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Arctic Natural Gas Transport Systems

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WITH THE HIGH COSTS associated with terminal and way facilities in the Arctic environment, the threshold volumes for the economic exploitation of reserves would be expected to be higher than for southern areas. Accordingly, the delivery systems are large to handle high throughput volumes. This so-called "big project" approach is evident for the four current major Arctic gas pipeline proposals—two in North America and two in the USSR. All these projects envisage pipelines at least 2000 miles in length, 48 inches to 56 inches in diameter tapping reserves that range between 11 to 50 trillion cubic feet (TCF).[2] The increasing use of liquid natural gas (LNG) tankers in the world opens another means of moving Arctic natural gas to markets, but in smaller amounts on a gradual or "incremental" basis, extending the life of the field to serve relatively small markets, such as the east coast of Canada. The development of gas reserves beyond 1980 in the very inaccessible Canadian Queen Elizabeth Islands (north of 75°N. latitude) could well be carried out by either "big project" and "incremental" transport systems, involving the pipeline or marine modes, or a mix of the two.

In the past several years, various gas industry consortia have been analyzing this transport problem, and their various solutions are now becoming apparent. The Polar Gas Group has filed with the Canadian National Energy Board a proposal for a 2338 mile 42-inch pipeline from the Drake and Hecla gas fields on Melville Island to Ontario (see Figure 1) for the exploitation of reserves estimated at 11 TCF. The pipeline would have 89 miles of marine crossings, at depths up to 1000 feet. An alternative, and competing project is proposed by Petro-Canada, a government-owned company which would call for this Melville Island gas to be liquified, stored and shipped on ice-strengthened LNG tankers. Two are proposed with a 125,000 M^3 capacity each for a pilot project.[4] Study is now underway for the various support systems required, especially for marine terminals, vessels and navigational systems.

This paper will examine these proposals, highlighting the economics and issues for natural gas exploitation. Reference will be made to gas pipeline projects in other parts of the world, and the increasing use of LNG tankers to supply industrial markets. But first, it is necessary to go back five years to summarize the economic and technical feasibility studies undertaken by industry to narrow its options to the marine and pipeline modes.

MULTI-MODAL ANALYSIS

The Canadian High Arctic (Queen Elizabeth) Islands contain a major hydrocarbon formation, the Sverdrup basin stretching in an arc from Melville Island to the upper portion of Ellesmere Island. Since 1962, a total of 129 wells have been drilled at a cost of over $500 million, or about $4 million per well with a discovery of 6 fields containing only about 11-14 TCF of gas. At least 50% of the cost of each well relates to transportation of rigs, support structures and supplies, and crews. Panarctic which owns the major acreage maintains a logistic base at Rea Point, which receives marine service during the short summer shipping season (August-September), and is served by Hercules, Electra and Boeing 737 and 727 aircraft throughout the year.

While the permanent polar ice pack lies to the north and west, the ice conditions throughout these islands are severe. The 1970 Arctic Waters Pollution Prevention Regulations require ships operating in the western part of the islands to be capable of penetrating 10 FEET of ice at 10 knots. Not only is near-permanent ice cover a problem, but the action of ice along the shoreline presents difficulties for both the laying of pipe and the establishment of marine terminal facilities. Ice scour to depths of 15 feet or more erodes sea-bed and shoreline alike.

The ice conditions, distance from markets (over 2500 miles), and uncertainties of reserves (only about 11 TCF versus more than 30 TCF for the Alcan Pipeline) have given rise to a number of "schemes" to bring the gas out. Various modes, and modal combinations have been proposed, some conventional and some quite unconventional. Because of the distance to markets, some have proposed airlifting the gas using either large fixed-wing vehicles (the Boeing resource carrier),[5] dirigibles or hybrids.[6] Marine possibilities range from a single,

