are visually impressive but are not the hazard laymen reckon them to be. Wherever there are bergs there you will encounter bergy bits and growlers. These are the bits of floating ice that must be respected though they are hard to see at times, especially growlers or, as the old whalers called them, "washing pieces" which is an apt description. In the last line of this paragraph the term "navigational" is ambiguous. If the APP ships cannot steer clear of bergs then the project is indeed in trouble.

Page 35

Para. 1 It is a sad commentary, but typical of Canada's lacklustre arctic performance, that the only iceberg distribution and census was taken by the U.S. Coast Guard in 1949. It is agreed that radar in fog can be unreliable and in iceberg waters ships had best be careful. This writer wearies sometimes at the endless mention of "sophisticated detection equipment systems". There is a tendency to try and overcome the challenge of arctic marine operations by introducing a mass of assorted gadgetry and black boxes onto the bridges of ships. It has to be stated somewhere, it might as well be here, that the real key to success of the APP will not be electronic wizardry but the officers who will be charged with the task of handling these ships. From where these people will come is not known at this time but Canada would be a poor place to find them for a number of reasons.

Page 36

Para. 1 A fair statement but, taking into account what has been written above about the routing in relation to Greenland, it is hard to see how else the APP could handle the routing challenge. Someone has to go first and in general the APP has planned routes which seem reasonable to this writer except for CARC's last caveat about "great biological importance". If more data are needed then it is the task of Federal Agencies, particularly the Coast Guard, to accomplish this and to create the year-round capability to do it. Forthwith. CARC, if it is going to seek a target for its weapons of concern, had better train them on the real villain of this piece.

Para. 2 Fury & Hecla is a possible alternative operationally and I know it well. Also Foxe Basin where a considerable hydrographic effort would first be required. However, the writer thinks that CARC, if it went more deeply into the matter, would become concerned at the biological significance of this route also.

Page 37

Para beginning "Actually....." Do not agree. Because ship-created channels in ice stay that way as in the Baltic is no assurance they will on the route to King Christian Island. They may. They may not. Why not find out? Another task for a Polar icebreaker if we had one. Why not ask the Russians if they would do it for us? It may not be that long before they will be doing it anyway whether we like it or not.

I simply cannot agree with Dome's Director of Marine Research that getting to Freeman's Cove on Bathurst Island would be more difficult than getting to King Christian.

<u>Para 3.1.2.3</u> Except for the fast ice along the coasts, it is reported by Graham Rowley, an authority on this subject whose opinions I respect, that Eskimoes do not use the ice in Lancaster Sound for travel. This is because the ice there, like that in Hudson Strait, is always on the move and does not, except in rare circumstances, become consolidated. The point has already been made that routing will not take the LNG ships anywhere near a line joining Thule to Umanak. This leaves Barrow Strait and it has yet to be demonstrated that hunting patterns there are well enough established to suffer disruption.

<u>Para. 3.1.2.3</u> (cont'd) "Inuit concern about the effects of year-round shipping is well known". Well known to whom? What is the actual risk to their livelihood? How many are involved? Where is the threat felt to be? Until someone can operate a ship through these areas on a year-round trial basis how can it be said that [there] is a risk? It is not Petrocan, or whoever, that should "bear the burden of proof, the risk, and ultimately the economic cost", it is the Government in the shape of the Coast Guard or is CARC inviting the APP to build an Arctic Class VII ship to get the answers?

Page 39

<u>Para. 1</u> It is somewhat unfair to compare the Trans-Alaskan Pipeline Authorization Act, which is of fairly recent vintage, to much older legislation like the Canada Shipping Act in this context. The emphasis is on oil spills and in Alaska the risk is considerable. We are talking about LNG, not oil, and even if we were, oil transported by icebreakers, large or small, would be safe. "Terms and conditions for shipping in our North" is a statement which causes the writer some apprehension. Whose North? What terms and conditions? We are being regulated to death. Remember we already have the Arctic Shipping Pollution Prevention Regulations.

Page 42

<u>Para. 1</u> The routing of ships, in the arctic, cannot be compared to that of aircraft which is severely and necessarily controlled. Ice is where you find it and the line of least resistance is the general track ships will follow. The long

way round is often the quickest way to one's destination. Masters may be directed to do their best to avoid environmentally sensitive areas at certain times of the year but they cannot be told exactly where they can and cannot go unless the landsmen indulging in such interference with things they know nothing about will accept the responsibilities for accidents and damage that may result.

<u>Last two lines</u> What are areas of "biological importance" and where are the "Inuit hunting areas". Or does the APP have to provide the answers to these questions?

Page 48

<u>Para. 1</u> "In terms of .....etc" It is incredible to read that CARC wants to impose its view on how the ships should be manned. There is going to be difficulty in finding enough intelligent, trained and qualified southern Canadians in the future. There are none now. The manning of LNG ships is something Canada cannot undertake now and these ships will likely have to be manned by foreigners at the outset. Northerners will have to compete with their southern brethren and let us leave it like that until Canada has created the specialized training facility that will be called for.

Page 52

<u>Para. 1</u> Good to see this laid out. Some day the U.S. will likely test us but this writer for one supports the view that Parry Channel is an international waterway.

Page 55

<u>Line 1</u> The subject of where the LNG ships should be built. It would be good to see Canada bite the bullet, spend the money needed to upgrade a selected east coast yard, and be prepared to build the ships in Canada.

<u>Last Sentence</u> This writer has pushed for a polar icebreaker for years but nothing happens -- plenty of planning but no commitment of real funds to build. Forget about arctic excellence. Of all large ships, LNG vessels are the lightest, shallowest, widest and most voluminous, all factors which mitigate against them being good in ice. If any year-round arctic ship is going to need the occasional leg-up, it will be an LNG one. A Coast Guard Polar VII or X

would be the only icebreaker, other than the LNG sistership, to get to the scene and break the victim free.

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<u>Para. 1</u> Full marks to Dome for building its own icebreaker. It is noteworthy that the master of the <u>Kigoriak</u> is an Englishman. It seems Canadians either are not available or if they are they do not want to leave the comforts of home and do a job of work. Manning all these ships CARC talks about, and Dome is planning for, is going to be interesting.

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<u>Line 5</u> Properly the <u>Polaris</u> mine, no longer <u>Arvik</u>. COMINCO will be using the M.V. <u>Arctic</u> in 1981 to haul concentrates so insofar as it[']s possible to use Canadian flag ships, that company is doing all it can but the law of the market place is such that you get the best rate to haul your product and if there is no Canadian capability to handle it all, then go to a foreign company. Nothing wrong with that. It is hard to see how the <u>Arctic</u> can handle both Nanisivik and Polaris in one season.

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<u>Line 10</u>. Why? The ice regime through which the ships will have to travel is different -- whether it is more difficult than that en route to Melville Island, remains to be seen.

<u>Penultimate para</u>. Routes will depend upon prevailing ice conditions and will be changing constantly to reflect these.

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APPENDIX

Marine Traffic Forecast: Northwest Passage

COMMENT

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Para. 3 It seems that no matter what geographic area is the object of an environmentalist's anxious scrutiny, some or all of it will end up being described as being undoubtedly "one of the most environmentally significant parts ...." It might be less wearisome if we were given a list of those few areas left that are not environmentally significant.

Rather than attempting to "calculate" the total number of ship transits, it would be wiser to attempt an "estimate". It is not an exact science.

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Para. 2 A reasonable approach to what at best is surmise.

For the Beaufort Sea, by 2000, less than 20 years hence, a fleet of 24 Class 10 icebreaking tankers is something to stir the imagination. Just where will these ships be built? Certainly not in Canada in such a time frame. Who will man them? Canadians? Being generous to a fault, let a figure of half the estimated transits be used -- 288.

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Para. 2 Ships on the King Christian Island trade will use Belcher Channel, Hell Gate, Jones Sound and not Penny Strait and Wellington Channel. While much hydrography is needed the first route is known to be safe insofar as Hell Gate, Jones Sound & Lady Ann Strait is concerned. Every indication is that Belcher is also safe but in any event it is common to both options. Penny Strait is not safe and has more difficult ice conditions. If it is attempted then besetments and groundings will become routine. Delete 60 transits a year.

Para. 3 Can it be confirmed there is enough oil to go into production? Doubtful. Some of that oil could be retained, surely, and used locally which was part of Panarctic's plan at one stage.

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Para. 4 Ships sailing from Bathurst Inlet cannot use Simpson Strait and James Ross Strait to get to the east unless they employ balloons to lift them over the shoals or draw less than 15 feet (4.5m). They would not use James Ross Strait because it, too, is too dangerous on account of shoals, the fact that it is uncharted for commercial use and offers really challenging multi-year ice conditions. They could, if cost and time was no object go west to Prince of Wales Strait and then head north and east to reach Viscount Melville Sound, Barrow Strait, Lancaster Sound and into Baffin Bay. But surely the market for Bathurst Inlet mines would be Japan and the west coast of America. Delete 16 tran[s]its.

Conclusion. This writer would cut the estimate of transits by the year 2000 to 550 and even that figure seems excessively optimistic. Marketing of products do change and it could turn out that North Slope traffic will head west rather than east to reflect changed circumstances. Mines have been known to shut down, cut output or even become mined out.

The one thread that seems constant throughout this whole exercise involving year-round marine traffic into high arctic waters, and through the Northwest Passage, is the requirement to acquire climatological, environmental and biological data on a year-round basis. It is necessary also to determine what the impact of ship activities on the ice regime will be. The requirement for an Arctic Class VII Coast Guard icebreaker dedicated to these tasks seems so obvious as not to need emphasis. For this, and for other reasons, it would seem to be in the national interest to have such a capability and CARC could serve a useful role in pressing for action now.

Finally, it seems to the writer that Canada might get better value for her money if some funds ear-marked for the Patrol Frigate Programme were diverted to the Polar Icebreaker Programme.

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Doc. 16: T.C. Pullen, The Northwest Passage -- Prospects for Year-round Navigation, Presented at the International Trade Fair & Conferences for the OFFSHORE Industry and the Subcontractors, 1-4 March 1983.

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OFFSHORE GÖTEBORG 83

International Trade Fair & Conferences for
the OFFSHORE Industry and the Subcontractors

Gothenburg
Sweden
March 1 - 4,
1983

Organized by

THE SWEDISH TRADE FAIR FOUNDATION IN CO-OPERATION
WITH NATIONAL MARINE RESOURCES COMMISSION

The Northwest Passage -- Prospects for Year-round Navigation

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In the words of a famous Polar explorer: “My successful voyage was the first navigation of the Northwest Passage and remains to this day the only navigation of it. Indeed it is most unlikely that anyone in the future will think it worth while to consider it for a second, in view of the fact that there were so many great difficulties and dangers involved”. Thus wrote Roald Amundsen and it remains to be seen whether he was as good a prophet as he was an explorer and navigator although for different reasons. Despite the perils about which he wrote there have been nearly thirty-four successful transits of the Passage since his epic feat. Not a large number considering the years that have passed. Indeed, there are still 'difficulties and dangers' though they are diminishing as ships grow in size, strength, and power.

That Northwest Passage, of course, is the fabled sea route which engrossed the imaginations and attentions of our forebears for centuries. It is a maze of ice-cluttered straits and sounds connecting Baffin Bay in the east to the Beaufort in the west, all involving a voyage of 1,000 miles or so, and is America's Arctic key to the linking of Atlantic and Pacific. Assured delivery of oil and gas from Arctic North America to world markets, both east and west, calls for year-round navigation of the Passage and adjacent waters. In my view prospects for operational success are good though they demand special ships the likes of which fire the imagination. They call also for special people to man them -- people who can rise to the challenge. Finally, of course, the economics must make sense -- and that seems likely to be the major problem.

For those who may be unfamiliar with shipping activities in Arctic North America it should be explained that at this time there is no such thing as routine year-round movement of ships anywhere in the north and there never has been. The annual resupply of remote settlements, the delivery of cargoes required on a recurring basis by exploration companies, and the ongoing scientific activities of the private sector and government agencies (oceanography, hydrography, seismology et al), are all planned and carried out during the summer months. That is the time when nature relents and some ice cover melts and retreats, permitting ships to penetrate selected areas to meet their commitments. These undertakings have been going on for years, the resupply of settlements for many years indeed, and all employ a mix of vessels including tugs barges, icebreakers, ice-strengthened and unstrengthened ships.

There are now two new producing lead/zinc mines in the Eastern Arctic shipping concentrates to Europe but this too is a seasonal activity and only adds to the summer traffic. It does nothing to extend the season significantly. Even Coast Guard icebreakers function only during the summer for they lack the qualities needed to do otherwise. Should they attempt to remain in the Northwest Passage long after freeze-up they would run the very real risk, indeed the certainty, of becoming trapped and a permanent part of the icy scenery -- at least for the duration of the winter which lasts until the following August or later. No -- year-round navigation calls for a different solution. It is essential to distinguish between the two.

The Northwest Passage[1] is not one but a number of passages, any one of which permits a vessel to navigate between Atlantic and Pacific depending, of course, on the bathymetry and prevailing ice conditions. There are eight variations from which to choose only two of which are suitable for very large, deep draft, ships. These are Parry Channel including M'Clure Strait, or Parry Channel via Prince of Wales Strait and Amundsen Gulf, both of which reach the Beaufort Sea. Parry Channel, it should be explained, is the collective to describe Lancaster Sound, Barrow Strait, Viscount Melville Sound, and M'Clure Strait. The ice conditions in M'Clure may be in such a jam that Prince of Wales Strait would be the preferred route. All the remainder are shallow and trend along the mainland coast. James Ross Strait, for instance, is known to have a limiting depth of only five metres and much hydrography is still needed there. A deal of surveying is also called for in Victoria Strait just to the westward where a minimum depth of nine metres is thought to exist. The draft of the great ships now being designed for the Passage will exceed 18 metres.

The search for a Northwest Passage, which started in 1610 with Henry Hudson's ill-fated voyage, lasted for nearly three hundred years until it was successfully accomplished by the famous Norwegian explorer, Roald Amundsen, who in 1903 sailed westward in the 47 ton fishing smack Gjoa reaching Nome, Alaska, in August, 1906. His route was via shallow James Ross Strait thence along the mainland coast to the body of water which now bears his name.

Thirty-six years were to elapse before the next successful attempt in 1942 when the Royal Canadian Mounted Police schooner St Roch, commanded by Staff Sergeant Henry Larsen, passed from west to east by much the same route as that taken by Amundsen. In 1944 Larsen with St Roch repeated the feat from east to west in one season via Parry Channel and Prince of Wales Strait. After another ten years, in 1954 Her Majesty's Canadian Ship Labrador, naval icebreaker, became the first deep draft ship, and the first warship, to navigate the Passage following in the wake of St Roch on her second voyage.

[1] FIGURE 1

Thereafter, transits became more frequent and progressively less momentous[.] There were exceptions, though, and one was the first of a number of submerged transits by USN nuclear submarines. Another was the huge 155,000 ton Manhattan to test some of the problems which would be involved in moving Prudhoe Bay oil to the U.S. east coast. This was most significant for it marked the first step towards year-round traffic through the Passage. To date there have been altogether only thirty-five transits, fourteen by icebreakers. It is of interest to note that to date no surface ship has achieved the Passage via M'Clure Strait though Manhattan tried but failed.

In general terms, the bigger the ship the more cargo she can carry at less cost. In the Arctic generally, and in particular the Northwest Passage, this size-profit ratio pays another dividend: massive ships make superb icebreakers. The prescription for success in breaking Arctic ice is as much a matter of mass or weight as it is one of power or thrust. The more massive the vessel the better the icebreaker, and if the requirement is year-round navigation through the Northwest Passage then only icebreaking commercial behemoths are capable of doing the job. It is out of the question to build a Coast Guard icebreaker large enough to compete with commercial ships in an icebreaking role because the necessary weight can only be achieved by filling a ship with several hundred thousand tonnes of oil or minerals. This is something which could create difficulties for Coast Guard icebreakers carrying out their supervisory role in the High Arctic.

