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Wilfred R. McLeod

Diana L. McLeod

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OIL SPILL CONTAINMENT AND REMOVAL IN ARCTIC ECOSYSTEMS

Wilfred R. McLeod   Diana L. McLeod

Marathon Oil Company
Houston, Texas

ABSTRACT

Statistics on 16 arctic and subarctic oil spills, their locations, the amount of oil spilled, combatant schemes used, and causes for the spills were culled from the literature. This information has been used to analyze the effectiveness of available chemical, mechanical, and destructive means of oil recovery or disposal under arctic and subarctic conditions.

The choice of the best cleanup procedures to follow in any particular instance is clouded by a number of variables and must be weighed against such considerations as wind, sea, and ice conditions, properties of the oil, and effects of chemicals on marine and wildlife. Access to remote arctic sites may well create a major difficulty.

Some recommendations for further research on these problems are also given.

INTRODUCTION

For the purpose of this paper, temperature is the only criterion used to define the limits of the arctic and subarctic regions (Fig. 1). The arctic region is the region in which the mean temperature for the warmest month is below 50°F and the average annual temperature is no higher than 32°F.[1] The subarctic region is the region in which the mean temperature for the coldest month is below 32°F, where the mean temperature of the warmest month is above 50°F, but where there are less than 4 months with a mean temperature above 50°F. The total arctic and subarctic water area is almost 10 million sq miles, compared with approximately 2 million sq miles for the arctic and subarctic land area. The total land and water area is more than 20 percent of the area of the earth.

Oil companies operating in the arctic and subarctic regions are taking greater precautions than ever before to protect the environment. In part this action has been forced upon them by public outcry; but it has also been taken because of technical problems associated with the environment as well as an increased awareness of responsibility to future generations. Their greatest concern is probably associated with the subsequent distribution of the oil.

It is inevitable that oil will get into the arctic and subarctic waters as a result of ship casualties, by accident, or through deliberate discharging of oil into the sea. The main problem facing governments and industry is that of planning effective countermeasures to keep spillage within acceptable limits.

Case histories of 16 arctic and subarctic spills have been analyzed to determine the suitability of current cleanup techniques under these conditions. Fig 1 shows the location of each spill event. The Appendix lists information pertinent to each event.

Behavior of Oil Spilled on Water

Observations made on small-scale tests carried out by the U.S. Coast Guard (USCG) in the arctic failed to discern the changes in spreading regimes as postulated by Blokker and others.[3-7] Comparisons of these theories with field data have not shown good results. This may be due in part to inaccurate field observations or in part to inadequate theories.

Behavior of Oil Spilled on and Under Sea Ice[15, 109]

There are no acceptable theories for predicting the rate of spreading of spilled oil on or under sea ice. However, observations made by various researchers indicate that the rate of spreading of oil spilled on sea ice will vary with the volume and temperature of the oil, with surface conditions, with the configuration of the ice, and with wind speed. A degree of absorption will take place in the surface layers of the ice.

Case studies, along with USCG tests, have indicated the containment possibilities of sea ice. Oil that has found its way under ice will accumulate on the underside of the ice. If the underside contains pressure ridges or pockets, the oil will be bound to the ice by capillary action. Even where the underside of the ice is smooth, the oil adheres more to the ice than to the sea water. This is evidenced by the fact that it is often possible to cut a hole in the ice and, by directing an airstream into the hole, push oil towards a collection point downwind from the sources of the airstream.

CLEANUP METHODS

The containment, collection, and destruction methods currently used to clean up oil spills are shown in Fig. 2. Any or all of these methods may be employed in any given spill event.

Booms and Oil Barriers[12-15]

The popular view is that although the boom concept offers potential for all oil-spill cleanup operations, none of the existing designs have yet proved effective in containing spills in sea states of 3 or greater. This would be particularly true when the containment of oil slicks is attempted in conjunction with or in proximity to ice in its many forms, when such ice will cause an overload on the barrier or boom, ultimately resulting in failure of the containment device.