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HIGH ARCTIC SYSTEMS

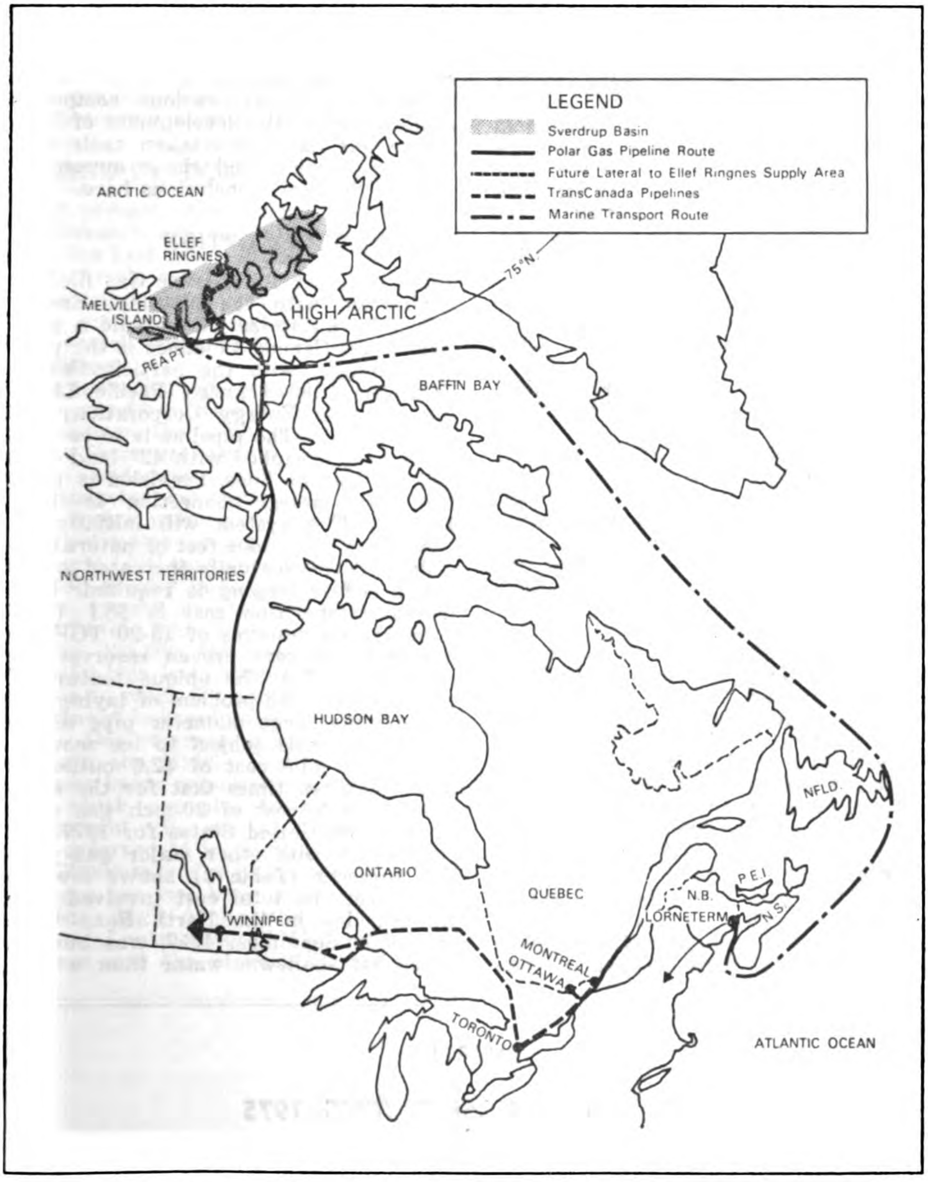

FIGURE 1

highly ice-strengthened vessel moving gas from the High Arctic to east coast markets to several types of vessels working in shifts to traverse the various Arctic marine ice zones. Submarine and semi-submersibles have also been examined, and the operational and cost parameters defined in a preliminary fashion.[7] However, the pipeline option is the only one to be tested in the field so far, in a multi-year (1973-75) engineering program for testing a through-the-ice approach to the laying of marine sections.[8] (Near shore sections will be buried to avoid ice scour.)