We have then the prospect of commercial ships with a far better Arctic capability than any Coast Guard icebreaker. Who will be assisting whom in the future? 'User-pay' is being mooted as Canadian Government policy for the services of its icebreakers assisting ships in difficulty in the ice. Such a course of action could, however, backfire because big commercial icebreakers are more likely to be in a position to give help to Coast Guard ships than to need it.

Conventional tankers, if one may employ such a term, are those which transport oil from the Middle East to Europe, Japan and America. They carry their oil resting against the shell plating, or the ship's skin, and are propelled by a single engine, single screw arrangement and with only one rudder. The consequences of a failure in such an arrangement can be awesome as the unfortunate Amoco Cadiz bore witness. In an Arctic context Dome Canada, planning for the movement of oil and gas from the Beaufort to market, is designing what it calls "an environmentally safe Arctic tanker". These ships will be doubled-hulled, with at least twin engines and twin screws, and be in every way icebreaking VLCC's (Very Large Crude Carriers) of all welded construction, employing high-quality steel, and with segregated ballast tanks.

All oil cargo tanks will be contained within a double hull, located inboard beyond the limits of the worst hull damage assumptions as laid down by I.M.C.O. (InterGovernmental Maritime Consultative Organization). Twin, independent propulsion systems will be isolated in separate engine rooms. The forward bridge will provide for the best possible visibility for handling the ship in ice. The strength of the inner of the two hulls in these icebreakers will be greater than the hull of a conventional tanker. Astern power available in an emergency will be about ten times that usually installed, and the time required to apply full astern thrust is designed to be 15 seconds, one sixth of the time needed in a conventional steam plant. If oil is to be transported by sea, it is difficult to imagine a safer means by which this can be accomplished.

Another marine project which envisages year-round marine traffic is the Arctic Pilot Project (APP), which is designed to test the feasibility of transporting natural gas in liquefied form from Melville Island to markets in eastern North America and possibly Europe. The proposed transportation network will involve piping natural gas from fields in northern Melville Island, and also offshore, to a liquefaction facility for loading into Liquefied Natural Gas (LNG) icebreaking bulk carriers for delivery. Two 140,000 m^3 ships will be employed as Arctic Class VII vessels[1] (i.e. capable of maintaining continuous headway through seven feet (2m) of fast ice).

<u>TABLE I</u> provides details of these ships, and for comparison, details also of Dome's Arctic tanker and the <u>Manhattan</u>. It is evident that the LNG ship will be shorter, and draw substantially less water than Dome's heavy oil tanker. This is important because the deeper the propellers are below the surface the more efficient they become and the less likelihood of ice damage. The LNG ship's displacement, in other words the total icebreaking weight available, is less than half that of the icebreaking oil ship but that notwithstanding, she will be just as voluminous -- it is somewhat like comparing a football with a cannonball. The weight of 140,000 m^3 is only about 70,000 tonnes[.]

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[1] Canada's Arctic Shipping Pollution Prevention Regulations (ASPPR)

TABLE I

	LNG Arctic Class VII[1]	Dome Arctic Class X[1]	Manhattan
Length - metres	374 (1,227 ft)	386 (1,268) ft)	306 (1,006 ft)
Breadth - metres	43 (141 ft)	50 (163 ft)	46 (150 ft)
Draft - metres	13 (43 ft)	20 (65 ft)	16 (55 ft)
Displacement - tonnes	135,000	300,000	155,000
Power - shp	180,000	150,000	43,000
Propellers	3	2	2
Rudders	1	2	2

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At this time the last all-year Arctic project, waiting in the wings, involves the natural gas fields located far to the north of the Passage in the area of King Christian and Ellef Ringnes Islands. The resulting LNG, from a liquefaction, storage and loading facility on the latter island at Malloch Bay, would be destined for Europe employing three Class 10[1] ships. Their route would take them south-easterly from Danish Strait to Hell Gate and through Jones Sound into Baffin Bay and open water. To be assured of year-round success their icebreaking capabilities, in addition to the complexities of their cargo stowage and handling arrangements, could make them the most costly commercial ships ever built.

For nearly a year now the pace of activity in the Canadian north has been slowing. Dome Petroleum, with great expectations, had instead a very disappointing drilling season in 1982. In addition, Dome is experiencing severe financial problems and recovery is going to be a long and arduous process. Unless there is some compelling international crisis involving the disruption of the flow of oil from the Middle East, or possibly a massive discovery of oil in the Beaufort, it appears as though it will be years before icebreaking giants flying Dome's colours will be navigating the Northwest Passage. There are those, too, who aver that pipelines are the preferred means by which to move Beaufort oil and gas.

[1] ASPPR

For its part the Arctic Pilot Project has seen its prospects for development suffer a setback, partly because of uncertainties which surfaced during the 1982 National Energy Board hearings into its application to ship LNG from Melville Island. Until the APP decides where it intends to market its product, that project is delayed. Development of the King Christian Island gas fields would also appear now to have slipped further into the future. At this time the immediate prospects for Canada's Arctic energy development scene are not overly bright. What are the prospects, then, for navigation of the Passage by foreign interests?

The Manhattan's successful 1969 journey from the Atlantic to Prudhoe Bay, Alaska, and return, did not seem to influence the decision-makers of the time. Construction of that costly trans-Alaskan pipeline went ahead willynilly and stands to this day as a sinuous monument to the inflexibility of such a delivery system -- but that is another story. When Alaskan production, including offshore oil the search for which is now being stepped up in the Beaufort, exceeds the capacity of the Alyeska pipeline, possibly by the year 2000, then the marine mode could be employed to get the product where it is needed -- the eastern seaboard. The icebreaking ships envisaged would have a capacity of one and a half million barrels, displace more than 250,000 tons and develop 200,000 shaft horse-power. Certainly this qualifies as a likely, but by no means certain, use of the Northwest Passage.

In a world where a secure and reliable source of oil is of critical importance, Japan, more than any other developed nation, is vulnerable. She depends entirely on imports but is far removed from her major supplier, the Middle East, which is in a perpetual state of turmoil. It is, therefore, understandable why Japan is turning more and more to Canada as a closer, and more reliable source of energy. Coal has been exported for years from British Columbia and will, if matters turn out as planned, be followed by LNG from the West Coast. In addition, Japanese interests have invested $400 million in the Beaufort oil play to be repaid later from oil production there.

Propinquity is another important factor. The Beaufort is only 3,600 miles from Yokahama which is approximately half the distance from Yokahama to the Persian Gulf. Canada must, of course, first achieve energy self-sufficiency before oil can be exported but future prospects for shipping Canadian oil to Japan should not be ignored. Japanese experts reportedly have been showing an interest in the eastern approaches to the Northwest Passage, namely Baffin Bay and Davis Strait. It seems reasonable to infer from this that movement of oil by Japanese icebreaking tankers from, say, the Hibernia field by way of the Northwest Passage could happen, but not in the nearterm, the distance, after all, is only 6,300 miles -- virtually the same as that separating Yokahama from the Persian Gulf.

The recent failure of the Organization of Petroleum Exporting Countries (OPEC), at its January, 1983, emergency meeting in Geneva, to come to an agreement on pricing and production quotas has caused widespread concern. The repercussions of world oil prices of $20 or even less a barrel on exploration and development in the Beaufort Sea, and similar undertakings elsewhere in the Arctic, could be far-reaching. Cheap oil, if that is what comes, and stays, will certainly put a damper on northern development and, of course, it follows that prospects for year-round navigation of the Northwest Passage by icebreaking tankers will suffer accordingly. The situation at this time is too uncertain to justify any further forecasts.

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Doc. 17: T.C. Pullen, Arctic Marine Transportation Issues: A Report to The Canadian Arctic Resources Committee (Arctic Ocean Programme), 2 May 1983.

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ARCTIC MARINE TRANSPORTATION ISSUES

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A

Report

to

The Canadian Arctic Resources Committee

(Arctic Ocean Programme)

prepared by

Captain T.C. Pullen

Ottawa, Canada May 2, 1983

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SUMMARY

Introduction

A brief description of the growth of Arctic marine transportation during past 30 years

Background

The types of marine transport involved in Arctic development leading to the commercial giants now being designed

Impact of year-round traffic

Issues raised by the prospect of year-round navigation of the waters of the Arctic and the need to obtain answers to these environmental questions

Foreign interest in the Northwest Passage

Not only Canada, but the United States and Japan, have a genuine interest in use of the Passage. Need for Canada to pay heed

Icebreakers -- Symbols of Sovereignty

Review of the present icebreaker situation and how Canada is failing to match the year-round Arctic requirement with a suitable icebreaker capability.

Cargo-carrying Submarines

The impracticability of the latest plan to use large submarines instead of ships.

Hydrography

The tendency to accord too much importance to the challenge of ice and not enough on the equally challenging problem of Arctic bathymetry.

Restrictions on Shipping

Traditional freedoms of shipmasters may have to be curtailed in an Arctic context and also the desirability of closer collaboration between mariners and environmentalists and conservationists.

Control of Shipping

The need to resist the desire of some conservationists/environmentalists to establish sanctuaries and national parks whose boundaries obtrude into shipping routes

Greenland Concerns

The perceived problem of Greenlanders on the routing of big ships and the alleged […] propeller noise they insist will ensue.

Marine transportation needs in the Arctic

Existing regulations, with the addition of some environmental additions, are adequate for the control of Arctic shipping. The Coast Guard's icebreaker capabilities, the needs of hydrography, the status of the waters of the Passage and the qualifications of people who will man the big ships. The setting up of a northern headquarters and, finally, the need to keep to a minimum the rules and regulations.

Impact of new technology

Examples of how well the needs of Arctic navigators are met by new technological developments.

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Arctic Marine Transportation Issues

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Introduction

In a marine transportation sense few regions have been subjected to such searching and sustained scrutiny as Canada's Arctic. This interest had its origins in the fifties when the first significant seaborne intrusions occurred. At that time, during three successive summers, the now almost forgotten undertaking to build the Distant Early Warning Line saw 324 ships deliver 1 1/4 million measurement tonnes of dry cargo, and more than 10 1/4 million barrels of oil, to destinations north of the Arctic Circle stretching from Barrow, Alaska, east to Greenland. An impossible feat without ships. Then in 1962 there occurred the discovery of the Mary River iron ore body in North Baffin (68% grade iron) which first posed the possibility of very large icebreaking ore carriers being built to deliver to Europe this rich, direct shipping, ore -- it has yet to happen. From that time, however, the pace of Arctic development accelerated significantly with the Prudhoe Bay oil discovery in 1968, followed by the subsequent successful Northwest Passage by the 155,000 tonne Manhattan in 1969, and in later years Canadian efforts to locate commercial quantities of oil and gas in the Beaufort Sea and adjoining land. These activities created the need to plan the sea transport of the resulting finds to southern markets.

Background

At the present time there is no such thing as year-round movement of ships of any sort, including icebreakers, anywhere in Canada's north and there never has been. The annual resupply of remote settlements, the delivery of cargoes required on a recurring basis by exploration companies, and the ongoing scientific activities of the private sector and government agencies (oceanography, hydrography, seismology), are all undertaken during the summer navigation season. This is the time when nature relents and some ice cover breaks and melts, permitting ships to penetrate selected areas to meet their commitments. Such undertakings have been going on for years, the resupply of settlements for many years indeed, and all employ a variety of vessel types including icebreakers, ice-strengthened and unstrengthened ships, and even tugs and barges on occasion.

Notwithstanding a slowing of development plans, the prospect of Arctic oil and gas, the latter in its liquid form (LNG), being transported to market remains, though recent developments will slow production plans somewhat. The economics of oil and gas production and transportation require delivery on a continuous, year-round basis calling for special ships whose chief features will be their tremendous size, strength and power. In general terms the larger the ship the more cargo she can carry at less cost. In the Arctic this size-profit ratio pays another dividend for such massive ships make superb icebreakers. The prescription for success in breaking polar ice is as much a matter of mass or weight as it is one of power or thrust. The more massive the vessel the better the icebreaker, and if the need is year-round navigation through the Northwest Passage then only icebreaking commercial giants will be capable of doing the job.

Impact of year-round traffic

The prospect of year-round traffic through Canada's Arctic waters raises a number of issues causing disquiet in the minds of northerners, and genuine concern to mariners. What, for example, would be the effect on the undisturbed winter ice regime in various locations when sundered by these great vessels? Will ships use the tracks opened by their predecessors thus adding to the accumulating icy rubble already there? Or will it be easier for them to carve fresh tracks on each pass? How long does it take for all this icy débris to refreeze? What impact will this activity have on northerners who traditionally use the smooth fast ice as a winter highway? It is possible, of course, that an ice sheet which has had a swath 60 metres (200 feet) wide cut through it, instead of refreezing, will see the fractured sheets come together creating ridges, a process which, if repeated over the winter, could convert a level ice surface to a rafted, hummocked, jumble of ice blocks. Again, what would be the effect on break-up patterns of ship traffic in the springtime. These questions, and others too, need to be addressed. To obtain answers calls for 'on site' investigations and experiments by ships, a role for a Coast Guard icebreaker but, because of the inadequacies of the present fleet, it is not possible. This is an example of work which calls for a Canadian polar [icebreaker].

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Foreign interest in the Northwest Passage

Year-round navigation of the Northwest Passage does not hinge necessarily on what happens, or does not happen, with Canadian projects in the Beaufort or the Arctic Islands. Canadians know that other countries have an interest in its availability, and a determination to take advantage of it in due time. Japan and the United States are two front-runners. In a world where a secure and reliable source of oil is of critical importance, Japan, more than any other developed nation, is vulnerable. She is entirely dependent on imports but is far removed from her major supplier, the Middle East, which is in a perpetual state of turmoil. It is, therefore, understandable why Japan is turning more and more to Canada as a closer, and more reliable, source of energy. Coal has been exported for years from British Columbia and will, if matters turn out as planned, be followed by LNG from the West Coast. In addition, Japanese interests have invested $400 million in the Beaufort oil play to be repaid later from oil production there.

Propinquity is another factor. The Beaufort is only 3,600 miles from Yokahama which is approximately half the distance from Yokahama to the Persian Gulf. Canada must, of course, first achieve energy self-sufficiency before oil can be exported but future prospects for shipping Canadian oil to Japan cannot be ignored. Japanese experts reportedly have been showing an interest in the eastern approaches to the Northwest Passage, namely Baffin Bay and Davis Strait. It seems reasonable to infer from this that movement of oil by Japanese flag icebreaking tankers from, say, the Hibernia field by way of the Passage could be in the cards. The distance, after all, is only 6,300 miles -- virtually the same as that separating Yokahama from the Persian Gulf.

The United States, ever since the Prudhoe Bay oil discovery, has given serious consideration to the year-round use of the Northwest Passage, to transport oil to the east coast. Indeed, the voyages of the Manhattan represented the first step in bringing this about. Because the decision was made to build the trans-Alaskan pipeline instead does not mean that plans to use the Passage have been shelved permanently. The marine mode is very much alive as an option and it is possible that when production rises to, say, more than two million barrels per day along the north Alaskan littoral, then the introduction of U.S. flag icebreaking tankers could become a reality, possibly about the year 2000.

In addition, the United States Coast Guard is engaged in tests and trials by its two new icebreakers, Polar Sea and Polar Star in the waters along the north Alaskan coast and the Northwest Passage. It remains to be seen whether these ships have the ability to navigate those waters successfully at the most difficult time of the Arctic year for ice -- March through April. Displacing just 12,000 tonnes but developing 60,000 shaft horsepower (with 'excursions' to 75,000) they lack not only the weight needed to triumph over thick, hummocked ice, they also obtain the high horsepowers through the use of gas turbines which are notoriously thirsty at high powers. A prolonged struggle through ice in, say, Viscount Melville Sound, could cause problems. Not only would dwindling fuel reserves become a source of anxiety, but when ships consume large quantities of bunkers they ride higher in the water, and become progressively less effective in the icebreaking role while also putting propellers and rudders at increased risk to ice damage.

Whatever the status of the Northwest Passage, it is essential for Canada to have the ability to deploy there convincing evidence of her sovereign will, against the day when foreign flag ships will attempt its navigation for whatever reason. This means the Canadian Coast Guard should have all the necessary plans and specifications ready to go to contract without delay for constructions of her first 100,000 horsepower polar icebreaker.