Slickbar, Inc.,[12] reported that during winter testing of some prototype booms, they accumulated a large quantity of broken skim ice with a section of boom without any adverse effects. The Marsan Corp.[13] carried out attitude tests and evaluated their oil barrier in ice conditions in Lake Michigan in open water with pack ice adjacent where the ambient temperature was below 20°F. Subfreezing conditions did not affect the operation of the boom.

It would be absurd to expect booms or barrier systems to withstand the forces exerted by icebergs, ice floes, or sizable chunks of free-floating ice.

Nevertheless, most oil booms or barrier systems can withstand the cold arctic conditions; that is, they can exceed cold crack tests at temperatures below possible arctic water temperatures. As a result there would be many instances when commercial booms or diverting barriers would be extremely useful if deployed carefully with an understanding of the existing conditions.

Skimmers[16-22]

Mechanical skimmers are being routinely used to remove surface oil from calm water in harbors and waterways. The effectiveness of skimmers in the open sea is yet to be demonstrated.

During the Chedabucto spill, skimmers were used successfully in sheltered water. At the Deception Bay spill, skimmers successfully removed 21 tons of spilled oil. There seems to be a definite place for skimmers in arctic and subarctic cleanup; however, because of the random nature of ice floes and chunks of free-floating ice, skimmer size can become a liability. Therefore, for transportability and maneuverability it probably would be more desirable to use small skimmers in gangs where large capacities are needed.

Dispersants[10, 23, 24]

Ecological considerations, practical experience in this country and abroad, and recent technological developments in the handling of oil spills have pushed the chemical dispersants very much out of the picture. Both the U. S. and Canadian Federal Contingency Plans[66, 67] discourage the use of chemical dispersants, recognizing at the same time that undoubtedly there will be times when dispersants may be the best defensive measure.

In the few instances in which chemical dispersants were used on offshore arctic and subarctic spills, their performance was disappointing. The problem of near-freezing water temperatures, sometimes compounded by the presence of slush or solid ice, caused the viscosity of the oil to increase until dispersants had little effect. Under these conditions, it is extremely difficult to properly apply enough mixing energy to allow the dispersant to work well. In tests carried out in the arctic, the USCG found chemical dispersants inpractical both on water and on ice for the reasons just cited.

Absorbents[25-32]

Generally, tests as well as use in field conditions have shown that the processed materials, such as polyurethane foam, absorb greater volumes of oil per unit weight of sorbent,[15,31,32,109] but natural materials, such as straw, peat, or bark, are more readily available at much lower costs. A common characteristic of all absorbents is that they must be spread on the spill before the oil viscosity increases to the point that absorption is no longer possible. In addition, oil-in-water emulsions, which are difficult to absorb, will eventually form as a result of wave agitation.

As far as the arctic and subarctic offshore areas are concerned, only straw and peat have been tested for their absorbing capacity. Straw has long been a favorite for use in oil-spill cleanup. It is readily available in large quantities, comparatively inexpensive, and absorbs up to five times its weight in oil. Many competent authorities agree that peat has a definite place among oil absorbents. The Irish and Finnish Peat Boards, reporting the results of their own tests, agree that peat possesses the hydrophobic and oleophilic properties that qualify a sorbent for use against oil slicks.[31] Artificially dried peat is more markedly water repellent and appears to be a more satisfactory oil absorbent. It has also been pointed out that while crude oil and distillate oils at normal temperatures are almost instantaneously absorbed by peat, the effect falls off as the oil becomes more viscous. Interestingly enough, during cleanup operations after the wreck of the Arrow in Chedabucto Bay, it was found that the Bunker C oil may not have been absorbed by the peat but that it merely adhered to the surface of the particles in such a way that the whole mass could be removed cleanly. Suitable peat is presently receiving wide use as an absorptive agent in Scandinavian harbors.