In 1973, Acres Consulting (Canada) Ltd. undertook for the Government of Canada an evaluation of the engineering feasibility and operational economics for these various forms of natural gas delivery systems, and this was updated in early 1976.[9] Ellef Ringnes Island (see Figure 1) was chosen as the source point because it is the most remote location, for which substantial quantities of gas have been found in this region. The first phase of the study was to isolate, using a modified Delphi-technique, the most probable modes or modal combinations of modes. The following multi-modal cases were used, for the time frame 1980-2000:

(i) Pipeline: 42" line from Ellef Ringnes following the route of the Polar Gas line:

(ii) Air/Marine: Boeing 747F tankers, carrying 300,000 lb. payloads take gas, in LNG form to a point on Devon Island for transshipment by ice-strengthened tankers of 125,000 M^3 capacity;

(iii) Pipeline/Rail: Gas moves to "mainland" Canada by pipeline, is liquified and then transported by unit train to southern markets;

(iv) Pipeline/Marine: Gas moves to a liquification plant on Devon Island for marine transport.

Reserves were set at over 20 TCF. Only systems considered feasible and likely to be available by 1980 were considered. A standard flow rate of 1.5 TCF per year was used, along with a 10% rate of return on investment. Table 1 sets out the tariffs, costs and fleet size for each.

The B747 and Arctic tanker case is neither "economical or realistic," as is the pipeline/railway one. The pipeline case is slightly more economical than pipeline/marine at 10% return (shown previously), but this position is reversed when a 15% return on investment rate is used. The study concluded that the pipeline/marine system appears to become more attractive at lower reserves. Since the publication of these results (and even before), various companies concerned with the development of High Arctic gas have undertaken their own, in-house studies, and these apparently confirm the basic conclusions here.

THE PIPELINE OPTION

In December 1977, Polar Gas filed an application with the National Energy Board for authorization to build a pipeline. Trans-Canada Pipelines is the project manager, with the participation of Panarctic Oils. Tenneco, Pacific Lighting, Ontario Energy Corporation, and Petro-Canada. The pipeline is to be 2338 miles long, designed with 42" land lines and 36" marine lines. Provision is made for later lateral connection to Ellef Ringnes. The system will initially receive 1.4 billion cubic feet of natural gas a day, to be eventually increased to 3.0 billion before looping is required. Estimated construction cost is $6.1 (1976 dollars) and reserves of 15-20 TCF are required. (Present proven reserves are about 11 TCF.) The unique feature of the project is the problem of laying and maintaining large diameter pipe across marine channels subject to ice scour.

The per mile cost of $2.6 million is more than ten times that for the average per mile cost of 30-inch gas pipelines in the United States for 1977.[10] A comparison with other major gas pipeline projects (Table 2) shows low reserves for the total cost involved. The Ekofisk line in the North Sea, which opened in September 1977, was built in somewhat shallower water than will be

TABLE 1

HIGH ARCTIC CASE STUDIES, 1975

Tariff ($/MCF)	$1.70	2.50	3.60	1.75
Capital ($B.)	$8.9	10.1 (66 Aircraft; 26 ships)	18.9 (84 Train sets of 110 cars)	9.2 (26 ships)
Operating ($M/Year)	196	2,040	550	795
Efficiency* (%)	90	67	86	76

SOURCE: Transportation Development Agency, Tables 5.1 - 5.5

*Delivered energy as a percentage of energy input plus energy used in transport.

the case for Polar Gas, while the ENI Algeria project crosses the Straits of Messina at depths of over 2000 feet. The Alcan project traverses the western Cordilleria mountain ranges, in contrast to the relatively flat tundra for the Polar Gas project. Large diameter pipelines are becoming very expensive.

MARINE SYSTEMS

At present, commercial ice-strengthened vessels can only operate in waters with ice half the thickness of ice in the High Arctic area. However, naval architects are confident that present hull and main machinery technology can provide for vessels that could withstand such conditions.