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Icebreakers -- Symbols of Sovereignty

The Canadian Coast Guard is presently undergoing a ship replacement programme for its aging fleet of front-line icebreakers and not before time, too, because three of its four ships are more than 25 years old. First, d'Iberville was declared surplus, and next will probably be the Labrador, built in 1953. To replace these ships and expand the fleet the Coast Guard is deploying a new design, the 'R' class, with the Pierre Radisson, Sir John Franklin and Groseilliers all now in service. A fourth ship is to be ordered.

These new vessels are reported to be very successful, however, no matter how satisfactory they may be, the fact remains the Coast Guard is replacing 'like with like'. In fact, the veterans John A Macdonald and Louis St Laurent are both heavier and more powerful and have the significant advantage of having three, not just two, propellers. An 'R' class ship, with her twin screws and centreline rudder, is less maneuverable and more vulnerable to crippling damage from ice than the two older ships mentioned above.

The world leader in numbers and size of icebreakers is, of course, the Soviet Union. The first surface vessel ever to navigate the Arctic Ocean and attain the north pole was the USSR's Arktika, demonstrating that icebreakers which are larger, heavier, and more powerful are able to operate further afield in the north, for longer periods, indeed even all-year, than the smaller ships which Canada seems intent on building as replacements. Large Soviet icebreakers have nuclear propulsion for unlimited endurance, displace more than 30,000 tonnes, and develop 75,000 horsepower. Canada, on the other hand, seems content to meet her Arctic responsibilities, for the next ten years at least, with ships which displace 7,600 tonnes and develop only 13,600 horsepower.

If there is a requirement for ships capable of operating all-year in the Northwest Passage, then a large, powerful, polar icebreaker is needed. The 'Vancouver Sun' editorialized as follows as far back as 1971: "The difficulty establishing and maintaining Canada's sovereignty in the Arctic is well understood in Ottawa . . . if there is any nation ready to dispute Canada's claims to the Arctic more than any other, it is the U.S. Canada's chances of dealing with pollution in the Arctic are not bright unless it can assert its sovereignty over the waters there . . . Canada needs muscle. One way to get it is to build ships, especially icebreakers, of sufficient power and range." At that time, 1971, the government announced plans for a super icebreaker and the Commons' northern development committee urged its construction. In 1983 'planning' continues.

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Cargo-carrying Submarines

A question which frequently arises concerns the feasibility of employing cargo-carrying submarines. One of the chief protagonists for their use in the context of delivering Arctic oil and LNG to market, General Dynamics, states: "the primary advantage offered by the submarine system over a surface system is the ability to deliver a constant cargo volume at uniform, predictable schedule intervals year-round, regardless of surface ice and weather conditions" and also this: "water depths of 400 metres or more would permit a submarine tanker to maintain . . . . depth and speed over . . the entire length of any proposed shipping route. Only in western Barrow Strait where depths as shallow as 91 metres (298 feet) are experienced, would a submarine be subject to operational constraints." This 'choke point' in Barrow Strait would seem to impose a very serious restriction on the sort of vessels General Dynamics is considering.

General Dynamics continues: "for several years nuclear-powered submarines have routinely cruised Arctic waters year-round without difficulty." This almost sounds like special pleading. To compare the Arctic achievements of United States Navy submarines such as Skate or Seadragon, to the monsters being proposed by General Dynamic[s], is to compare minnows with whales. Skate, 183 metres (310 feet) long, displaces 4,280 tonnes. The General Dynamics leviathans would be nearly 448 metres (1,500 feet) long and have an incredible submerged displacement of 860,650 tonnes.

The prospect of these enormous vessels groping their way safely between the rocky bottom of Barrow Strait, where as little as ten degrees change of trim from straight and level would result in grounding at one end and collision with the overhead ice canopy at the other, is cause for justifiable concern. Cargo-carrying submarines of this sort, if they can justify the economics of bulk transportation, might better be deployed on trans-polar routes in the Arctic Ocean where there is ample room in all directions.

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Hydrography

While westbound in the Beaufort Sea in September, 1969, the 155,000 tonne Manhattan, trailed by a Canadian icebreaker, sailed unknowingly over an uncharted shoal on which she was within seven metres (20 feet) of impaling herself. It was subsequently established this was what is referred to as a 'pingolike' feature. There are 1,500 or more of these large mounds of ice covered with soil on land in the Tuktoyaktuk area but this was the first indication they also existed offshore. After intensive surveying by the Canadian Hydrographic Service (CHS) in the years following several hundred similar features are now known to exist in the Beaufort Sea. The prospect of ships drawing more than 20 metres (65 feet) transiting those selfsame waters on a recurring and year-round basis may make it necessary to confine them to 'safe' or 'swept' channels until such time as first class surveys of the entire area can be completed.

This near-miss points up the risk to shipping that is still to be found throughout Arctic waters to this day and re-inforces the requirement for a great deal of hydrographic activity if vessels of every type, but particularly the big ships, are to navigate there secure in the knowledge there are no underwater hazards with which to be concerned. In the field of Arctic marine transportation those with 'landlocked minds' tend to dwell overmuch on the obvious -- ice, ice of every sort, but in fact the chief danger remains the uncharted pinnacle. If there is an element of bathymetric risk for surface ships, it can easily be imagined how much more those huge cargo-carrying submarines would be at risk for it would be of critical importance for them to know not only all about the icy stalactites above them but even more so the existence and precise location of all undulations and rocky stalagmites beneath them.

Many Arctic charts still in circulation are based on reconnaissance data more suitable for smaller ships drawing less than 10 metres (30 feet). The experience of the Manhattan related above is an example of the pressing need to accelerate Arctic hydrography but to bring this about it will be necessary first to support the CHS in acquiring the requisite resources to accomplish this goal. That Service is well aware of the need but is presently fully committed.

The cause of Canada's disputed claim to sovereignty over her Arctic waters, in particular those of the Northwest Passage, is unlikely to prosper should she be dilatory in completing their accurate survey and charting. The task is a big one and the time needed for its completion should not be under-estimated. The same amount of work which can be accomplished in a year in southern waters occupies two, three, or more, years in the north. In locations where the ice rarely, if ever, dissipates or retreats, spot soundings through the ice cover do not meet the criteria for standard hydrographic surveys. In waters such as those linking King Christian Island gas fields to Baffin Bay and the Atlantic, surveying techniques acceptable to the CHS have yet to be deployed.

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Restrictions on Shipping

The traditional rights of shipmasters to be free to go where they will subject, of course, to certain obvious constraints could, in an Arctic context, be liable to have these modified somewhat. Environmentally sensitive areas, such as are to be found in Lancaster Sound for instance at certain times of the year, might have to be deliberately avoided even though an ice-free and obvious target for a ship seeking the easiest path through the pack ice. The customary method of passing important information of a navigational nature, viz. 'Notices to Mariners', may in future include environmental 'cautions and warnings' to ships advising them of the need to sidestep selected areas.

There should be no reason why mariners and environmentalists cannot co-operate effectively to resolve the legitimate concerns of both parties. The Arctic qualifications of masters and mates could well include a sound knowledge of such environmentally critical matters.

Environmentalists and conservationists who would wish to impose severe restrictions on ship routing in Parry Channel, and other Arctic waters, should be urged[,] if not required, to get some sea-time experience in the north the better to appreciate the difficulties confronting the mariner working his ship through the heavy Arctic pack ice and at the same time get their concerns and views across to the seafaring fraternity.

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Control of Shipping

An issue which must be resolved is the conflict between conservationists and environmentalists on the one hand, and on the other the mariners who will be sailing the great ships year-round through Parry Channel and other straits and sounds nearby. In the former case there is a desire to impose controls and assorted regulations over shipping using Parry Channel year-round including traffic lanes and 'no go' zones. Mariners, however, cannot maneuver their ships along 'tram lines' because ice prevents this in many instances. Icebreakers always seek the line of least resistance and to achieve this must steer a sinuous course. This is, of course, a state of affairs which conflicts with traffic lanes and traffic control. Masters must continue to have this freedom of maneuver though in many circumstances conditions may be such that ships will not need to pass through an area where wildlife should not be disturbed or disrupted. Again, it is a case of both parties working out some sort of 'modus operandi'. The Arctic, unlike more temperate waters, does not adapt kindly to such things as 'Vessel Traffic Management'.

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Greenland Concerns

Greenlanders have voiced loud concerns at what they perceive as year-round traffic of big ships passing 'close' to the coast of West Greenland interfering with traditional over-ice hunting routes. There are also apprehensions about the effect of propeller noises on marine mammals. The Inuit of East Baffin have joined the chorus of protest.

The Arctic Pilot Project (APP) at the National Energy Board (NEB) hearings into the former's application to proceed with the plan to ship LNG to market using two Arctic Class VII ships, produced some diagrams which showed the routes the ships would take going into Melville Bay and running very close to the coast. Why those representing the APP would have made such an error is not known though it is reported the routes were the result of a computer programme. It is all much ado about nothing.

If ships with an Arctic Class VII capability can defeat the predominantly multi-year ice regime in Viscount Melville Sound then there is no need for them to seek an inshore route off Greenland. The ice regime in Baffin Bay and Davis Strait is for the greater part only first-year ice and those icebreakers would be perfectly capable of steering a track through the middle of Baffin Bay where they would be 150 nautical miles removed from both Greenland and Baffin Island. The reason small ships favour the eastern side of Baffin Bay is because the conditions there are the easiest on account of open water and loose pack.

As to the question of propeller noise, it will have to be proved that such is the case. It is hard to fathom why this particular concern has surfaced when in other parts of the polar regions a similar outcry has not been made.

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Marine transportation needs in the Arctic

As a consequence of the voyages of the S/T Manhattan in 1969 and 1970, and the concerns felt by some at the threat to the Arctic environment of oil spills there in the future, the Government passed into law the Arctic Waters Pollution Prevention Act. The implementing regulations are known as the Arctic Shipping Pollution Prevention Regulations and these divide the Arctic into 16 Zones and lay down the periods during which ships, from unstrengthened vessels to the ultimate icebreakers (Arctic Class 10*) are permitted to operate therein.

* Defined as the ability of an icebreaker to make continuous progress through ice 10 ft (3m) thick.

Considering the speed with which the regulations were drafted, they have in the main proved to be well conceived and realistic. However, as experience is gained it is apparent there should be some modifications the better to reflect improved knowledge of ice, ship performance and construction standards. However, as a means of control over the capabilities of ships operating in our northern waters these regulations, suitably modified and brought up to date in the light of new information, should continue to serve as a basic document. What is needed now, in addition, are guidelines that will satisfy the real concerns of conservationists and environmentalists, not so much from the threat of pollution, already catered for, but rather the operations of ships and those areas which, conditions permitting, should be avoided.

Those unfamiliar with nautical matters but who have responsibilities in that area, especially in an Arctic context, always appear to resolve their concerns over the possibility of some unimaginable disaster by decreeing that 'navigational aids' should be provided. To enable ships to navigate safely two principles should be established: first, that for the most part the ship herself should carry on board all the necessary gear to achieve this, rather than litter the shorelines with aids, whether electronic or physical, and secondly, to resist 'overkill' in the variety and amount of sophisticated gear, some of it more desirable than essential, installed on the bridges of Arctic ships.

The Coast Guard has, and will continue to have, an adequate icebreaker force for its summer season commitments in the north. As for the all-year scenario the need for an Arctic Class VII or better capability remains and in the long run more than one ship of this class will be needed. Until the first of these powerful vessels makes her appearance, it will not be possible to obtain answers to the numerous questions concerning operational challenges during the period November to June inclusive, some of which are mentioned elsewhere in this document.

An additional commitment for the Coast Guard is the summertime requirement of the Canadian Hydrographic Service, a creature of the Department of Fisheries and Oceans, to be allocated ample icebreaker time for in no other way can the CHS carry out its Arctic surveying commitments.

It is important that the status of the waters of the Northwest Passage be resolved before the start of year-round operations there by what could be foreign-flag ships and that Canada have ready and in place the requisite icebreakers, navigational aids, charts, sailing directions, and tide tables. There should also be international acceptance of Canada's regulatory measures for the safe conduct of ships through her waters whatever the status of the Passage may be at that time.

Consideration should be given to special qualifications, and certification thereof, of masters and mates who will be engaged in year-round operations in the Arctic and suitable training facilities set up including the extensive use of simulators.

Reliable communications, the establishment of some form of command with its headquarters in the north, either afloat in the flagship of the icebreaker fleet, or ashore.

There should be resistance to the imposition of irksome and unnecessary regulations.

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Impact of new technology

Given that an environmentally-safe Arctic Class tanker can be built, and that professionally able and dedicated people can be trained to handle such a ship in the demanding circumstances she will be operating, there remains the matter of what might be called the 'safe and timely delivery' of cargoes after a voyage through waters which, while challenging and unique, are really not all that formidable. A knowledge of the climatological and environmental factors with which masters will have to cope, and the ability to navigate the ship safely and handle her effectively, will be accomplished thanks largely to what is best referred to as new technology.

For instance, it is difficult to maintain an accurate record of a ship's position if she is zig-zagging to avoid heavy ice and is denied any means of obtaining frequent and reliable fixes. In the wide expanses of Baffin Bay, Davis Strait, and the Beaufort Sea, land features are not in visual or radar touch and many ships simply rely on 'dead reckoning' until they make a landfall. Celestial navigation presents some difficulties in high latitudes and in any case is often frustrated by the presence of whiteout conditions, fog and indeterminate horizons. Hyperbolic navigation (Loran C, Omega et al) is available but unreliable or wanting in accuracy.

An example of new technology is the satellite navigation (Satnav) system now available. It is very accurate, reliable, compact and inexpensive. The system employs satellites in polar orbits providing position updates every 30 minutes, a short period during which 'dead reckoning' navigation is acceptable and even this can be offset by accurate speed inputs from another technological advance -- doppler sonar which can generate accurate speed readings provided, of course, an errant ice floe passing under the ship does not damage the transducer. There is, therefore, in the sea approaches to the Arctic Islands, a fixing capability available on a continuous basis regardless of weather and atmospheric conditions.

A Satnav fix, accurate to within a few metres, is of little practical value if one is obliged to plot it on a chart based on reconnaissance data and on which islands and other features may be as much as ten miles in error. In the case of Viscount Melville Sound, where a ship could find herself out of radar contact with the land, Satnav would be useful, otherwise fixing relative to the nearest land, for the reason stated above, is the prudent and recommended technique employing radar ranges. For the most part, then, within the Arctic Islands, land is within visual and radar reach. In the eastern half the land is precipitous and high, giving excellent radar returns.

In the matter of ice detection, classification, and interpretation, there has been good progress in recent years. Satellite imagery, laser profilometers, infra-red sensors, low-light level television, and side-looking airborne radar are some of the developments which have appeared on the scene to assist in coping with ice in all its manifestations - icebergs, bergy bits, growlers, pack ice, fast ice, and ice islands. Long range fixed wing ice reconnaissance aircraft, fitted with every imaginable product of new technology, patrol the northern seas and the intelligence thus gathered, together with satellite imagery, result in ice reports for forecasters ashore and ships at sea transmitted in both digital and facsimile format.

Forward-looking sonars for ice detection have not been developed because of the difficulty in protecting the associated transducer from being demolished by the very ice it is intended to locate, and also the risk of weakening the hull structure at a location where strength is critically important. Modern echo-sounders supply accurate depth information, digitally and graphically, and warn also of shoaling water and other hazards. They also have built-in alarms to alert an inattentive or harassed mate on watch that his ship has entered shoal waters.

In the centuries-old struggle of man against ice, the modern ice navigator has available to him an impressive array of technical marvels. It is not so much a question of whether he has been well-served in this regard, rather that he may have more than he needs or can handle. Every additional ‘black box’ installed on his bridge means there is one more item requiring his attention, whose technical intricacies must be understood, to be calibrated and tuned to maximum pitch, and concerning which he, the man on watch, must know enough to sense whether the information being presented is to be accepted or rejected. Each additional aid is also one more item capable of malfunction and an additional workload on maintenance personnel.

