OIL SPILL COUNTERMEASURES FOR THE BEAUFORT SEA

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INTRODUCTION

A major area for oil exploration in Canada is the southeastern Beaufort Sea. This, along with the adjacent Mackenzie Delta, has an estimated recoverable potential of 22 billion barrels of oil equivalent.* The southeastern Beaufort Sea, unlike offshore areas elsewhere, is ice covered for nine months of the year and is subject to intrusions of moving ice at any time. As a result, offshore exploratory drilling has aroused the concern of the government which has not only the responsibility to ensure future energy supplies but to ensure that disruptions to the society and the environment are minimized in the process.

On July 31, 1973, the Canadian government in a cabinet decision granted "approval-in-principle" for offshore exploratory drilling in the Beaufort Sea. This form of approval means that individual oil companies or consortia who can show that their exploratory drilling plans are well engineered can proceed with the construction of drill ships and offshore platforms. Before drilling is permitted, however, a drilling authority is required. The cabinet decision contained two important riders: firstly, no offshore drilling authorities would be granted prior to the summer of 1975 (this was later changed to 1976 in a statement made by the Minister of Indian and Northern Affairs), and secondly, a "very strict" environmental assessment of the southeastern Beaufort Sea would be required.

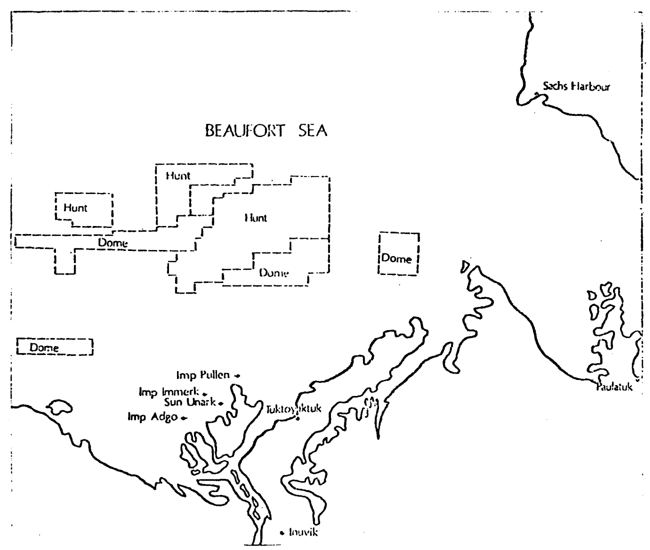

Figure 1. Beaufort Sea: Offshore lease and artificial islands

The Beaufort Sea Project

Twenty million acres are leased in the southeastern Beaufort Sea. This lease area extends from the Alaska-Yukon border in the west to Cape Bathurst in the east (figure 1). The leases extend northward beyond 71°N and some are in water depths in excess of 1,000 metres. Most Beaufort Sea leaseholders are members of the Arctic Petroleum Operators' Association (APOA). The formation of the APOA was encouraged by the Department of Indian and Northern Affairs for joint funding of the research required for the special Arctic conditions under which drilling systems are expected to operate in the Mackenzie Delta. APOA-funded research in the period 1970-1973 cost the petroleum industry $2,500,000 in the support of applications for "approval-in-principle" in the Delta.

When approval-in-principle was granted for Beaufort Sea drilling, the Department of the Environment designed an environmental assessment program consisting of 29 specific studies, with the cost identified at $5,300,000. These studies were designed to be complimentary to the APOA research. After some months of negotiation, the oil industry agreed to support 21 of the 29 studies to the sum of $4,100,000. The balance or $1,200,000 required for the remaining eight studies was to be funded from within the Department of the Environment. An agreement under which the industry was to transfer funds to the government was signed in May 1974. This agreement states that the government will coordinate the Beaufort Sea studies and maintain cost control. Provision is made for an industry project manager to monitor progress on behalf of the oil operators and to jointly, with the government project manager, reallocate funds between studies. Target date for completion of the studies is December 1975.

Objectives

The objectives of the Beaufort Sea Project are:

1. to increase knowledge of the southeast Beaufort Sea so that the Arctic Waters Oil and Gas Advisory Committee, and ultimately cabinet, can rule on petroleum industry applications for offshore exploratory drilling;
2. to define the seasonal and geographical sensitivities of the Beaufort Sea so that the impact of future drilling activities in the region will be minimized; and,
3. to provide a design for a weather and sea-ice prediction system so that drill ships and platforms can do exploratory drilling with a minimum of hazard to their personnel and the environment.