Examination of marine systems to move gas from the High Arctic has only burst upon the public eye in the past year. There are various confidential reviews underway, both by government and industry, but the basic concept, general design parameters and preliminary cost estimates have been made public.

World LNG tanker operations have expanded greatly in recent years and dramatic growth is predicted up to 1990. In 1974/75, there were no LNG tankers in the 125,000 M^3 class. However, by 1976/80 this is to reach 53; by 1981-85, this is to reach 73; and so on.[11] This requirement is based on a "low case" situation. Gas reserves in southern Alaska, Algeria, the Middle East and Indonesia are now being exploited with these tankers, which are able to serve markets throughout the world. (The Algerian field referred to in Table 2 will support both tankers and a pipeline to Europe.)

There are two basic marine proposals for the High Arctic, the Dome Arctic Marine Locomotive (AML) plus LNG tankers and the Melville Shipping ice-breaking LNG tankers. The former would see a 150,000 horsepower AML with ice-strengthening to permit penetration of the inner area of the Queen Elizabeth Islands to Ellef Ringnes Island (and the King Christian Island gas fields) pushing tankers with ice-strengthened hulls. These tankers, in the less severe ice areas south of 75°N. would then be able to proceed under their own, much lower power. The Melville Shipping concept is to pipeline gas to Melville Island for liquification, and then transport it by ships with somewhat less ice-strengthening than the AML to east coast markets. At present, 10 different propulsion systems (gas and steam turbines with various types of propellers) are being tested. No decision has been reached on where the two 125,000 M^3 capacity vessels for the pilot project are to be built.[12] One earlier suggestion by Panarctic Oils, which owns the gas, was to have a $25 million 400,000 DWT conventional tanker converted in Japan rather than pay in excess of $100 million to build a new one from scratch.[13]

Dome announced in March 1978 the awarding of a design contract for their $125 million AML, with construction not to commence until financing is negotiated with the Federal Government. A leasing arrangement with government has been discussed.[14] However, the rationale for its use rather than Canadian Coast Guard vessels for year-round patrol of the Arctic has been altered somewhat by government approval for its own $300 million, 150,000 horsepower nuclear/gas turbine powered ice-breaker capable of operating in all the areas that the AML would.[15] The proposals for all these vessels do not call for their delivery before 1981-83.

Total project costs are not available for the marine system proposals. The

TABLE 2

GAS PIPELINE PROJECTS

Project	Reserves	Cost Estimate	Length	Cost/Mile
Polar Gas	11 TCF	$6.1 B.	2249 Miles	2.6 M
Alcan	30 TCF	$7.8 B.	2759	2.8 M
Ekofisk (North Sea)	3.3 TCF	$4.0 B.	220	18.2 M
ENI Algeria	54 TCF	$2.5 B.	681	3.7 M
IGAT II (Iran)	35 TCF	$2.5 B.	880	2.8 M

SOURCE: Polar Gas; various issues *Oil and Gas Journal.*

cost of liquification plants is estimated in the area of $ 1 B., subject to reduction through new technology. Vessels range from $100 M. to $300 M. each, with 6 or more required beyond the pilot project phase. Further research is required for the problem of navigational systems for passage through ice-choked waters. Preliminary indications are that total project cost, and tariffs in the south would be lower than for the pipeline project.

One important reason for interest in the marine transport of natural gas is the approval in February 1978 for Tenneco Atlantic Pipeline to construct from Lorenterm, New Brunswick a natural gas pipeline to Rhode Island at a cost of between $4 and $5 billion to carry about one billion cubic feet of Algerian gas a day, starting in 1981. Over the 20-year life of the project, more than 7 TCF would pass through the Lorenterm natural gas facility. Polar Gas intervened against the project. Ultimately, Lorenterm could handle High Arctic gas and ship it west to central Canada and the United States via a new pipeline system. The choice of delivery system could well involve a combination of High Arctic lateral (or collector) lines, marine tankers, and southern pipelines. Or, the pipeline may be used to go all the way.