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Doc. 18: T.C. Pullen, Bathurst Inlet: A Short Report to Strathcona Mineral Services on Shipping Possibilities (Marine Mode) to Ports East and West, October 1985.

HBC Archives H2-141-2-2 (E 346/1/59)

November 5, 1985

Mr Graham Farquharson
Strathcona Mineral Services
Suite 400, 44 Victoria Street
TORONTO, Ontario
M5C 1Y2

Dear Mr Farquharson:

In accordance with your instructions I submit herewith two copies of a report entitled "BATHURST INLET -- A Short Report to Strathcona Mineral Services on Shipping Possibilities (Marine Mode) to Ports East and West".

It is interesting to note that the three possible destinations are the same distance, give or take a few miles, from Bathurst Inlet.

The charts of Bathurst Inlet indicate no soundings beyond Burnside Bay to the southeast, a reach extending inland another 35 miles to the mouth of the Western River. If this straight stretch of water turns out to be deep it could lead direct to better terrain for a loading facility than that in the vicinity of Burnside Bay. It would be somewhat closer to Contwoyto Lake (about 10 miles as the raven flies) and assuming deep water would provide no navigational challenge to ships. It might bear investigation.

If you wish I can obtain the two charts to which reference is made in the accompanying report.

Yours sincerely

T.C. Pullen

Enclosure: Report (2 copies)

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BATHURST INLET

A Short Report to Strathcona Mineral Services
on Shipping Possibilities (Marine Mode) to Ports
East and West

by

Captain T.C. Pullen
Ottawa Canada

October, 1985

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BATHURST INLET

Shipping Possibilities (Marine Mode) to Rotterdam,
Yokahama and Vancouver

INTRODUCTION

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1 At the request of Strathcona Mineral Services, of Toronto, the writer was asked to address briefly certain matters relating to the movement of product to market by sea from Bathurst Inlet, [Northwest Territories] This has been attempted under the following headings:

Conclusions	para 2
Assumptions	para 3
Distances & Routes -- General	para 7
East to Rotterdam	para 8
West to the Pacific	para 16

Ice -- General	para 20
Transit Times	para 27
Ships & Regulations	para 32

CONCLUSIONS

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2 From this brief examination of Bathurst Inlet and its possible use to move product to market overseas by ships with a deadweight tonnage of approximately 25,000 tonnes the following conclusions were drawn:

a) The bathymetry of the Inlet is favourable for such use by bulk carriers of the size being contemplated.

b) A standard hydrographic survey of the waters adjacent to the loading facility (wherever located), and its approaches from sounded waters in Coronation Gulf, would be an essential pre-requisite.

c) The Inlet is equidistant from Rotterdam, Yokahama and Vancouver, viz. 4,000 nautical miles.

d) All things being equal it should be feasible for one ship to make three deliveries to Vancouver or Yokahama during the summer navigation season.

e) Sailing east to Baffin Bay and Rotterdam, if ice conditions are average or better than average, could result in two deliveries per ship during the summer navigation season.

f) Except in very good ice years, icebreaker escort for ships heading east to Rotterdam would be essential in Victoria Strait and likely also farther to the north as well.

g) Victoria Strait is the only route to Rotterdam presently available for the ships being considered for this service and it requires a standard hydrographic survey to determine if it would be safe for such bulk carriers.

h) The Arctic Shipping Pollution Prevention Regulations require that for eastbound traffic from Bathurst Inlet at least a Type B ship would be required while to the west Type D would be permitted.

ASSUMPTIONS

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3 The quantity of product to be shipped during the open water navigation season has been taken arbitrarily to be 150,000 tonnes, a ship capacity of 25,000 tonnes deadweight, at an average voyage speed of 12 knots to make allowances for delays due to ice and weather.

4 The loading point in Bathurst Inlet was taken to be Burnside Inlet (Can. Chart # 7988 corrected to Oct. 25, 1985). No account has been taken of the general terrain in this area, including the approaches to tidewater, and its suitability as a loading site. Distances have been measured from an anchorage there in position 66 degrees 51 minutes north, 107 degrees 59 minutes west. The actual location does not have a significant effect on voyage times, ice transits and suchlike. Whatever other site may be chosen the total distance would be reduced somewhat rather than increased and not by many miles at that.

5 That ships would not over-winter at the Bathurst Inlet site but would have to penetrate from east, west, or both, to load the first cargo.

6 Tugs and barges have not been considered.

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Doc. 19: T.C. Pullen, Private Journal of the 1988 voyage by SOCIETY EXPLORER (Capt. Heinz Aye) through the Northwest Passage, west to east, 1988.

HBC Archives H2-141-2-2 (E 346/1/59)

CAPTAIN T.C. PULLEN RCN (Ret'd)
Ice Master

Private Journal of the 1988 voyage by
SOCIETY EXPLORER (Capt. Heinz Aye)
through the
Northwest Passage, west to east.

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Wednesday Aug. 17

Uneventful flight to Vancouver via Winnipeg. Brief meeting with Brian and Sarah at the former, then on to Seattle. Society Expeditions dinner party with Susan Zehnder, Heinz Aye, Victoria and Peter Cox.

Thursday Aug. 18

Press interviews a.m. then to the airport. Flight to Anchorage and another hotel - this one very comfortable - the "Clarion["]. Not so with our digs in Seattle - the "Camion". Welcome dinner where we, with other staff members, were introduced. I thought Alan's reference to the bar (in the ship) and Betty was in questionable taste. Weary. Turned in early.

Friday Aug. 19

Inevitable bus tour and then our flight to Dutch Harbour where, in a crosswind, our pilot came in fast touching down hard, hit the brakes and everything else to stop us before the end of a very short runway. There was very little left when we stopped. A lengthy delay before getting the luggage and, finally, off by school bus to join the little red ship once more - for the fifth time. A friendly welcome and champagne in the Explorers' Lounge where we met a few more affable souls. The ship sailed at 1900 and we are on our way.

With the pack under pressure on the coast at Barrow and onshore winds I fret that a challenge will meet us so early in the voyage. Heinz Aye (hereafter H) has all my ice information and reports of my two telecons with Ice Central in Ottawa while at Anchorage - and not promising either. Can only hope that by the time we make Point Barrow the winds will be favourable and there is room to squeak through.

Hope my request to Brian Veal of Ice Central to include us in the daily sitrep on ice and weather which is made to the icebreakers will bear fruit (it did not). Turned in early feeling rung out. Our quarters are very fine though no larger than the pilot's cabin of 1984.

Sat Aug. 20

Ship moving about enough to cause distress for a few passengers. Following wind and sea as we make for the Pribiloffs (St George and St Paul Islands). Gave the radio officer information on Fax schedules for the ice reports. What reports we have posted on the bridge indicate northerly winds at Barrow and eastward to Barter Island. Chatted with Jack Johnson, the U.S. pilot we are obliged to take. He seems to have heard of me. Why we need his services I cannot see and he wants to stay to Tuk.

Arrived off St George at noon and anchored. During the forenoon two bowhead whales in sight with H announcing enthusiastically over the P.A. system "Picture, picture, picture" and away we went in careful pursuit but with no real results.

Captain's introduction of the staff. By what I hope was a slip of the tongue I was referred to as "Mister". Champagne all-round and then H's welcoming dinner. We sat with Ralf Zander.

Sun Aug. 21

0700 anchored off St Paul Is. Sent for a Telex ice report as the Fax is useless. A super ice chart came back but the information it contained is discouraging, with N and NE winds pushing the pack on the coast from Barter Is. almost to Herschel Is. Little indication of improvement.

(P.S. The situation was discouraging. The ice chart for Aug 20 had a note on it for me to the effect that the "lead nr. Point Barrow slightly closing due to forecasted onshore flow". The pack (2/10 multi-year & 4/10 thick first-yr) was on the coast at both Cape Simpson and Cape Halkett while there was also 6/10 thick first-yr from Barter Is eastward to Komakuk Beach and also between Herschel Is and Shingle Point. The daily drift of the pack was shown as 5 nm to the westward. To assist H to understand the ice charts I coloured them as follows: Blue - open water, yellow - 5/10 or less = navigable with care, red - no go and dark red - the arctic pack 9+/10 mostly multi-yr. On this date there was absolutely no route available to a ship like ours, hence the message I prepared for the office in Seattle.

Spent a long time discussing the situation with H during which I recommended that we should not round Point Barrow and head for Tuk until there was some assurance the pack, not far off the coast most of the way, would not close in on us or behind us, effectively trapping the ship. H asked me to draft a message outlining the situation and the possibility (of) the Tuk passenger exchange taking place at Barrow. Worked on this all p.m. and then another long meeting when we massaged it into final form:

> "A marked change in wind direction is needed soon to open our route from Point Barrow to Tuk presently blocked by heavy pack pressing on the coast, in particular 9/10ths plus ice between Barter and Herschel Islands, unchanged since early August."
>
> "If, repeat if, waiting for favourable conditions is called for on arrival Barrow, and because of the very exposed nature of the north Alaskan coast, it is intended to do this in ice-free waters southwest of Pt. Barrow. At least five days could be taken from the programme for such a contingency."
>
> "What is very latest date you need from us to initiate arrangements to fly Tuk-bound passengers to Barrow?"

Earlier our talk centered on the ship's draft and entering Tuk. Ralf Zander went off in a zodiac to check - 16 ft aft, or just a little less, and 13 ft plus for'd. I composed a message to Marsh Dempster on the subject to see if at that draft we can get in. His reply (Telex communications at sea are now so good and quick) within hours reports 16 feet too deep but that the pilot is still available. However, it is still by no means certain we will reach Tuk at this stage.

Mon Aug. 22

A forenoon zodiac cruise along the precipitous cliffs of St Matthew Is. Seabirds in great numbers but I especially enjoyed the crested and horned puffins. Took a few pictures including, of course, the ship which no one else thought worthy (of attention).

During the noon hour we shifted our position for a landing and then ashore for a vigorous walk. Great quantities of wooden flotsam, plastic and metal containers, rope, packing cases, beer tins and other evidence of the sea's rejection of man's garbage.

Joined Guy Morrison, our Canadian bird expert, and shared the sighting of some rare McKay's buntings - old and young. A special treat for life listers and birders generally. Also a snowy owl, evidence of many lemmings. Returned with wet and muddy boots. Dennis and Sabena Mense, joint expedition leaders, expressing delight that we have at last ventured out of the ship.

The evening pre-dinner recaps. are turning into prolonged affairs - lectures almost. Guy is good but goes on a bit but Poppy, our anthropologist, is a terror - "umming" and "awing" and wittering on and on.

The August 22 telexed ice chart shows a rather better situation at the Barter Is. choke point. Had a good session with H as we discussed possibilities. Suggested an ice recco be flown when we arrive at Barrow to get a hands-on feeling for conditions right up to date. Well received. Told me Werner had called in response to our message and they were investigating flights and so forth.

P.S. The latest ice chart was markedly improved and possibly navigable eastward from Pt Barrow as far as Barter Island but after that definitely a no-go situation. There was still too much heavy ice lurking off-shore for my liking.

Tues Aug. 23

Anchored before 0800 off Boxer Bay but we decided to remain on board. Diary writing in Explorers' lounge a chancy business. First Neal Prince (precious) of New York wanted a full explanation of the ice chart and Egg Code. A pause and then the same treatment for Patrick Strachan of Victoria, B.C. (who was with us during) the 1986 failed NWP attempt.

Busy drafting a message for H to set up an ice recce from Barrow to Herschel, with Alaska Marine Agencies in Anchorage.

In the p.m. much hubbub associated with a visit to the Soviet port of Provideniya - a first of some sort. H very excited. A Russian-speaking American from Gambell conducted a 90 minute telephone discussion with the Mayor of

P. Much talk of the impact on our program. We'll lose a day but worth it. Left Gambell after 1800 heading for P where we are due at 2300. When we cross the International Date Line it becomes Thursday and our clocks go back three hours in one gulp to P time.

At 1225 (0024 new time) awakened by an announcement from Alan that we are alongside in P, that our passports will be returned to us and we are to remain in our cabins until the Russian Customs & Immigration officials inspect us to ensure we are who we are. Passengers and crew - seems a great folderol for a few short hours - visit but anything to achieve Heinz's determination for a "first". I got up and dressed to await the "knock on the door in the middle of the night". In due course it came when I was met by a Soviet official in green cap and uniform - who examined and kept our passports. Turned in for a few hours sleep and up at 0700.

Thurs Aug. 25

Rain. Forbidden to photograph the harbour. Off at 0950 for a bus tour - crowded. First stop (of many) at City Hall where we all mustered for speeches of welcome and replies. Much applause and all-round bonhomie. Then numerous photographers went about photographing everyone - several times in fact. One man had four flash cameras.

Then a succession of visits at high speed (for these "roads") lurching and heaving to a machine shop (poor facilities), to a steel fabricating shop (ditto), to others including the school library, nursery school and where little children are fed. We saw 4-year olds with impeccable manners at their midday meal, then the museum and, at 1330, back to the ship. Still raining. Security guards on the dock and a guard ship anchored close by outside on our starboard side. Our program changed again as we got next to Nome to re-enter the U.S.

A very good drum dancing performance after tea - the best we've seen anywhere. The lounge jammed to the deckhead for the dancing followed by speeches, translations of speeches, presentations, and vigorous embraces. The children were very appealing in their costumes. Thoroughly enjoyable.

Another great passport ritual to clear the ship for sailing. The 6th for B and the 5th for me. The Russian officials, smartly turned out in their uniforms, were a little less formal at the end.

Did not bother to watch the departure maneuvers nor take illegal pictures - too dark and too rainy. A cheerful dinner party with Charles

Swithinbank joining us - six in all. At 2100 it suddenly became midnight and Aug. 25th as we cross the International Date Line during the night.

Thurs Aug. 25

Wind and sea kicked up considerably - awoke with the ship cavorting about - still a good turnout at breakfast. Telephone call from Roy Friis in Tuk. Advised him of the possibility of the passenger exchange being done at Barrow, that I would call him back to advise what the plan is and with another careful look at our maximum draft, if in fact we do come to Tuk. Understood from Ralf that it is nearly 15 ft. Roy's voice very faint especially with nearby background hubbub. (Visit to Nome now cancelled in favour of Barrow)

Closed the Diomedes. Received an ice map for August 24 based on stale data really, which gave a promising overview and which encouraged H. Then at 1600 three more came in dated 25 August and based on up-to-date satellite and ice recce information. The scene is now discouraging with three choke points, east of Barter Is. and both sides of Point Barrow. H now depressed.

P.S. H blew hot and cold and was too easily discouraged. The Aug 25 ice chart pretty well convinced me the traditional route along the Alaskan coast was, for 1988, a no-go proposition and Brian Veal's words were becoming increasingly significant, in that the best route appeared to be to seaward of the pack. From Barrow a vast area of 3/10 pack (easily navigable for this ship) leading to open water was beckoning but first we had somehow to get through xx miles of 6/10 thick first-yr and then yy nm of 9/10+ equally heavy going, or so the ice chart seemed to indicate.

A possible alternative is opening well to seaward which could prove to be significant. I hope so. No response to our request for info. concerning an ice recce flight along the coast to Herschel Is. Jack J. checking with Anchorage office. Two ice charts of James Ross and Barrow Strait showing a blockage still in Larsen Sound. Victoria Strait showing signs of opening and could prove to be the preferred route. But first we have to get there. During the p.m. making northing in the Chukchi Sea.

Fri Aug. 26

Wind and sea up during the night - NNE Force 8. The ship jumping about but mostly pitching. No ice chart during the forenoon, possibly due to lack of fresh data. This wind, if it is the same force and direction, will pack the north (Alaskan) coast for certain. Looks as if we will be two days late at Barrow and even it may be inaccessible or threatened by the pack.

Tried, but seem to have failed, to persuade H not to use "knots per hour" in his enthusiastic sitreps to the passengers. Slow progress - four knots. Asked by H if I would say a few words at re-cap or "wash-up" as I call it. Complied. Invited to dine with H and three other passengers. A long session listening to a torrent of self-adulation from H about his experiences - they are impressive but we were a captive audience.