The primary difficulty in using absorbents lies in distributing them over the slick, and then harvesting and disposing of the oil-soaked material. Equipment for spreading and harvesting is available for most commercially manufactured absorbents. Natural products such as straw and peat are for the most part laboriously spread and collected by hand. The lack of mechanical means of spreading and collecting these materials has limited their use on large offshore spills. These difficulties have been noted in the arctic tests, and as a result, straw is rated superior to peat on the basis of handling ease along. Although the peat did prove to be more difficult to spread and pick up, the data show that it absorbed more oil both on water and on ice than did the straw.

Some studies have indicated that both peat and straw could be burned in place once the oil has been absorbed. Peat has been successfully burned in place in a number of instances. The Finnish researchers have found it possible to ignite and burn oil mixed with peat even during wintry conditions in water. For best results, the peat must contain less than 30 percent moisture, and a small area of the slick must be covered with peat soaked in kerosene or diesel oil to facilitate the igniting of the oil-soaked peat.

Burning[32-39]

Experimental as well as actual oil burns in the arctic and subarctic with and without fire promoters and burning agents involving oil on cold water and oil on ice have demonstrated the effectiveness of this method. In reporting the results of their arctic burns, the USCG made the following observations: (1) The ability of North Slope crude oil to burn seems to be virtually unhampered by its residence on ice. (2) The burning agent has some effect on the residue. (3) Ice and snow aid combustion by providing a wicking action. (4) The wind is a definite factor in forcing the oil into pools thick enough to support combustion without the presence of burning agents. It was also observed that above a certain wind velocity, blowing snow extinguishes the fire. Snow either blowing or falling onto oil will form a "slush" containing up to 80 percent snow.[109] Since these slushes will not ignite, they present a considerable cleanup problem. At the present time, the only means of disposal seems to be to collect the slush, melt the snow, and then separate the resulting oil-water mixture. This becomes a laborious and difficult procedure if one is dealing with a large spill in an isolated arctic location.

The U. S. and Canadian governments agree that burning agents and techniques may be used and are acceptable, so long as they do not in themselves, or in combination with the material to which they are applied, increase the pollution hazard.

Biodegradation[40-50]

There are hundreds of articles in the literature pertaining to hydrocarbon microbiology. Refs. 40 through 45 are among those most often quoted.

Kriss[40,41] points out that although the arctic and subarctic waters are areas of very low microbial population density, these regions are highly likely to contain more strains of microorganisms that hydrolyze proteic substances and ferment carbohydrates--petroleum-metabolizing bacteria--than are the tropical regions. He also observed that there are seasonal fluctuations in the development of microbial life in the central part of the arctic ocean under the pack ice. The period of depressed activity corresponds to the advent of the dark period of the year and occurs in spite of the practically unchanging temperature of the water.

The rate of decomposition of oil by microbial action depends on the number and type of organisms present, the amount of oxygen available, the physical state and chemical nature of the oil, as well as many environmental factors; it is by no means easy to predict. In general, the process seems to be more rapid if the oil is in the form of an oil-in-water emulsion, oil adsorbed on solids, and thin flims of oil floating on the sea than if it is in a large coherent mass. It is widely recognized that sinking agents and dispersants may also affect the rate of bacterial degradation. However, studies to determine these effects have thus far been inconclusive. Even the highest estimated rate of biological decay (350 gm/cu in/yr) would be much too slow to rely on as a way of cleaning up major oil spills.

Recently there has been much speculation on the seeding of oil slicks with microorganisms to hasten the natural degradation process. Whether or not this approach is practical is still open to question.[47]

CONTINGENCY PLANS[66-70]

The federal governments of both Canada and the U. S. have drawn up contingency plans for oil spills that not only serve as a guide for action on the national level in case of massive spills, but also provide an outline for the development of regional and local planning in the event of small spills.[66,67] Both plans show a number of similarities. Each country and its offshore areas is divided into several regions and subregions. On-scene coordinators (OSC) are provided for and their duties are defined. Alerting and reporting procedures in the event of an oil spill are designated. Recommended techniques and equipment for handling oil spills are described. But the actual procedures to be followed for any given spill are left to the discretion of the OSC, who must consider such factors as location and size of spill, weather conditions, and the environmental effects of the spilled oil and of the cleanup techniques.