The Beaufort Sea Project is a crash catch-up program which cannot by itself provide full and detailed information on this remote,

*1973 Geological Survey of Canada estimate of 6.2 $\times$ 10^6 bbl of oil and 93.5 $\times$ 10^9 cf of gas where 6,000 cf of gas is the energy equivalent of 1 bbl of oil.

hostile, and ecologically sensitive region. It is important to have clear statements on what is known by December 1975. These statements will be based on knowledge accumulated through many years of arctic research, much of it by the project scientists, and on new knowledge to be collected during the 1974 and 1975 field seasons.

Scope of the project

The scope of the project is defined by three main constraints. Firstly, its concern is with the southeastern Beaufort Sea. Secondly, it is to be completed by December 1975. Thirdly, it is confined to the impact of the exploratory drilling phase of offshore oil operations.

During offshore operations a major threat to the environment is the oil-well blowout. Most drilling could be conducted from drill ships floating in the open water during the short summer season. A well blowout is most probable at the end of the summer, a time when a relief well cannot be drilled with the time remaining before the ice closes. Such a well could run for a year before being brought under control. It has been estimated that, in the Deltaic formations encountered offshore, a blowout would likely produce 2,500 barrels (2,500 × 5.6 ft^3) per day of crude oil initially, dropping to 1,000 barrels per day after one month's time. Accompanying this oil would be 800 ft^3 of gas per barrel of oil, resulting in a release of 325 million ft^3 of gas in one year. Should such a blowout occur in lease acreage north of the fast-ice zone, the problems of detection, oil containment, removal, and cleanup in the moving pack ice in the dark and cold of an Arctic winter could prove to be enormously expensive, if not impossible.

On the positive side, improvements in drilling technology have been significant and the probability of a blowout is greatly reduced where properly trained and alert drilling teams are in control. However, as the number of exploratory holes increase, and as long as human error remains to plague us, a blowout at some future date is almost inevitable.

In the face of a blowout risk, the Beaufort Sea studies have been designed to answer the following questions:

1. What can be damaged in the environment of the Beaufort Sea? Examples are fisheries, marine mammals, birds which depend on the sea, and possibly the world's climate.
2. How are pollutants transported and to where? Important mechanisms about which we know little include the ocean currents, sea-ice movements, and storm surges.
3. If damage does occur, how can changes be identified? For example, the detection of changes in a living system requires knowledge of the system prior to the commencement of offshore drilling.
4. How can exploratory drilling occur with minimum damage to the environment? We need to make knowledgeable choices of the time of year and location where drilling will be permitted.
5. What threats does the environment pose to the safety of offshore drilling? The critical factor here is the validity of the engineering data used for the design of drilling systems.

Scientists of the Arctic Biological Station, near Montreal, the Freshwater Institute in Winnipeg, and the Fisheries Operations group in Vancouver are studying fish, marine mammal populations, and marine ecosystems. The Canadian Wildlife Service in Alberta is studying seabird, seal, and polar bear populations. Physical and chemical oceanographic studies and sea-ice problems which involve the inclusion of crude oil in sea ice, are being undertaken by the Pacific Region of Ocean and Aquatic Affairs in Victoria. Oil detection, containment, and cleanup studies are the responsibility of the Environmental Protection Service in Burlington.

Other work includes marine geophysical studies by the Geological Survey of Canada in Ottawa and by the Bedford Institute in Dartmouth; sea-ice thickness distributions and measurements by the Inland Water Directorate in Ottawa; meteorological studies by the Atmospheric Environment Service in Toronto; ice climatology studies by Ice Central in Ottawa; and Mackenzie River flow studies by the Inland Waters Directorate in Regina.

None of the studies referred to are directly related to the engineering integrity of offshore platforms or equipment. Rather, the concern of the Department of the Environment is with the effect of the intrusion of drilling operations on the environment, and whether or not the environmental data used by the systems and structural engineers in the design of offshore drill ships and platforms is valid.

Oil and ice in the Arctic Ocean

While the scope of the Beaufort Sea Project is limited to the exploratory drilling phase, the results can be applied to the production phase, with perhaps further studies of specific sites undertaken in the future. The assumption has to be made at this time that there will be a step-by-step learning process in development by the petroleum industry from exploratory drilling under environmental constraints to production and transportation, again under environmental constraints.

The realization that large quantities of crude oil could be spilled into the Beaufort Sea has spoused world wide concern for the possibility of producing a catastrophic change in world climate. This concern is displayed in two recent articles by W. J. Campbell and S. Martin [1] and by R. O. Ramseier [2]. These articles, in turn, have produced a rebuttal by R. C. Ayers, Jr., H. O. Jahns and J. L. Glaeser [3]. Although these articles are based almost entirely on speculation, they do point out the necessity for field data on the fate of oil entrained under sea ice, and for more definitive studies on its destiny in the circulating ice of the Beaufort Sea gyre and Arctic Ocean. If large quantities of oil were to be swept up under ice and in open leads, all of it could end up at the surface after a few years. The oil would enhance the decay of the sea ice by reducing its solar reflectivity. In turn, this could result in more open water than usual, which also has a lower reflectivity. If large areas were affected, the ice cover could irreversibly disappear, resulting in a serious alteration in the world's climate.