Sat Aug. 27

Sea moderated during the night. Gave a talk to the passengers on "Hummocks, Bummocks & Sastrugi" at 0930. during which we encountered an increasing amount of ice - first sighted at breakfast in small quantities. As I talked the ice increased substantially. By the time I could get away we were in the thick of it.

The next two hours on the bridge with H and Jack J. extricating ourselves. Reversing course until 1230 when it became possible to begin hauling gradually around to the SE, then E, and then onto a course for Barrow inshore. H at one point becoming very down at such an unexpected turn of events. Much telephoning to find that the beach off Barrow is clear of ice.

1320. No ice in sight on the starboard side through my cabin window - long may it remain so. Last night H told us Society Expeditions had been obliged to post $1 1/2 million bond with the Canadian Government before the voyage was permitted. News to me. Apparently in '85 it was $1 million. By this morning the passengers had the '88 figure as high as $10 million! (Note. Oct 10 I was advised by Werner Zehnder that it was the U.S. Govt. not Canada, that required the bond)

During our ice encounter H closed the bridge to passengers which had my approval. 1450. Wainwright bearing 100 deg (True). The coast abeam distant 12 nm. H once again in high spirits and regaling us with Antarctic feats of derring-do.

We appear to be safely inshore of the pack and our ETA Barrow is now 2100. Officialdom awaits us. Jack J advises that his wife in Seward reports our visit to Provideniya is national news and described as “mischievous”.

If we do an ice recce it will be in a Navaho-type aircraft. Also arranged for Charles Swithinbank to be one of the team. He asked and I kick myself for not having thought of it myself first.

Reminded by B this day 52 years ago we parted on Bronte beach when I went off to join the navy.

Ice-free run up to Barrow anchoring at 2100. Spoke at the re-cap on plans for Sunday. Drinks at 1830 with Peggy and Dick Krementz and others. He has charts for the whole voyage. Sent a message to **Martha L. Black** asking for an opinion as to the better route - coastal or NE into 3/10ths after negotiating a 12 mile band of heavy ice.

P.S. My actual message read: “For Master and Ice Observer (who I knew - Larry Solar - from 1986) Reference 18OOZ 27 Aug 88. Alaskan coast ice chart just received. Request ASAP your opinions on committing ourselves to coastal route or what appears to be an alternative 60 nm north of the coast through an area of mostly 3/10 ice. Our ETA Point Barrow 2100 local time to-day Saturday bound Tuk. What is your present position please?”

A helpful reply recommending the latter. H in a lather of indecision. Ice Recce laid on for 0700.

Sun Aug. 28

Up at 0630. H, J.J. and Chas. S. on the bridge discussing **M.L. Black**’s reply and canvassing my opinion. I opted for the route north about the heavy 9/10+ ice extending all along the coast, and threatening the coastal route which is the traditional way to go - but not this year. It is already on the coast at Cape Halkett and east of Barter Is. according to the ice map for this date.

P.S. This recommendation by me was one of the key factors in the entire voyage. If I had opted for the coastal route I wonder what would have happened. With H being so unsure I do not believe he would have gone against my advice. The plan was to steer for the narrowest neck of 9+ (7/10 thick first-year and 3/10 old ice) as shown on the ice chart for Aug 27.

H makes a meal of any decision but after extracting a definite recommendation from me several times, and supported thus by everyone else, we eventually shaped our course on a northeasterly heading and set out.

M.L. Black's response to my message was timely and helpful indeed.

Brian Veal of Ice Central suggested before I left Ottawa I recall that our proposed route appeared to be the way to go - and is now proved right but it will be a challenge whatever way we go.

Weather and visibility conditions generally, particularly at Dead Horse (Prudhoe Bay) where we have to refuel, unsuitable for flying, so the ice recce to Herschel and return goes by the board.

Lunch with B helping three visitors from Barrow (referred to inelegantly, but accurately as I recall, as Muck City). Weighed at 1400 and headed north about Captain Beechey's Point Barrow, then altering north eastward toward the pack ice lying in wait and visible ahead of the ship.

Entered the pack shown on the ice chart to be 5/10 but it seemed rather heavier. Steering toward the narrow band on the 28th - no - 27th chart as 9+ thick winter and multi-year to break into more 5/10 to the NE.

P.S. We were not aware at the time but I subsequently discovered that the so-called neck marked A on the 27 Aug chart (3/10) was just a computer extrapolation. It certainly did not reflect the conditions we encountered struggling to the northeast.

A lot of bridge time with H getting discouraged. Advising and soothing and helping as much as he would accept. A long time on the bridge. Got away for dinner which B had organized but was called back and I never did get a decent bite.

A fine polar bear sighted on a floe - on his hindlegs for a better look. Aye in transports of delight - all thought of progress instantly abandoned and announcing "picture, picture, picture" producing a stampede of people and cameras. We struggled along in close pack until after midnight when it became unproductive to continue and we hove to for the rest of the night.

H gets discouraged too easily and with no urging would quite happily retreat to Barrow. Fatigue I feel (is part of the problem) but he needs to be kept encouraged. Weary.

Mon Aug. 29

This was the day of the bear sighting - not yesterday. It is so hectic and time demanding I cannot recall events.

Called at 0525. Up to continue - slow going. H spent too much time going north and south looking for a lead to the east. There were no leads and there were dire threats: “Vis is too much, ve go back” and “No vay we get through” and other signs of irresolution. I took up a position right beside H and succeeded in getting him to head into the pack, on an easterly heading, to take a nibble and test it.

This we did and at first it was soft going but unfortunately we soon came up against an old floe which blocked the way. This called for a deal of maneuvering and more indications of retreat. However, we pressed on and H learned a lot about ice, shiphandling in ice, and we advanced through what he thought had been an impenetrable barrier. He was unaware that he should have his rudder amidships when moving astern, did not know (what) “his” ice horn was for. We worked as a team and he accepted my instructions on throttle use, using floes to assist in turning the ship, on speed, on rudder, and it was a good forenoon’s activity and eventually open water appeared but it served only as a polynya with yet more heavy pack to be dealt with (beyond).

P.S. I believe this forenoon activity turned out to be the key to the whole voyage. I stood beside him with the engine controller between us and together we headed east easing the ship into the pack. For hours I explained how to nudge the ice, keep power on without gaining damaging speed, telling him when to ease up, when to put the boots to her, how not to kill headway by over-use of the rudder but instead to use ice floes to change direction, and so forth. It was a great success. He became very excited deciding that the pack was not such an obstruction after all.

During this there were reports to be made and then no time for lunch. Krista, thanks to B’s intervention, appeared with a platter of sandwiches. A tiring business but Heinz, after the morning’s performance, pronounced me the best Ice Master. A piece of hyperbole but acceptable after a long session in the ice. I told him I would be prepared to certify him (now) as competent in ice. He said Antarctic ice was nothing like this - while Charles Swithinbank, the academic, averred that there were some pretty able Soviet icebreaker captains and I would agree - also that H (who says he has completed 52 Antarctic voyages and has never seen ice like the stuff we have just been through) was ignoring the heavy pack to be found in the Weddell Sea.

At it all pm and after dinner. A long day and we are not making significant progress. When we stop for the dark hours the current carries us back a goodly distance.

Note: At this time the question of asking for icebreaker assistance was raised by H, and by Seattle through H, to me. Before formally asking for such help I sent a message to **M.L. Black** with our position and saying that we were "experiencing difficulty making headway through heavy pack where promising conditions on the ice charts do not square with the ice we were experiencing. Would your operational commitments enable you to respond to a call for assistance from us to Nordreg to-morrow Tuesday at the latest". Captain Mellis replied that such a request would have to go to higher authority, which I knew, and that anyway he was four days eight hours away in Victoria Strait. So that gambit did not work.

P.S. The actual messages read: To **Martha L. Black** (for Capt. Mellis). Our 300500Z Position 71 deg 38 min N 155 deg 41 min W. Experiencing continuing difficulty making headway through heavy pack. Forecast conditions on ice charts do not square with those we are actually confronting. Would your operational commitments enable you to respond to a call for assistance from us to Nordreg to-morrow Tuesday at latest." His reply was: "It read: "I understand that your present position is 71 deg 38 min N 155 deg 41 min W. With reference to your query concerning whether operational commitments would enable CCGS Martha L. Black to respond to a call from you for assistance, be advised that this is a decision that can only be made by District Manager Hay River (ye gods) in liaison with the Director Northern Region CCG Ottawa. In addition our present position is Victoria Strait and our transit time to your position would be 4 days 8 hours."

Tues Aug. 30

Call at 0500 (on my own initiative) to contact Carol Stephenson early in her office four hours later. She was supportive and will examine the problem and call back. She did and had a lot of information, all of it useful. The best news is that **Pierre Radisson** (Claude Guimont - Ho-kay Ho-kay & No Prob-lem no prob-lem fame) is topping up with fuel and is ready to give us a hand. This is a development that was preceded last night by a call (by me) to William (because I could not raise Carol or Len Forrest at their home numbers). Briefed

W and I felt confident he would get the ball rolling. I wanted to know what the reaction and response would be to a request (from me) for icebreaker assistance with us so far away and in Alaskan waters.

Carol advised, to my great relief, that **Pierre Radisson** is in readiness, that a ship, **Mount Fuji**, 30 ft draft 25,000 dwt or more, will be rounding Pt Barrow Sept 4 to follow our route (and is she in for a surprise!) The M/V **Western Polaris[,]** a U.S. seismic vessel, is 30 nm SE of Barter Is. delayed by heavy ice. A drill rig, the **Kullik**, off Tuk leaves 31st with the **Terry Fox**, "**Kalvik**" & "**Ikaluk**", all icebreakers, for Belcher 141 West on the U.S./Can border ETA 3 Sept. The M.V. **Arctic Ivik** is in the Tuk area, a smaller harbour tug on charter by ATL to Gulf. The "**Canmar Explorer III**", drill ship, escorted by the Arctic Class III icebreaker **Robert Lemeur**, leaves Tuk Sept 2 for Barrow which means the drill ship will complete the Northwest Passage, albeit interrupted by a number of years, and can be added to my NWP list. The icebreaker will then return to Tuk, maybe with the Fuji. The SSD **Caisson** moves to Pauline Cove on the 10th.

This was the day that a report came from the **M.L. Black** that David Cowper in **Mabel E Holland** had been sighted in Queen Maud Gulf bound for Cambridge Bay, pumping 200 gals of water leaking in every day. Am so relieved and pleased for him. His plan is to overwinter at Tuk and set off for the Pacific in 1989.

H organized two ice recce flights from Barrow ahead and on either side to find the best route through the 8 to 9/10th heavy pack blocking our way through to that elusive area of 5/10ths lying to the eastward.

Endless talk with H about the best route to take, the results of the recon flights, ice conditions and icebreaker help, and all the while a sense of irresolution, a pusillanimous approach, to this challenge posed by a bad ice year along the Alaskan coast.

(I am) reluctant to ask for help because I think with a little more determination we could get through and I don't want to destroy my credibility with our Coast Guard. I did tell Carol this would be the last NWP by Society Expeditions.

Finally bit the bullet and sent to Nordreg: "Request icebreaker assistance. Our position 71 deg 48 min N 155 deg 38 min W 1740Z. Steering 045 deg True, speed two knots or less toward reported easing of conditions 100 miles ahead. Ice conditions being experienced now and reported athwart our track by local ice recon eight to ten tenths. Bound Tuktoyaktuk. Sgd: Master[.]" His name, my text.

So much going on it is difficult to recall the sequence of events. To save time I called Ottawa and passed the same message to Ivan Cote. A while later Dave Johns (DJ) called back to tell me **Pierre Radiss**on would be sailed very shortly. My relief on hearing this considerably tempered by the time, distance, cost, and possible political implications involved. Very conscious of the degree of support I'm being given. Considerable relief shown by H. Next was a message asking if I had checked all possible commercial alternatives. I immediately got on to the expensive ship-shore telephone and contacted the only possibilities - Gulf and Dome. The former advised they had nothing available and eventually Dome was also a no-go and so Nordreg was advised thus clearing my yardarm and the use of a C.G. icebreaker legitimized as it were.

Despite all our efforts we remain not very far from Pt Barrow. It is very slow work. Stopped for the dark hours at 2300 and a quiet few hours sleep.

Wed Aug. 31

Moving again at 0600. Very little overnight drift - SE 0.8 nm. I was able to attend Charles Swithinbank's talk and slide show of the **Manhattan** voyage.

Reminded of the arctic motto "haven't you heard, it[']s all been changed" when a call came from Ottawa (DJ) telling me that **Radisson** will not now be coming but will remain in the vicinity of Cambridge Bay to see us through the Larsen Sound leg - or so I understood. Instead the USCG **Polar Star** is coming sailing from Nome, Alaska, to-morrow. A message from USCG Ops in Anchorage that we should confirm there are no U.S. civilian ships available and capable of doing the task. Fair enough.

So another flurry of telephone calls to Anchorage and Prudhoe Bay. The only candidate was Crawley Maritime of Seattle and I talked to Carl Stubbs, who I met some years ago on another arctic-related job. He offered an icebreaking barge pushed by two tugs in stern notches. The tugs designed for the task were unavailable but he wanted to talk to the principals of a company in New York who had two laid up somewhere. Sounded like a lash-up job and in my opinion totally unsuitable but Stubbs wanted to get the opinion of his own marine experts. O.K. I called USCG and got into an argument of sorts with a U.S. Lieutenant who said it was not my opinion that mattered, nor H's either, as to what was suitable and what was not, and that U.S. taxpayers should not have to rescue passengers stuck in the ice where they had no business being. I became a mite testy but we eventually cooled it and agreed to see what Stubbs came up with.

He (Stubbs) called shortly after to say his marine people were not in favour of the barge idea in the circumstances. I called Anchorage and had a pleasant talk this time with Lt. Flory and it was agreed **Polar Star** would sail the evening of the next day. Altogether a hectic period including a message covering the matter to all involved.

Stopped in the afternoon and now that an icebreaker is coming a diminished resolve to press on is apparent.

A baby Beluga whale swimming around the ship - mistaking us for mother maybe - was the opinion of some. Weather quite good but we'll have to make more effort to help ourselves which we are perfectly capable of doing. Very weary after a tense day.

Thurs Sept. 1

Up at 0700. Temp. 28 deg F. Drifted less than a mile while stopped. 10/10ths loose pack all about us. Only 107 nm from Pt. Barrow. 360 to go to reach open water. Beluga still with us.

DJ calls from Ottawa for a report on our situation. **Polar Star** ETA 031900. I brief H and call Roy Friis at Tuk to arrange 100 tons of fresh water @ 16 1/2 cents per gallon during a six hour stay.

Most of the day spent stopped while zodiacs go away with passengers to plant flags on floes, take pictures and have fun - getting them out of the ship and into the fresh air - plus hot spiced cognac fruit juice (gloog) on return. Good for morale and not a waste of time for that reason. (But) time now to force on. I explained earlier to H that if an icebreaker is en route to our assistance we have to be seen to be doing more than just sitting idle.

1620 Hoisted all rubber boats. H decided to go east into the pack as tho' it was a new idea - whatever - "iss goot". We are heading east.

1630 Working into and through easy ice.

1720 Open water, fog.

1730 Daily ice chart arrived.

1800 Cruising along with an excess of timidity making for open water reaching it in 20 minutes. Later, at 1900, I left the bridge to rest my legs and no sooner was I below than a USN patrol aircraft buzzed us three times. I never saw it and efforts to raise it on radio were fruitless. (I suspect it was checking us out and a good thing we were seen to be moving east)

Talked with a Los Angeles newspaper and endeavoured to set the record straight - i.e. we were not "trapped" in the ice but "stopped". However, the truth is not sufficiently lurid for the media. Turned the phone over to H who settled in for a 30 minute wildly exaggerated discourse of our situation and prospects.

2300 Hove to for the night.

Fri Sept. 2

0630 under way. 1 to 2/10ths, poor vis. The urging to get cracking is paying off.

0710 To the bridge. Fog and open water go together and that is what we've got. Ship has consumed enough fuel to make her tender as she responds to rudder movements.