Private companies and oil company cooperatives have also formulated their own contingency plans in accordance with federal regulations. By the end of 1972 there were 84 cooperatives in operation in the U. S., and at least 17 others were being developed. Their contingency plans are expected to enable the petroleum industry to handle minor or moderate spills without direct assistance from federal sources.

To our knowledge, there is currently only one U. S. cooperative in operation in the arctic and subarctic regions - the Cook Inlet Cooperative, formed in May 1970.

CONCLUDING REMARKS

In the Arctic, whether on land or water, most of the currently available cleanup methods will find applications although human discomfort coupled at times with visibility-limiting conditions will hamper control and recovery efforts. This, in turn, will cause the unit cost of cleanup to vary considerably.

In the 16 arctic and subarctic spills studied, commercial booms have, for the most part, been disappointing because the oceanographic and environmental conditions encountered were more or less outside the accepted range of applicability of current designs.

In field tests carried out by commerical boom manufacturers, sub-freezing temperatures do not affect the performance of their booms. Therefore, it is more likely that oil barrier boom systems will find use in arctic and subarctic waters provided open water could be assured. Unconventional booms made of such materials as logs or wire and spruce boughs are also a likelihood.

The case studies along with the USCG tests have indicated the containment possibilities of sea ice. Oil which has found its way under ice will accumulate on the underside of the ice. If the underside contains pressure ridges or pockets, the oil will be bound to the ice by capillary action. Even where the underside of the ice is smooth, there is greater coupling between the oil to the ice than to the sea water. This is evidenced by the fact that it is often possible to cut a hole in the ice and by directing an airstream into the hole push oil towards a collection point downwind from the sources of the airstream.

Ice floe or iceberg "booms" are another possibility since some oil companies active in the Arctic have shown that the idea of "roping" an iceberg and towing it into a pre-designated position is feasible.

The use of chemical dispersants has not been ruled out by either the U. S. or Canadian environmental agencies. Generally speaking, it is unlikely that existing water-base dispersants would be useful in the Arctic since most of them would freeze in the extreme cold. It is possible that a new generation of non-water-base dispersants may find use.

Physical removal of an oil slick is the most positive way of dealing with oil pollution. Absorbents offer such a means. Laboratory tests have shown that commercially prepared absorbents such as polymeric foams, polyethylene and polypropylene fibers have the highest sorption capacities for oils. However, these materials have not been used extensively in oil spill clean-up because of their relatively high cost in comparison to such naturally occurring absorbents as peat and straw. In arctic and subarctic regions where availability of the natural absorbents and distance of the spill from logistic supply sources are significant factors, the higher absorptive capacities and the secondary recovery features of synthetic materials may offset the initial cost advantages of the naturally occurring absorbents. Another advantage of the synthetic materials may be that they produce cleaner residues when the oil-soaked absorbent is burned.

In those spill events where clean-up procedures are described, burning is the ultimate method of oil disposal. Field tests demonstrated that North Slope crude and Arctic diesel oil will ignite and burn on ice, snow or in cold water either with or without fire promoters. It is suspected that the disposal of

Bunker C or other heavy oils by burning would require the use of burning agents. However, the added task associated with the removal of the increased residue resulting from the use of fire promoters is of concern.

The primary areas for further research seem to be in the development and manufacture of cheaper synthetic absorbents with high oil absorption capacities, means of mechanically spreading and collecting the absorbent, harvesting oil from the absorbent, and re-use or disposal of absorbents. In addition, investigations should be carried out on collection and disposal of residues from burning and treatment or disposal of snow-oil slushes.