Oil-in-ice studies

On specific study entitled "Oil-in-Ice" is designed to reduce the speculation surrounding this serious question of the possible spread of oil from a blowout in the southeastern Beaufort Sea. The study includes several key components. The first is a field experiment where crude oil is floated under sea ice within containment booms at various stages of its growth. Here, detailed heat conductivity and solar reflectivity measurements will be made. The second concerns scenarios for underwater blowouts in the offshore lease areas of the Beaufort Sea. The third concerns sea-ice factors which can package, confine and disperse oil in the Beaufort Sea and the Arctic Ocean. A fourth component includes an examination of the year-to-year variations in the natural extent of open water in the Arctic Ocean. These are caused by variations in the world's climate and by other changes such as melting caused by river outflows and atmospheric dust on the ice in the Arctic Ocean. These natural changes will be compared with estimates of change which could be caused by oil entrainment. If the estimate of change in heat flow caused by oil entrainment is several orders of magnitude less than the change in heat flow resulting from the natural year-to-year variations, then the threat to climate could be dismissed.

Countermeasures studies

The main thrust of past APOA industry funded studies has been aimed at the "safe operation" concept of offshore drilling—that is, the best way to deal with a blowout is to make every effort to prevent it. As a result, oil cleanup action plans for blowouts under the sea ice are dismally inadequate. This is not to say that the crude *must* be cleaned up in all circumstances. Our studies must assess what the threat would actually be if no action were to be taken. The objective of the oil cleanup studies is to determine the engineering feasibility and costs of cleanup. Is it possible to detect oil under ice and its extent? Are remote sensing techniques useful? What techniques are available to contain oil under ice? What equipment can be used to pump the oil to the surface and how can it be deployed? How is the recovered oil to be disposed of? These and many more questions must be answered and related to an assessment of the threat of a well blowout.

Progress to date: December 1974

(Progress to March 1975 will be presented at the conference in San Francisco)

As mentioned earlier, the southeastern Beaufort Sea is ice covered for nine months of the year and, for the period of open water, is subject to ice intrusions. Therefore, much of the effort has been directed toward increasing the knowledge of ice, its movements, its distribution, and thickness and to the interaction of oil and sea ice.

A drill ship operating in the Beaufort Sea wants to obtain advance warning of an ice intrusion headed in its direction. Such a warning would allow the suspension of drilling operations and the ship to sail out of the path of the ice. To provide this type of information all of the available historical, climatic, and ice information is being analyzed and computerized in an effort to construct an ice prediction model. This model would take climatic information and, if conditions were favourable for an ice intrusion, predict the movement of the ice.

What are the thicknesses of ice and what is its thickness distribution are questions which must be answered. A study is underway to map the distribution of ice types and open water by the use of satellite and aircraft remote sensing. By overflying on predetermined lines it is hoped to obtain both ice thickness information by UHF radar and ridge distribution and height by laser profilometer. The radar, a prototype, was built and tested in late 1974. It was designed to be helicopter mounted. The Department of National Defense will be supplying a maritime reconnaissance aircraft for laser profilometer. Also in 1974, arrangements were made with NASA-Goddard to analyze jointly Nimbus 5 microwave imagery of the Beaufort Sea area.

The interaction of oil and sea ice is a large study involving both field and laboratory work. Field work is underway at Balence Bay on Cape Parry which is at the eastern end of the Beaufort Sea. Here, eight 100-foot diameter circles made of oil containment boom were positioned in a circle and sea ice was allowed to grow around the booms. Starting just after freezeup in October, eighty tons of crude oil from Swan Hills, Alberta, and Norman Wells, NWT, will be injected under the ice. The oil will be injected sequentially at ten tons to a circle periodically throughout the winter. The last injection is planned for late May just prior to breakup. This field work will investigate oil interaction in ice, the vertical and horizontal migration of oil in ice, the mechanisms by which oil is transported through the ice to its surface, the aging of oil in water under the ice, the loss of the light fractions, and the effect of under-ice surface contours on the horizontal transport of oil and on the mixing and emulsification of oil with cold sea water. In addition to these measurements, an attempt will be made to clean up the spill during or after breakup.

The laboratory section of this study will attempt to determine the destination and direction of oil from a blowout in the Arctic Ocean, the modeling of the oil-gas plume from a well blowout and its dispersal in the water prior to reaching the water surface or the ice, and what effect ice leads have in pumping water from under ice on to its surface.