0800 Bowling along making good easting. Herschel Is. visit scrubbed. Steering direct for Tuk.

0915 In the radio office trying to work **Polar Star** but a lot of background noise and a very faint voice. Made out three questions they had - what speed (answer 8 knots), did we have a helo (negative) and did we still need assistance (please standby was my response to that). Off to discuss with H but by the time we wanted to get back to **Polar Star** we had lost touch.

1015 CANICE 3, the Canadian ice reconnaissance aircraft calls in - loud and clear - flying ahead to tell us about conditions on our track.

1030 Still trying to raise **Polar Star** - static and now a hammering sound - impossible. Radio still has problems it seems. Ice 9/10ths, one mile visibility in fog.

1045 320 nm to open water. The scene on this bridge is something to behold. Passengers asking questions, bridge doors being banged open and shut, the buzz of the SatCom phone, plus the roar of the port lifeboat diesel being run up in the background and voices from two bridge radio speakers, all contributing to a sense of confusion.

1110 CANICE 3 calls in 80 nm east of us and going on, voice fading.

1125 Oral report of ice - Fax to follow. Very hard to hear, kept fading.

1157 Below to rest my legs and have a beer.

1330 On the bridge drafting messages re customs clearance and ETA Tuk. Discussions with H.

1415 Drafting message to Tuk agent (Capt Smith). Anxious to get an ice chart. It[']s Friday and a holiday weekend coming up and people ashore will be heading for home. H occupies the radio office for a prolonged press conference (in which he revels) and I cannot get through to Ice Central.

1500 Message sent by me to **Polar Star** indicating we wish her to continue in our direction but that we will release her as soon as attainment of open water is assured.

1540 Called DJ re lack of ice intelligence and he suggested Nordreg and the fellow there promised to try and help.

1550 Talked with **Polar Star** (just legible or is it comprehensible) and advised him (her captain) that after one more recon we could be in a position to release her. Message (in) we are to get another recon to-morrow.

Barbecue dinner. Canadian get-together (Patrick & Jean Strachan) also Dennis and Sabena & Guy Morrison. We took our Canadian flag and B handed out NWT pins. Later there was dancing. Talked with a German professional photographer who gave me some tips and strongly recommended Fuji film for its outstanding colour quality - especially blues and greens (ice!).

Easy running through fog and mist at slow speed.

Sat Sept. 3

WW II started all those years ago but that, in the present company, is hardly a conversation starter. Our 0700 pos. 71 deg 30 min N 142 deg 00 min W speed 12 in fog.

0725 CANICE3 overheard working SD III.

0740 We are in touch. Most helpful. Got promising report of good conditions and clear visibility ahead.

0750 B and I left the bridge for breakfast and as the door closed behind us there were long blasts on the whistle to signal we had emerged as through a curtain into bright sunshine, blue skies and seas. Lovely and thus it remained all day to the delight (and relief) of all.

0825 Talked to **Polar Star** with advance word that we were able to continue on our own unaided and tried to express gratitude.

About this time we crossed into Canadian waters as it were - joy amongst the Canadians who attributed the marked change to that fact. Sent our position to Nordreg and later another with all the details they demand, and before long a reply arrived giving us permission to enter, which we already have.

Ice is easily navigable, strings and belts 2 to 3/10ths.

In the afternoon at H's request because he wanted to sleep, would I help Franze the Second Officer through the ice. He and I had a fine time and for the most part I left him to it. H should give him more opportunities to handle the ship. Given trust and the confidence of his captain he would become a better officer and he is a good one now. I discussed this with H and he absolutely refuses, as he puts it, to risk the ship. I disagree strongly with this attitude.

A warm sunny afternoon. Everyone out taking pictures pictures pictures and enjoying a glassy calm sea - extraordinary. Two seals sighted and by me one walrus.

Charles Swithinbank asked me why Canada signed the Antarctic Treaty in May this year. Haven't any idea but, like a midshipman, I will find out. Spoke to Roy Friis at Tuk about our ETA and how he is to meet us - all arranged.

Sun Sept. 4

A scratching sound at our door finally wakened me. A nervous Philipino [*sic*] from the bridge reporting I was needed. Time 0300. Up and dressed to find there was some misunderstanding and I was not needed at all. I decided to stay and chat with the Second Mate. Lovely night - brilliant array of northern lights, moon, stars. We moved slowly towards our rendezvous. Peaceful. It is many years since I kept a middle watch - or part of one at least, and all of the morning watch which was 46 years ago before my first command. Approached Tuk, picked up our pilot, Roy Friis, who knew all about me. We had met during an ice recce during the (1983) Northern Light barge operation.

Entry into Tuk was an interesting operation. We were drafting 15 ft and the maximum allowed. It was slow going through muddy water but all went well and after a struggle to berth the ship in a strong off-jetty wind, accomplished the operation. Remained on board and tried to snatch an hour or so of sleep but, alas, loud banging on the door interrupted that plan. Two chaps from shore welcomed me heartily but for the life of me I could not place them. Later at sea the next day I had a radio call from Keith Jones who must have been one of them but I still cannot place him or them and felt badly.

Roy Friis on board at 1530 to report the NE wind was lowering the level of the channel so much we run aground (if we sail as planned) though he didn't say that and H, after some humming and hawing decided to remain overnight.

Mon Sept. 5

Had ten hours solid sleep, the first for a long time. Awoke with the ship outbound and the promise of fine weather. No wind to speak of. Our departure was uneventful but the local who promised to come out and take Roy back never showed up - typical - necessitating a long zodiac trip in and out by Dennis and a long wait for him to return. Away we went at full speed steering first for Cape Bathurst then Holman direct in worsening weather conditions - all day.

Cheerful dinner party with Guy Morrison, Have, Isobel, Fred and Inini and good wine. Later that evening a presentation was made to H by the "Lost Tribe of Tuktoyaktuk" (our 25 new passengers) acclaiming his feat in getting the ship through the ice. Later still, following dinner, a card was slipped under our door, anonymously, which pleased both of us. Who? It was addressed to "Captain T.C. Pullen and his lovely lady Betty" and read "On behalf of the others in the ship who were not the lost tribe of Tuktoyaktuk we wish to confer an honorary degree in calm poise and charm to the captain who deserves much acclaim for getting the good ship Explorer through the ice to Tuk."

Tues Sept. 6

Rough seas, strong winds. Anchored off Holman rather far from the settlement. Excessive caution I thought. B and I landed with H who went directly to the Post Office with 3,000 post cards which rather overwhelmed the staff of one. Thence to the fine new municipal office building where the mayor did not seem willing to meet H - resplendent in his patch-festooned parka and white fur cap - hat really. Once his worship had completed his coffee-making chores he removed to his office by then wearing a baseball cap and colourful wind-cheater - badges of office? He appeared rather offhand but it may have been shyness. Next to the little church where there is a fine rendering of the

Last Supper in sealskins. Finally to Holman's impressive new school with facilities that equal any in the south. Many chattering happy polite healthy youngsters milling about.

Back to the ship which was bursting with a horde of visitors. "The last zodiac for shore is ready to leave" kept coming over the PA system with a marked reluctance on the part of our contented coke-guzzling guests to leave. Weighed and proceeded at 2000 and were soon pitching and rolling on our way to a rendezvous I set up with David Cowper in **Mabel E Holland** sheltering in the lee of Cape Young.

Wed Sept. 7

H rather uncertain about going into the unsounded bay where David is lying. Gale force winds and steep seas which could be seen crashing onto the exposed coast facing the watery onslaught from the NE. Up early and with Ralf Zander as he made the approach. H arrived and I was pleased to watch him take the ship into the unnamed bay and also uncharted bay. Anchored as close as we should prudently go. Well done H. On the radio with D who was obviously surprised and delighted to see us - "it[']s absolutely marvellous" came over the air repeatedly (as close as D can get to being excited).

Ralf went with a zodiac to fetch him and we, B and I, had a heart-warming greeting at the head of the gangway. Up to the bridge after he had divested himself of his well-worn outer protective garments to meet an enthusiastic H. A shower followed by breakfast in the officers['] dining saloon. At 0930 a jammed and expectant audience filled the lecture room. I introduced David and he gave us all an excellent talk, unrehearsed, followed by questions all of which lasted an hour. H thanked him. Coffee and great chatter in the dining saloon with the wind blowing hard and the seas rolling in. Eventually it was time to go. Much picture-taking and then Ralf returned David to **M.E.H.** and his lonely vigil. His next sheltered stop lies 135 nm to the west along this exposed coast. He must await a break in the weather before setting forth. It was a good visit and I am grateful to H. for seeing it through.

We weighed and proceeded towards Cambridge Bay.

Thurs Sept. 8

Arrived off Cambridge Bay in and after rough seas and winds of 30 plus knots. At 0145 called by H (no phone in our cabin) to talk with **Pierre Radisson** who I saw passing down our port side - a blaze of light. A great discussion. She is being deployed to Tuk. Up at 0600. Called **M.L. Black** and found that she was at anchor inside. Tried to carry on a reasonably intelligent conversation with them while H was shouting more at me at the same time. Found that our chart of the approaches and harbour is out of date with respect to channel markers. In the end she said she would come out and lead us in which is a great relief for H and most considerate of her - and so we entered safely to anchor two or more cables off the jetty. **M.L.B.** anchored nearby.

Ralf (as Staff Captain and captain in waiting he seems to have a lot of odd tasks to perform) went over to and brought Captain Mellis and Larry (the beard) Solar, Ice Observer, back for discussions. Larry, who looks like an enormous Farley Mowat and twice as pleasant, brought a collection of the latest ice and weather charts while Capt M had nautical ditto. Very useful exchange of views. H wanted me to ask for an escort out but I felt reluctant to keep asking for favours. He did it himself and M agreed. A very prolonged talk between H and M as to routes and times with the former incapable it seemed of coming to a decision. After a glass and the supply of soda water, cigars and other commodities, M and S returned to their ship.

A wet windy visit (ashore for the passengers) and a rude reception given to the first group to visit the DEW line station. Neither B nor I went ashore. Under way during dinner and after parting company from **M.L.B.** set off to the east for Gjoa Haven.

Fri Sept. 9

Spent an interesting two hours on the bridge during the transit of Simpson Strait. Anchored off Gjoa Haven at 1415 and went ashore where we found a telephone and made two collect calls to Donnally (Pullen) and Noel (Quinn). All is well. Attended drum dancing and throat singing which is a repetitious performance. Wandered about meeting, greeting and dodging high-speed three wheelers. 1800 returned to the ship. Dinner with Ralf as our guest plus Guy Morrison.

We will remain at anchor until 0200. To-day is the 85th anniversary of Roald Amundsen's arrival here in 1903 so our visit is timely. H brought off the local quality for cokes and talk.

Sat Sept. 10

Up on the bridge just after sunrise - 0630 - when the transit of Simpson Strait had been completed. All forenoon in Requisite Channel and towards a

1330 rendezvous with **M.L.B.** but which (for lack of time) was cancelled. Instead, I talked with Larry S. and took down all his latest ice information. Pressing on and making northing in Victoria Strait. Warned H about the need to watch the depthfinder and of the need to be alert in what are still poorly surveyed waters.

Gave a talk on Bellot Strait to the passengers. On to the bridge at 1800 and because of ice had to refuse a dinner invitation.

As we made progress the ice appeared in increasing quantities and generally as described by Larry S. During the first watch we trended north and east to seek open water. Finally H and I remained to indulge in shiphandling sinuosities through and around the pack including a number of heavy floes. A deal of crunching, bumping and crashing to remind our passengers of where we were. It took hours trying to end-run the pack so we could steer for Bellot to the north.

By 0330 we rounded the pack by which time the ship was at the northern entrance to James Ross Strait. In open water I left the bridge at 0345 and H followed at 0400. A long day and far more ice time than I expected.

Sun Sept. 11

A sound sleep and B got me breakfast so I did not have to rush. A shower and ready for another day. Approaching Bellot a few strings and belts of old ice off its western entrance. A quick lunch and then into the strait. Guy Morrison spotted a polar bear far up on the rocky hills on our port side, tiny, being so far away but a bear all right. Very observant of him.

A smooth run. A few multi-year floes in the middle and quite a lot in the vicinity of good old Magpie Rock swirling about in the eddies but we were able to steer around them. Magpie had a thick flat chunk of ice perched on top but little eddying nearby. Everyone interested in seeing the rock site and also Zenith Point, northernmost tip of (continental) North America.

H anchored off Fort Ross - much too far (in my opinion) from the landing place. Hasse Nilsson would have gone much closer to the beach. It makes for hard work for the zodiacs.

Ashore with B and everyone else. Good weather but a cold wind. A number of heavy multi-year floes grounded near the landing beach. Fort Ross building vastly changed from the shambles it was in 1986. Evidence of Caroline's hand with everything neatly stowed and arranged. Signed (B did) the book H left there in 1985. Inspected the M'Clintock memorial, flagpole and the other hut which is in a sorry state with all the windows broken - bears? Eskimos? Climbed the higher ground for pictures. A glass of hot "gloog" and back to the ship.

An enormous heavy old floe drifted onto the ship but passed slowly and safely down the starboard side and clear.

1830 underway and into Prince Regent Inlet however a vista of pack ice athwart our track indicated a long night of ice navigation. I could not equate the situation with Larry S's confident assertion that P.R.I. was open water. It could have been a belt of ice with open water beyond but (from our low vantage point) that we could not determine. After a brief discussion (remarkable for H who goes on and on regurgitating even the simplest of decisions) we turned back with my full concurrence to go by way of Peel Sound.

A Canadian dinner with flags and champagne. Dennis and Sabena Mense, Guy Morrison, Jean and Patrick Strachan, Jan Tennant, Roger Matheson and ourselves.

An ice-free run, for the most part, through the strait. The same block of ice was sitting atop Magpie but this time there was the furious turbulence with which I associate the rock.

Turned in at 2330 and enjoyed an uninterrupted night as Ralf and others took **Explorer** up the clear waters of Peel Sound with the pack lying against the western side.

Mon Sept. 12

A tap on our door at 0630. Up, washed, dressed and to the bridge. We were just a few miles to the west of Limestone Island with ice to the west, ahead and on our starboard bow. H asked me "vich vay ice master?" To the northeast around the pack I replied which was the response he wanted or expected. It was the only option and so off we went in open water all the way to Resolute where we anchored at 1100.

Spotted **Des Groseilliers** anchored outside. Spoke them on Channel 6. Female French voice at the other end. **John A Macdonald** (now there's a good icebreaker) reported 30 nm to the west off Cape Airey.

Passengers went off in twin Otters to inspect muskox and beluga. Remained on board. In the p.m. an invasion by barge of 25 from the icebreaker who, after a perfunctory look around, attacked the bar and with gusto proceeded to enjoy themselves.

The uniform of the officers is smart - naval buttons too. Some of the males very unkempt with long hair and scraggly beards. A French-speaking group - all of them it seems. Quebec-based and some with a little English. Our Swiss passengers could not understand them and the Andre's [*sic*] from Paris only the odd word.

At 2030 H, Ralf Zander, the 2nd and 3rd officers, Chief (Engineer) and myself went away by zodiac to visit the 'breaker after we had shifted our anchorage close abeam. Ralf commented that the cream of the team was out of the ship and what might the passengers get up to? Later, we learned that as soon as we left the gangway a voice announced over the P.A. system "At last, the ship is ours!" Dick Krementz at play.

A rating was at the gangway when we arrived and someone led us through passageways and up a number of stairways to the captain's cabin (Gerrard Guesneau) who greeted us, organized drinks and chatted of this and that. A female, whose identity and name I did not catch, was already ensconced - informal attire. Maybe his wife for all I know.

A quick tour of the bridge and after expressing our thanks, departure. A lot of our passengers went over and all seem to have been impressed. The bridge, of course, is gigantic especially compared with ours. They are expecting orders to head for home. I suspect she has not been very busy and has had a lot of anchor time. I would like to have had a chance to inspect her log. Resolute, not my favourite place but an important way station. Now we will be heading east, not north, and completion of the Northwest Passage is assured.