ISSUE AND PROSPECTS

The evaluation of these two types, or rather combinations of delivery systems will be difficult for the National Energy Board and the Canadian Government. In both cases, present technology will be used, but the cost of adaptation to the Arctic environment will be high. The proven reserves are somewhat low, increasing the risk and the probability of extensive government involvement. (Both Panarctic Oils Ltd., which found and owns the gas, and Petro-Canada which is promoting development of delivery systems are controlled by government.)

The total domestic energy supply and demand picture is now under review and basic questions are being asked as to whether expensive frontier reserves, such as the High Arctic should be brought into production.[16] One opinion is that the Polar Gas December 1977 filing was premature, and while the need for Arctic gas in the future is recognized, the lower costs of new finds in Alberta and British Columbia seem to dictate a delay for the Polar Gas project. The large gamble inherent in the "big project" approach could give way to the "incremental" development of these gas reserves for LNG marine transport. "Panarctic is now pinning its hopes of early sales and cash flow on the Petro-Canada backed LNG project" . . . .[17] The operational efficiency and throughput economics of the pipeline could give way to the more flexible, and in this case somewhat less costly marine mode. The final decision, however, will probably not be made until about 1980.

FOOTNOTES

1 The views herein are the author's and do not necessarily reflect government policy.

2 W. G. Sanders, "Arctic Lines—Today and Tomorrow" in PETROLEUM 2000, Special 75 Anniversary Issue of Oil and Gas Journal, Vol. 75, No. 35 (August 1977), pages 292 - 306.

3 "Proven Need to be Central Issue for Polar Gas Pipeline Authorization," OILWEEK, Vol. 29, No. 3 (February 27, 1978), page 16.

4 "Arctic LNG Pilot Project to have Maximum Canadian Content," OILWEEK, Vol. 29, No. 2 (February 13, 1978), page 15.

5 See pages 190 - 192 in Richard Rohmer, Ultimatum (Simon and Schuster: 1973) for a description of the role for a 16-engine Arctic resource carrier aircraft. Various other aircraft proposals were made to the Canadian Government between 1971 and 1974.

6 "The Induction Lift Systems Transporter is 1200 feet long by 800 feet . . . has a gross weight load of 9 M. pounds, with a minimum of 6 M. pounds deliverable cargo over a range of 3000 miles at $.005 per ton mile . . ." Summary of Presentation to Canadian Government by Induction Life Systems, Inc. of Denver Colorado, June 26, 1972.

7 Northern Associates, Arctic Resources By Sea (Ottawa, 1973)

8 "Critical decision near for Polar Gas," The Oil and Gas Journal, Vol. 73, No. 18 (April 7, 1975), pages 62 - 63.

9 Transportation Development Agency, Arctic Oil and Gas Transportation: Summary and 1975 Update (Montreal, April 1976).

10 "Spending Down for New US Gas Lines," The Oil and Gas Journal, Vol. 76, No. 2 (January 23, 1978), page 36.

11 E. Fariday, "Marine Operations and Market Prospects for Liquified Natural Gas," in LNG 1974 - 1990, Quarterly Economic Review Special No. 17 (June 1974), The Economist Intelligence Unit, Part III, Figure 8.

12 "Propulsion System Studied for Icebreaking LNG Ships," The Globe and Mail, March 2, 1978.

13 "Ship Sought from Japan by Petrocan," The Globe and Mail, October 2, 1977.

14 "Ottawa Interested in Dome Ship Plan," The Globe and Mail, September 30, 1977.

15 "Basic Plan Approved for Giant Icebreaker," The Globe and Mail, March 7, 1978.

16 "Polar Gas to Join Oil Hearings," The Globe and Mail, March 22, 1978.

17 "Frontier Reserve Accessibility Determines Future of Exploration," OILWEEK, Vol. 29, No. 3 (February 27, 1978), page 13.