All of the previously mentioned studies provide useful information in developing the countermeasures to deal with oil in ice-infested and ice-covered water. In the past when oil has been spilled in the Arctic it has usually been onto the surface of the ice or upon water. In-situ combustion was the only method available to the cleanup crews for oil on ice. A study completed several years ago for the Environmental Protection Service indicated that 20% of the original oil remained in, on, and under the ice after in-situ combustion [4]. When one looks at the quantities of oil which might be spilled from an offshore well blowout before a relief well is successful and applies this 20% figure and disregards the air pollution aspects, there is still an excess of 10,000 tons of oil free after in-situ combustion. Therefore, the EPS in their countermeasures studies decided to concentrate on cleaning up the oil as it emerges and spreads from the well. The techniques of oil cleanup on cold water have been applied previously in Canada and could be applied to open water Arctic conditions. All countermeasures studies in the Beaufort Sea are directed to the problem of detecting, containing, and recovering of oil in ice-infested and ice-covered water and to the disposal of this oil in the Arctic.

In the Beaufort Sea various types of sea ice are encountered. These ice types are shore fast ice, transition zone ice where the ice may be built up into pressure ridges or may be nonexistent because of open leads and, finally, pack ice. Countermeasures must be developed to operate in these various ice types.

In order to develop countermeasures, it is necessary to know the state-of-the-art. Therefore, through consultants, EPS is presently assessing available knowledge in the areas of remote sensing, containment, recovery, and disposal of oil.

In the remote sensing study, the consultant is assessing such techniques as multi-spectral scanner, microwave, and radar as to their effectiveness in detecting and quantifying oil in the ice conditions previously mentioned. They also are considering the logistical problems of a remote sensing operation in the Beaufort Sea area. Examining, specifically;

(a) the limitation imposed, by the environment, on a remote aircraft operation
(b) the criteria to be used to judge the suitability for remote sensing in the Arctic environment, and a listing of such aircraft which satisfy these criteria
(c) the availability of airstrips for remote sensing aircraft operations
(d) ground-to-air communications and alerting procedures for Arctic remote sensing operations
(e) the role of the Long Range Patrol Aircraft (LRPA) in Arctic remote sensing

From the results of this study it is anticipated that recommendations will be forthcoming to: (1) fill the gaps in existing systems and/or procedures in the event of a Beaufort Sea oil spill, and (2) identify areas of research and development beneficial to Canada's national interest in remote sensing technology applied to Arctic oil spills.

When oil has been detected and its movements known, the next step is containment. Oil moved under ice by the water currents will rise to the water surface when a lead of sufficient width is encountered. Taking advantage of this fact, a consultant is studying the problem of creating artificial leads or trenches in ice. These trenches would be sufficiently wide to allow recovery equipment to operate. The trenches can be created by mechanical equipment and/or explosives. The fastest method will be the best for countermeasures. In addition to the method of opening sea ice, the consultant will be looking at:

(a) the effectiveness of the technique with relation to the various ice types
(b) size, location and number of trenches required
(c) location of equipment stockpiles and the quantity of equipment at each stockpile
(d) logistics of equipment deployment in a spill event
(e) methods of keeping the trenches open.

Not all of the oil will move toward these trenches as it is anticipated that under-ice hummocks and the keels of pressure ridges will contain a portion of it. The recovery of this trapped oil is a third study. A consultant is investigating methods by which sea ice can be penetrated rapidly to these oil pools and the method of withdrawing this oil. After the oil is brought to the surface of the ice, it has to be handled. The consultant is also investigating what equipment is available to pump, separate, and hold recovered oil in the temperatures which will be experienced in the Arctic winter. These temperatures can dip to −50°C.

On the basis of his studies, the consultant is also charged with the responsibility of preparing conceptual designs of self-propelled and contained modules that can accomplish: (1) the ice penetration and oil recovery operation, and (2) the oil/water transfer and separation function plus facilities for holding the separated oil prior to disposal. All of the modules and holding facilities will be expected to operate offshore on the sea ice.

Finally, the disposal of recovered oil is to be considered. The Arctic area, as Dr. Ross mentioned, is extremely fragile and slow to recover from stress; therefore, the feasibility of disposal in the Arctic or whether the oil should be moved south for disposal is also to be considered. Because of this, the consultant is investigating methods of disposing of the oil. Some of the disposal alternatives are:

(1) in-situ combustion

(2) burial
(3) microbiological degradation
(4) mechanical combustion.

In all of the Beaufort Sea studies outlined in this paper, EPS's basic objectives are to assess the best practical technology and, thereby; obtain direction for future Arctic technology development.

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