During test spills, absorbents were spread and collected manually. In the event of a large spill, however, more effective and faster methods requiring fewer man-hours would undoubtedly be necessary. Moreover, some means for mechanically mixing the absorbent with the oil may be required to insure optimum performance. Recovery of the absorbed oil and subsequent re-use of the absorbent offer a potential economic benefit in the reduction of cleanup costs.

If weather and slick characteristics permit, burning can dispose of 70 to 90% (by volume) of the spilled oil. Disposal of the burned residue from large spills could present a pollution problem approaching in magnitude that of initial treatment of the spill. Schemes for removal and ultimate disposal of this residue need to be developed.

Snow either blowing or falling onto oil will form a "slush" containing up to 80% snow.[109] Since these slushes will not ignite, they present a considerable cleanup problem. At the present time, the only means of disposal seems to be collecting the slush, melting the snow, and then separating the resulting oil-water mixture. This becomes a laborious and difficult procedure if one is dealing with a large spill in an isolated Arctic location. An effective scheme for dealing with these slushes will also be needed.

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APPENDIX

Case Histories: Arctic and Subarctic Spills

Date of Spill: Spring 1958.
Location: Mackenzie River (Norman Wells) Canada
Cause and Extent of Spill: A break or draining of a pipeline across the river ice spilled an undetermined amount of crude oil on the ice.
Environmental Conditions: River iced over.
Cleanup Procedures: Oil confined by log booms and burned.

Date of Spill: Winter 1968-69.
Location: Tuktoyaktuk Harbor, 26 km east of the Mackenzie River Delta.
Cause and Extent of Spill: A leak or break in a large fuel tank owned by Northern Transportation Co. Ltd. spilled thousands of gallons of diesel fuel onto the ice.
Environmental Conditions: Harbor was iced over.
Cleanup Procedures: Local residents scooped up most of the fuel, separated it from ice and snow in barrels, and used it to augment their supply of household fuel.

Date of Spill: March 3, 1969.
Location: Cook Inlet, Alaska.
Cause and Extent of Spill: The tanker Yukon was damaged when it struck a submerged object and spilled a small amount of oil into Cook Inlet. The Coast Guard reported an oil slick 10 miles wide and 18 miles long.
Environmental Conditions: None given.
Cleanup Procedures: Chemical dispersant was flown to the site but not used. Surveys a few days after the incident revealed no trace of oil. It was assumed the oil was dispersed by ice and heavy tides.

Date of Spill: June 23, 1969.
Location: Cook Inlet, Alaska (II).
Cause and Extent of Spill: Because of machinery and a considerable internal spill of fuel oil, a Liberian tanker left a wake of contaminated water the full length of Cook Inlet.
Environmental Conditions: None given.
Cleanup Procedures: None.

Date of Spill: Dec. 2, 1969.
Location: Channel between the islands of Emasalo and Kalvo, Finland.
Cause and Extent of Spill: Oil thought to be discharged from the engine room of the 43,000 DWT Greek oil tanker Neil Armstrong caused an oil film approximately 3 to 4 km x 200 m.
Environmental Conditions: None given.
Cleanup Procedures: None given.

Date of Spill: Dec. 9, 1969.
Location: Ajax Shallows, 17 km southeast of Hanko at the entrance to the Gulf of Finland.
Cause and Extent of Spill: 5,860 DWT Finnish cargo ship Eira went aground and sank, releasing approximately 15,000 liters of diesel oil. A slick approximately 18 km x 20 to 30 m was observed.
Environmental Conditions: Snowing.
Cleanup Procedures: Booms - used unsuccessfully. Burning - oil was burned using paraffin oil as a fire promoter.

Date of Spill: Dec. 15, 1969.
Location: West of Emasalo, Finland.
Cause and Extent of Spill: 50,000 DWT Russian tanker, the Raphael, went aground, spilling more than 60 tons of crude oil, which formed a slick 10 km long and several meters wide.
Environmental Conditions: Snowing.
Cleanup Procedures: Booms - used unsuccessfully. Burning - peat, fuel oil, and petrol used as fire promotors and burning agents to remove 90 percent of spilled oil.