Tues Sept. 13

Under way during the night for the short run across Wellington Channel to Beechey Is. Anchored at 0750. At 0830 gave a brief 25 min. talk to the passengers on the history of the island and what is there, stressing that it is a place of ships and seamen - a naval place. Also emphasis on the aura of sadness, frustrated hopes and melancholy. Well received I think. I also stressed my strong objections to all the modern clutter that has been deposited there. With my binoculars I could see that the mast of the yacht "Mary" (John Ross) has fallen down, either pushed by bears using it as a scratching post, or on account of the bloody idiots who make a game of throwing rusty barrel hoops over the top, and the cumulative weight became sufficient to fell it. It has been leaning at an angle for years. Must get the Coast Guard to re-rect it, they have plenty of time for such things it seems.

Ashore at 0930 landing near the graves and was soon surrounded by red-coats asking questions. Never did get a close look but all seemed in order and no sign of the recent exhumation activities. Set off with H and B to walk along the beach to Northumberland House & etc. Had a thorough look around while answering queries and posing with H for pictures. A little ceremony at my Labrador cairn with H while we stuffed a document into the Lab. copper pipe. Cold work with bare hands. Took plenty of pictures. Some of the hardier souls climbed atop Beechey and after some difficulty located the Franklin cairn and reported a new pole has been erected - steel - and thin with no barrels so likely invisible from seaward. It was all very evocative and possibly my (our) last visit but I am grateful for the opportunity. I still deplore the modern additions and many passengers agreed with my views.

Mid-day we left Erebus Bay and shaped our course east along the Devon Is. coast. No ice to be seen. At 1800 we sighted a large berg, 160 ft high, visually at 24 miles. H closed and circled it so all could look with wonder and take pictures. Much excitement and a great amount of film was exposed.

Calm sea, blue sky as we glide by the coast of Devon Is. and we look forward to the end of this voyage now scheduled for Narsarsuaq instead of St John's, Nfld.

Wed Sept. 14

Anchored off Nungavik, Navy Board Inlet, location of an archaeological dig. Ashore and a good hike with my friend across the tundra, eventually to the shore and then back to the landing beach. A helicopter overhead first heard by B, and then the **Des Groseilliers** came into view homeward bound after what I would suspect has not been a very strenuous season.

On the bridge earlier with H discussing the visit p.m. to the Sermilik Glacier on Bylot Is. 3 1/2 miles off its foot (such as it is) the closest sounding is 407 fms and he dismissed my gentle persuasion that he might go a little nearer as too dangerous. Good grief, the water is 2,442 ft deep. Such timidity, some expedition ship. I could not believe it. In the event we made an unhesitating perfunctory sweep past (in deep water) and headed for Pond Inlet settlement.

I wrote an entry (at his request) for Heinz's personal record book plus a picture of a polar bear and one of my bookplates.

Went ashore for a walkabout, the place has grown impressively, population now approaching 1,000 and 550 are under 16. Went in search of Herman Steltner. He spotted us and shortly were inside meeting Sophie and hearing a full report since we were last here in 1986 and S collapsed in the **World Discoverer**'s lounge. We thought (then) she might have had a stroke, but not so. He has a very low opinion of the Yellowknife Govt, (according to him) a gang of neo-fascists and if he is right something should be done. He excluded John Parker, the commissioner who, Sophie said, had been made powerless. Interesting visit.

Sailed at 1930 and at 2000 the NWP dinner at which we were two of H's guests at his table. He proposed a toast to me as Ice Master in the process making a flattering speech about me only part of which I could hear. It was as unexpected as it was pleasant to receive such a public tribute. He did the same for Alan, our hard-driven cruise director.

Thurs Sept. 15

We had entered Coutts Inlet at dawn and by the time I got up the head of the inlet, 38 nm in, was in sight. Where we turned was a perfect specimen of a growler which was recorded on film by me for future use.

This was the wedding day for Stewardess Isobel and Erhart, the electrician. Everyone dressed and a ceremony conducted by the inimitable Aye. It was a Spartan affair and bore no relation to the service in the book of Common Prayer. I suppose it is legal, being a Bahamian ship. Much joy, giving of presents, we the passengers did a whip round and came up with more than $500. More champagne. Philipino dinner, dancing, frivolity. Turned in earlyish and had a good night's sleep. Still catching up. Asked by Sabena if I would talk on the NWP to-morrow. I would and will.

[page missing]

Sat Sept. 17

At one point we passed between two huge bergs, vertical walls of gleaming, glistening and menacing ice 120 ft high. Glad we did not tarry. Took a great many photos, having to change film fumbling with cold fingers in a great rush. Twelve of us and everyone enjoyed the outing.

Weighed and left Jacobshavn just before dinner to continue southward overnight. During the evening went to a movie **Bounty** (version 3) and no better than its predecessors. During the performance we started to roll more heavily than usual and one especially heavy lurch resulted in a great crash of equipment and a cessation of the screen action - briefly alas. An uncomfortable night wallowing and making sleeping difficult.

Sun Sept. 18

Up at 0700, dressed quickly and to the bridge where H and Ralph were making their approach to Holsteinburg. R told me the lights on the two range marks were visible 12 nm to seaward. H told me he had included in his report that this NWP transit was my fourth. Enjoyed the entry and berthing which was well executed though it should with the availability of a 400 hp bow thruster. Nice to walk down a gangway instead of a zodiac ride. By bus to the school for a walkabout. Back to the jetty and a walk to the local marina where a helpful local told us where John Bockstoce's **Belvedere** is lying. He understood and pointed to the very inner-most head of the harbour and inaccessible on foot. Got as close as possible and took two pictures with a 50 mm lens when I should have had at least 200. During all this the coastal ship **Disko** came in berthing ahead of us. Same red painted hull and about the same size, carrying a large number of passengers.

Slipped and proceeded at 1200 to make room for an incoming general cargo ship - also red.

We continued coastwide to Itivdleq Fjord to anchor off the settlement. 65 people went ashore but we did not having been here twice before. Instead some Egyptian P.T. and then I went to Charles Swithinbank's second lecture on Ice Sheets. 97% of all water on the face of the earth is salt water and 99% of the remainder is ice and 1% is fresh water. An impressive statement. He showed some excellent sides of tabular bergs and I must ask if I may acquire copies.

Highlights. For myself I would list, not in order of preference, the following:

1 The visit to Siberia and Provideniya

2 Our struggle through the ice in the Beaufort Sea

3 The navigation of the shallow channel into Tuk.

4 Visit to Holman and in particular the school there

5 The rendezvous with David Cowper

6 CCGS **Martha L Black** & her help in entering & leaving Cambridge Bay plus Larry Solar's ice information

7 Welcome at Gjoa Haven & telephone calls home

8 My first navigation of Victoria Strait, the ice & the historical significance of the place

9 Bellot Strait, east & west, Magpie Rock & Fort Ross

10 CCGS **Des Groseilliers** at Resolute

11 Beechey Island

12 Encounter with large berg in Lancaster Sound

13 Ditto with berg in Baffin Bay and the polar bear

14 Zodiac cruise around the bergs at Jacobshavn

15 Completion of my fourth NWP transit

In retrospect I should add the day in fog, mist and overcast skies when we were approaching the Alaska-Yukon border and suddenly towards noon, as though through a curtain, we glided into bright sunshine, calm seas and blue sky without a cloud to be seen. Everyone's spirits rose and life took on a cheerier note. This was another timely happening, and a good one, a succession of which punctuated our voyage.

Dinner as guests of Alan Billingsborough, Cruise Director, others included Guy M, Charles S, Ellen and B. Ellen told me that Sabena's introduction to my talk the other day was meant not only as that but also as a sincere tribute and recognition of my role as Ice Master in getting the ship through the Alaskan ice.

Alan, in so many words, asked me what I thought of H - a question I did not answer in such circumstances in public, albeit staff, feeling it would be improper whatever my views. There seems to be a feeling that he has too massive an ego and that he is always grandstanding. I suppose it is a result of all the voyages he has done, including 52 to Antarctica, where he is the focus of admiring attention. I understand Alan refers to him as Bozo (the clown).

Mon Sept. 19

Arrived Gothaab now Nuuk in good time and overcast skies. Watched our approach, embarking the pilot and berthing. So easy with that bowthruster. By bus to the museum and we were impressed. Three buildings, one houses examples of kayaks and oomiaks, also a dory; another some fine sculptures; the last and largest displays many items of interest but the most intriguing is that showing the mummies from Umanak, north of Disko, 400 yrs old of women and at least one infant.

This day I wrote the Introduction to the log of the voyage at Heinz's request. It is a challenge to satisfy his penchant for the high-flown phrase and hyperbole while telling the truth. Sailed out into Davis Strait. During the evening the weather deteriorated and the ship became quite active. Turned in early but with so much pitching, rolling and lurching, it was hard to get much rest.

Tues Sept. 20

Not much sleep. Visit to Frederickshab cancelled due to weather delays so our course was directed towards Narssarsuaq. A day rolling along in a confused swell. Gordon Fountain gave us an informal talk about Admiral Byrd and his 1932 expedition to Little America (mid-point of the Ross ice shelf) on board the barquentine **Bear**.

Captain's farewell dinner but before that in the Explorers' Lounge he made a lengthy speech, including a large chunk of "hidden corners stuff", and in the course of which he made a number of flattering references to my contribution as Ice Master and also presented me with a silver bottle opener. Much applause. Gratifying and appreciated. Champagne flowed again.

When we reach N in the morning the ship will have covered 5,483 nm. It has been an interesting voyage full of happenings and of the six I have made with Lindblad and Society Expeditions this has been unquestionably the best.

Wed Sept. 21

Up early, finished packing and then watched the berthing operation. H always makes a meal of it as though he was berthing a battle cruiser. B and I reluctantly vacated our cabin - 144 - as did everyone else theirs. Waited and wrote as time dragged on. Finally, buses to the hotel; for a fine lunch and yet more waiting. An impressive sculpture of a polar bear and two cubs in the foyer, standing about 12 ft tall, all white. B took a pic.

In the end the chartered 727 arrived with the new lot of passengers. After more delay, we straggled along to the next waiting place - and eventually boarded. Three hours later into Halifax and after a quick rush through

Immigration and Customs back onto a now empty plane save for three of us (Roger Matheson of Vancouver) and off to Ottawa.

So ends another adventure, a fourth successful transit of the NWP and it has been a challenging time. Who would have reckoned on Alaskan ice being the problem. Our attention has been focussed on Larsen Sound and Franklin Strait for too long. Nature is still calling the shots.

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Ottawa Fri Oct. 7

The ice conditions have steadily and quite rapidly deteriorated off the Alaskan coast. I called Dave Johns, Coast Guard, to-day and he confirmed that the arctic pack is hard on the coast from Icy Cape to, and around, Point Barrow. **Pierre Radisson** despatched to assist **Martha L. Black** around Pt B and into open water, in this both ships were unsuccessful and **M.L.B.** has severely damaged both her propellers - loss of blades and bending of the remainder. (Able to make nine knots)

Polar Star was involved too and to no avail. DJ told me the pack is under pressure and now **P. Star** cannot get through to the west and open water. She is down to 40% fuel remaining (those thirsty gas turbines) and has also lost the use of her centerline turbine. **M.L.B.** and **P.R.** have retreated eastward and are presently in the vicinity of Jenny Lind Is. and escape to the east is assured.

DJ told me also in confidence the **John A Macdonald** is topping right up with fuel in readiness for despatch to the western arctic to succor the U.S. icebreaker. What price a Polar icebreaker! Shallow draft icebreakers with their twin screws are vulnerable to damage in heavy going i.e. **M.L.B.** and even **P.R.** which draws only 23 ft because she is designed for the St Lawrence Seaway locks.

Ottawa, Tuesday Oct. 10

According to C.G., **Martha L. Black** is now at Pond Inlet and **Pierre Radisson** in Lancaster Sound transferring fuel to **Sir John Franklin**. **Polar Star**, whose center shaft is now operational, failed again to break through to and around Point Barrow. Permission has been sought, and given, for her to transit Canadian waters to get to the east.

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Appendix A: Alec Douglas, Obituary of T.C. Pullen, 1990.

HBC Archives H2-141-2-2

<u>Captain Thomas Charles Pullen, OC, CD, RCN (Ret'd), 1918-1990.</u>

A great seaman, one of the world's foremost arctic navigators, and an active member of the Anglican laity, Tom Pullen died on 3 August, 1990. At All Saints Cathedral, Ottawa, where his funeral took place on 6 August, there was hardly an empty pew. Former naval persons and serving sailors made up a very large part of the congregation, a naval funeral party escorted the coffin to the cathedral, and naval officers served as pallbearers. The navy, as so many have remarked, has a great sense of occasion. The person to whom the navy and others present were paying their respects for the last time was no exception to the rule, and the ceremony was accordingly appropriate to the circumstances.

The Pullen family has a long and distinguished naval pedigree, one that Tom himself tracked down over the years. It began with Nicholas Pullen, who in 1781 found himself in the Royal Navy and went on to serve for 37 years, achieving the rank of Warrant Officer, and it included sixteen other Pullens who subsequently joined the Royal Navy, the merchant service, and the Australian and Canadian navies. They accumulated between them more than 400 years of service.

The connection with Canada began with Vice Admiral William John Samuel Pullen RN, and his brother, Tom's namesake, Captain Thomas Charles Pullen. It was a remarkable coincidence, in view of Tom Pullen's association with the arctic, that these brothers, early in their careers, took part in the search for Captain Sir John Franklin in the Canadian arctic archipelago. The principal Canadian sailors in the family tree, Tom and his older brother, the late Rear Admiral Hugh Francis Pullen RCN, seem to have been indirect descendants of a third brother in that nineteenth century naval family, an earlier Hugh Francis Pullen (1825-1883). He had served as Paymaster-in-Chief of the Royal Navy.

Tom was born in Oakville, Ontario, where his parents had settled, on 27 May 1918. He fell in love with the navy and ships as early as he could remember, and in 1936 followed his brother into the RCN after going to what is now called Lakefield College School. His early training, like that of all Canadian naval officers of the time, was with the Royal Navy, and he was one of a very successful lot, including Vice Admiral Ralph Hennessy, Vice Admiral William Landymore, Rear Admiral "Bob" Welland, and Rear Admiral "Bobby"

Murdoch. Among the members of this term, however, even if he did not reach flag rank, T.C. Pullen's seagoing achievements stand alone.

His midshipman's journal, the preparation of which was to so many "young gentlemen" a dreadful penance, shows the orderly mind and indestructible enthusiasm that would stay with him throughout his career, both as a naval officer and as Canada's leading authority on ice navigation. His early service in the Second Destroyer Flotilla of the Mediterranean Fleet, perhaps the most efficient, certainly the most competitive part of the Royal Navy between the wars, was an important formative influence. During the Second World War he qualified as a specialist gunnery officer, served in the ships Assiniboine, Chaudiere, Ottawa and Saskatchewan, and spent much more time than he wanted (about a year) at the gunnery school in HMCS Cornwallis, the training establishment near Annapolis, N.S. He was first lieutenant of Ottawa when she was torpedoed on 13 September 1942, first lieutenant of Chaudiere during the long hunt and destruction of U-744 on 5-6 March 1944, and captain of Saskatchewan from August 1944 until October 1945. It is noteworthy that he commanded the RCN's contingent at the Victory Parade in London, England, on 8 June 1946.

In his postwar career he ran the RCN's gunnery school at Halifax (1945-8), managed to take virtually every staff course then available to RCN officers, (the Royal Navy's tactical course, the staff course at the Royal Naval College Greenwich, both in 1948, and the Imperial Defence College in 1958), was the executive officer of HMCS Cornwallis, which was now the New Entry training establishment, from 1951 to 1953, then took command of HMCS Huron for service in Korean waters. He was for a while Commander Canadian Destroyers Far East, before receiving a two year appointment to Naval Headquarters in Ottawa in 1954.

It was in February 1956 that he received the prize of his naval career, command of HMCS Labrador. The navy acquired this Westwind class icebreaker, built in Davies shipyard, Quebec, to give the RCN the capability of navigating in Canadian arctic waters at a time when Canada was participating in the supply of Distant Early Warning stations. Under the command of Captain O.C.S. "Robby" Robertson, RCN, Labrador in that year completed the first deep draft navigation of the Northwest Passage.

Having sailed in the ship for familiarisation in the eastern arctic and Foxe Basin in 1955, Captain Pullen took command, and also assumed the task of Senior Officer, US Navy, US Coast Guard and Canadian Eastern Arctic

DEW-Line sealift convoys in 1956. In 1957, when he was 39 years old, he became the US Navy Task Group Commander for the survey and opening of Bellot Strait. As stated in an obituary published by the London Daily Telegraph "he drove Labrador so hard during 211 days at sea that she sailed through 37,000 miles of largely uncharted waters without dropping anchor once." Pullen was the second and last naval captain of the ship; the navy turned Labrador over to the Department of Transport in 1958. It is safe to say that under naval command the ship had a more purposeful and productive career than it has had since.

In 1960 he took command of the naval air station, HMCS Shearwater, and of the first-of-class supply ship Provider, from 1963-4. He made his mark there by conducting, for the first time, a 20-knot night refueling of the Mackenzie Class Destroyer Escort HMCS Yukon. It was his last seagoing command in the navy. In 1965, as the army, navy and airforce were enduring the transition to a single unified service, he was one of those sailors who decided to follow their avocation elsewhere.

He established himself without pause as a consultant on arctic navigation and an ice master. The "list of credits" in this role is too long to list in its entirety, but it includes six arctic surveys with the Canadian Coast Guard, the 1969 and 1970 voyages of the Manhattan in the Northwest Passage, advice in 1976 for the design and building of icebreakers in Finland, seven seasons serving as ice master in the arctic and one in the antarctic. Tom assessed his most important efforts as the double transits of the Northwest Passage in one season "of that enormous 155,000 ton icebreaker Manhattan"; the successful tow from the St Lawrence of a 12,000 ton process barge "in the face of so many critics who were determined it could not be done"; the completion of four Northwest Passage transits; and the "circumnavigation of Baffin Island, including the navigation of Fury and Hecla Strait and the heavy pack in the Gulf of Boothia, late in the season, and totally unaided". In recognition of his services to arctic knowledge he was appointed to the Order of Canada in 1984, and the Royal Canadian Geographic Society in the same year awarded him the prestigious Massey Medal.

For several years Tom has served on the council of our society, and made lively and useful contributions to the meetings he attended. It always worried him that he was "sailing under false colours", but there was no doubt in the minds of his fellow directors that his presence on the board was of the greatest value. In May, 1990, Tom wrote in a letter, declining the nomination for First Vice-President: "I have continuing commitments now for two companies involved in arctic cruising, and subsequently demands for my services as Ice Master for voyages through the Northwest Passage and also into Soviet Arctic waters leading, it is to be hoped, to an attempt on the Northeast Passage. Three new expedition ships are building to meet a growing demand for these specialist cruises .... It is my determination to carry on being involved in the arctic operationally (rather than in research) for as long as I am physically up to it..."

It was of course that full seagoing life that made him so important to those of us who attempt to write about the sea, and it is the connection between the seafaring community and those who engage in research about it that gives our society its lifeblood. When that letter was written nobody had any idea how soon, how sadly, and in what an untimely fashion his plans would have to be abandoned. The committee chosen by the Admiral's Medal Foundation to select this year's winner of the Admiral's Medal was no exception. Thus it was not until 22 October that Tom Pullen was announced as recipient of the award for 1990. The citation reads:

> For his significant personal contribution to navigation, exploration, geographical knowledge and the advancement of science in the Arctic. By continuing to apply his rare expertise and remarkable intellect to problems of Arctic operations and through his tireless and ongoing studies, he made himself a leading expert in his field, which is of extraordinary and special importance to Canada and to maritime affairs.

The world has lost a precious asset in this modest, supremely competent and good humoured man. We extend our deepest sympathy to his family.

Alec Douglas

Appendix B: Captain T.C. Pullen, *curriculum vitae* (revised, posthumously, 29 July 1999)

HBC Archives H2-141-2-2 (E 346/1/60)

Captain T.C. Pullen
O.C., C.D., Royal Canadian Navy (ret'd),
D.Sc. (Hon), F.A.I.N.A
1306 Chattaway Ave, Ottawa, Canada, K1H 7S4
(613) 733-8352

--ooOoo—

Adviser and consultant on arctic marine operations to governments and industry for 24 years following 30 years naval service. …

Ice Master for four successful transits of the Northwest Passage, two as the Government of Canada's official representative on board the 155,000 tonne icebreaking tanker Manhattan. The third, in 1984 aboard the M/S Lindblad Explorer, realized the centuries old dream of using the passage to reach the orient. The ship sailed from St. John's, Newfoundland to Yokahama, Japan.

Additional operational undertakings include icebreaker operations, arctic towing, convoying in ice, arctic hydrography and oceanography. Author of more than 50 studies and papers for clients on arctic matters.

Commanding Officer of the naval icebreaker H.M.C.S. Labrador. Senior officer of United States Navy, U.S. Coast Guard, and Canadian ships, deployed to the Eastern Arctic for construction of the Distant Early Warning Line, 1956-57. US Navy Task Group Commander for "Operation Bellot"- 1957.

Writer and lecturer on arctic marine operations, the Northwest Passage, and sovereignty issues.

Expert witness in litigation involving mishandling of ships in ice. Witness on arctic marine matters before committees of both the House of Commons and the Senate.

Awarded the Massey Medal of the Royal Canadian Geographical Society, 1984. Appointed an Officer of the Order of Canada, 1984. Doctor of Science (Hon), 1985. Fellow of the Arctic Institute of North America and the Explorers Club.

Awarded the Admirals' Medal, an annual award established by three retired Admirals to recognize work done by former Naval personnel, October 1990 (awarded posthumously).

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Selected Studies & Undertakings

Personnel Considerations in the safe operation of ships transiting the Canadian Arctic. (Melville Shipping - Study - 1985)

Public Lecture series on the successful 9,000 mile transit of the Northwest Passage by the expedition ship "Lindblad Explorer", Ottawa, Toronto and Victoria- 1984.

Adviser to the Federal Environmental Assessment Review Panel on moving Beaufort Sea oil to market by ship. Environment Canada- 1983.

Proposed navigation of the Northwest Passage by "Arctic Shiko". Study and recommendations prepared for Federal Commerce- 1983.

Report to the Department of Fisheries & Oceans on the level of client satisfaction provided by the Canadian Hydrographic Service - 1982.

Consultant to the Govt. of the Northwest Territories for National Energy Board hearings into the shipment of liquid natural gas (LNG) by sea to market by the Arctic Pilot Project- 1982.

Consultant, with Dutch experts, to Dome Petroleum concerning the design and use of icebreaking dredgers in the Beaufort Sea - 1982.

Witness before the Standing Senate Committee on Foreign Affairs (Sub-Committee on National Defence) on the Navy's Arctic role- 1982.

"Manhattan" - the 155,000 tonne icebreaking tanker's Northwest Passage Voyage. Post voyage report to the Dominion Hydrographer- 1970.

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Selected Speeches

Royal Canadian Geographical Society, Convocation Hall University of Toronto.

NORTHWEST PASSAGE—1984.

Canadian Centre for Mineral & Energy Technology, Ottawa, 1984.

THE ARCTIC SHIPS & BRITTLE FRACTURE .

Arctic Circle, Ottawa, 1984.
THE NORTHWEST PASSAGE LINDBLAD EXPLORER IN 1984.

Swedish Trade Fair, Gothenborg, 1983.
THE NORTHWEST PASSAGE -PROSPECTS FOR YEAR-ROUND NAVIGATION.

Arctic Circle, Ottawa, 1982.
TOW OF THE 'ARVIK II TO THE ARCTIC.

Canadian Meteorological & Oceanographic Society, Ottawa. 1982.
ARCTIC SURVEY.

Northwest Territories Chamber of Mines, Yellowknife, 198 2
ARCTIC OVERVIEW.

Royal Nova Scotia United Services Institute, Halifax, 1981
THE ARCTIC MARINE SCENE.

Arctic Circle, Ottawa, 1978.
THE ARCTIC MARINE SCENE.

University College Alumnae Association, Hart House, 1971.
NORTHERN WATERS.

Women's Canadian Club, London, 1971.
THE MANHATTAN's ARCTIC VOYAGES.

Dominion Marine Association, 1971.
IN THE WAKE OF THE 'MANHATTAN'.

Ditchley, Oxfordshire, 1971.
ARCTIC OCEAN CONFERENCE.

Canadian Club, Ottawa, 1970.
LESSONS FROM THE 'MANHATTAN' VOYAGES.

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Canadian Clients

Albery. Pullerits. Dickson & Associates, Toronto
Alfred Bunting & Company, Toronto
Aquitaine

Arctic Canada Transmission Company, Toronto
Baffinland Iron Mines. Toronto
Bechtel Canada, Toronto
Brissct, Bishop, Davidson. (Advocates), Montreal
Canadian Hydrographic Service. Ottawa
Canada Centre for Remote Sensing, Ottawa
Chemacryl Plastics, Toronto
Cominco, Vancouver, Toronto & Yellowknife
DeLeuw Cather. Ottawa
Dept. of the Environment, Ottawa
Dept. of Fisheries & Oceans, Bayfield Lab., Burlington
Dept. of Indian Affairs & Northern Development, Ottawa
Dept. of National Defence. Ottawa
Dept. of Transport, Ottawa
Dome Petroleum, Calgary
Falconbridge Canada, Toronto
Federal Commerce & Navigation, Montreal
German & Milne. Naval Architects, Montreal
Government of New Brunswick. Fredericton
Government of the Northwest Territories, Yellowknife
Great Plains Committee. Toronto
Hudson Bay Mining & Smelting. Toronto
Imperial Oil, Calgary
International Iron Ore Co .. Toronto
James Bay Development Corporation. Montreal
Lalonde. Valois. Lamarre & Associates. Montreal
Lea, Benoit & Associates. Montreal
LGL Environmentalists. Toronto
Leslie Engineering. Toronto
Marinav Corporation, Ottawa
Melville Shipping. Calgary
Montreal Shipping Company, Montreal
Pacific Petroleums. Calgary
Polar Gas Project. Toronto
Protective Plastics, Toronto
Price Pulp & Paper. Newfoundland
P. S. Ross & Partners, Ottawa
Royal Canadian Geographical Society. Ottawa

Strathcona Mineral Services (Nanisivik Mines)
Sun Oil Company, Calgary
TransCanada Pipelines. Toronto
Transportation Development Agency. Montreal
Watts, Griffis & McOuat Limited, Toronto
Western Decalta. Calgary

International Clients

Atlantic Richfield, Seattle
Discovery Reederei, Hamburg, Shipowners & Operators
Donovan, Maloof, Walsh & Kennedy, Solicitors, New York
Henry, J. J., Naval Architects, New York
Holman, Fenwick & Willan, Solicitors, London
Humble Oil, Dallas
Lauritzen, J., Shipowner, Copenhagen
Lost River Mining Corporation, Alaska
Lindblad Travel, New York
Noble Denton & Associates, Ocean Engineering, London
Norton, Rose, Botterell & Roche, Solicitors, London
Raymond and Whitcomb, New Y ark
Salen Lindblad Travel, New York
Salen Shipping Companies, Stockholm
Seatrain Lines, Inc., New York
Society Expeditions, Seattle
Zanen Verstoep NV, The Hague, Holland

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Polar Experience: A Summary

1955	HMCS *Labrador**	Eastern Arctic & Foxe Basin- Distant Early Warning (DEW) Line Sealift familiarization.
1956	HMCS *Labrador**	Commanding Officer & Senior Officer, USN, USCG & Canadian Eastern Arctic DEW-Line Sealift Convoys.
1957	HMCS *Labrador**	Commanding Officer & US Navy Task Group Commander for "Operation Bellot", the survey & opening of Bellot Strait.
1965	CCGS *John A Macdonald**	Eastern Arctic (Milne Inlet, Eclipse Sound, Baffin Bay) route survey for Baffinland Iron Mines.
1966	CCGS *d'Iberville**	(as for 1965)
1967	CCGS *John A Macdonald**	(as for 1965)
1968	CCGS *Camsell**	Alaskan & western arctic sea route survey to Coppermine, NWT, from Point Barrow, Alaska, for mining interests.
1969	*S/T Manhattan**	Northwest Passage (Halifax, NS, to the Chukchi Sea & return) as Canadian Government representative, co-ordinator of supporting icebreaker operations, & adviser to Humble Oil (now EXXON).
1970	CCGS *Louis St Laurent**	Second Manhattan Arctic Tanker test voyage to Pond Inlet, Baffin Is. (representing Hudson Bay mining).
1971	USCGC *Glacier**	First survey of winter ice regime in the Bering Sea to assess shipping prospects.
1974	M/S *Lindblad Explorer*	First cruise by an ice-strengthened passenger ship into high latitudes of Canadian arctic waters including Kane Basin.
1976		To Wartsila Shipyard, Helsinki, with Government team Design & building of large icebreakers
1977	M/S *Gothic Wasa*	Ice Master for the first ship to load product at the new lead/zinc mine at Nanisivik, North Baffin.
1978		To the Chukchi Sea, Alaska, to select a port site near Kivalina for U.S. mining interests.
1979	CCGS *Sir John Franklin* *	Hydrographic survey of uncharted Prince Albert Sound, Victoria Is, NWT for Polar Gas Project.

1979	M/S *South Rainbow*	Ice Master. 80,000 ton Swedish bulk carrier. Ice transit, Gulf of St Lawrence.
1980	CCGS *J.E. Bernier**	Hydrographic survey of uncharted Minto Inlet, Victoria Island, NWT, for Polar Gas Project.
1981	O/T *Irving Cedar*	Ice Master. Ocean tow, Three Rivers, PQ, to the High Arctic of the 12,000 ton process barge *Arvik II,* & to represent the owner's interests (Cominco) & prime contractor (Bechtel).
1982	M/V *Lindblad Explorer*	Ice Master for a 7,000 mile voyage Iceland, Greenland and the eastern Canadian arctic
1983		To Prudhoe Bay, Alaska, representing underwriters during ice transit of a 26,000 tonne, $350 million, sea-water treatment plant on tow from Korea.
1984	M/V *Lindblad Explorer*	Ice Master. Northwest Passage voyage from St John's, Nfld, to Yokahama, Japan.
1986	M/V *World Discoverer*	Ice Master. Unsuccessful attempt on Northwest Passage - Greenland to Larsen Sound & return.
1987	M/V *Society Explorer*	Antarctic voyage- Cape Horn, Drake Passage, Antarctic Peninsula, Falkland Islands, Strait of Magellan & Beagle Passage.
1988	M/V *Society Explorer*	Ice Master. Northwest Passage from the Aleutians & Provideniyeh, Siberia to Southwest Greenland.
1989	M/V *Society Explorer*	Ice Master. Greenland., Foxe Channel, Frozen Strait & Hudson Bay

(* denotes icebreaker)

CCGS	Canadian Coast Guard Ship	O/T	Ocean Tug
HMCS	Her Majesty's Canadian Ship	S/T	Steam Tanker
M/S	Motor Ship	USCGC	U.S. Coast Guard Cutter
M/V	Motor Vessel		

Of all the foregoing, a number stand out as having particular significance:

- The double transits in one season of that enormous 155,000 ton icebreaker *Manhattan*
- The successful tow, from the St Lawrence to the high Arctic, of the 12,000 ton process barge in the face of so many critics who were determined it could not be done.
- The completion of four Northwest Passage transits.
- Circumnavigation of Baffin Island including the navigation of Fury & Hecla Strait, late in the season, and totally unaided.

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Captain T.C. Pullen’s Contributions to Arctic Knowledge

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Captain Thomas Charles Pullen (1918-1990), also known as “Pullen of the Arctic,” became a noted authority on and explorer of the Arctic after he took command of the naval icebreaker HMCS Labrador in 1956. After his thirty years of active naval service, Pullen served as an advisor and consultant to government and industry on arctic marine operations for another twenty-four years, earning the reputation as North America’s foremost expert on Arctic navigation and icebreaking. This volume reproduces key consulting reports that he produced for clients on Arctic maritime and development issues from the mid-1960s to the late 1980s, covering a range of subjects from icebreaking conditions, to vessel design and supporting infrastructure needs, to cruise tourism.

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