Date of Spill: Feb. 4, 1970.
Location: Chedabucto Bay, Nova Scotia.
Cause and Extent of Spill: The Liberian-registered tanker, Arrow, carrying 16,000 tons of Venezuelan Bunker C fuel oil went aground and broke up, spilling most of the oil into the bay. Several slicks formed and 190 miles of coastline were polluted.
Environmental Conditions: Water temperature 0°to 1°C; air temperature much lower. Storm winds 40 to 50 mph. Severe wave conditions. Water depth, about 100 ft.
Cleanup Procedures: Booms - floating booms were unsuccessful. Homemade booms of wire mesh covered with spruce boughs were more successful than commerical semiflexible, nonporous booms. Skimmers - "slick-lickers" were used successfully in sheltered waters. Dispersants - Corexit 8666 was sprayed on the slick, but could not penetrate thick layers of oil that

formed as a result of low temperatures and weathering; BP1100B was effective in removing oil on rocks. Absorbents - peat moss proved to be a good absorbent; straw was used on some beaches. Burning - wicking agent, SeaBeads, used successfully on beaches and on isolated slicks in 1° to 2°C water; part of spill was burned by spilling two drums of fresh oil and igniting it with Kontax; onshore oil deposits at Arichat were ignited with mapalm and a flame thrower and burned well.

Date of Spill: Feb. 1970.
Location: Kodiak Island, Alaska.
Cause and Extent of Spill: Ballast discharges from tankers enroute to Cook Inlet washed ashore, polluting 1,000 miles of shoreline.
Environmental Conditions: None given.
Cleanup Procedures: None.

Date of Spill: March 20, 1970.
Location: Tralhavet Bay, Sweden.
Cause and Extent of Spill: The tanker Othello collided with another tanker, the Katelysia, spilling 60,000 to 100,000 tons of Bunker C fuel oil The oil formed large blobs 0.45 to 0.6 in. in diameter, which sank except for a few centimeters showing at the surface.
Environmental Conditions: Low temperature; harbor ice was in the process of breaking up.
Cleanup Procedures: Because of the coldness of the waters and the formation of icepacks, the dispersants, absorbents, and containment booms were impractical. Wicking agent Cab-O-Sil ST-2-0 was used successfully to burn oil.

Date of Spill: April 1970.
Location: Unimak Island, Alaska.
Cause and Extent of Spill: Spill of highly toxic diesel oil of unknown source polluted shores of Unimak Island.
Environmental Conditions: None given.
Cleanup Procedures: None.

Date of Spill: April 25, 1970.
Location: Alaska Peninsula, Egegik to Port Moller.
Cause and Extent of Spill: Diesel fuel from two Japanese ships that sank in a storm April 21-22, 1970, formed a slick 10 miles wide, which washed ashore, polluting 700 miles of coastline.
Environmental Conditions: None given.
Cleanup Procedures: None.

Date of Spill: June 6, 1970.
Location: Deception Bay, Quebec (Western Judson Strait).
Cause and Extent of Spill: A slush avalanche moving through a tank farm damaged five storage tanks, which spilled 369,000 gal of arctic diesel fuel and 58,000 gal of gasoline. The affected areas were the permafrost just below the tank farm, the shorefast ice, the tidal crack network, and the sea ice.
Environmental Conditions: A flat expanse of sea ice covered all of the bay and closely spaced blocks of ice over most of the intertidal zone. Daytime temperatures ranged from 34° to 40°F. Winds varied from calm to 35 mph.
Cleanup Procedure: Skimmers - a skimmer of 7 kg/sec capacity was used to reclaim 21 tons of oil trapped in pools. Burning - oil on the ice and contained by near-shore ice was burned; the remaining oil was pumped onto the ice from the water and burned. All of the oil was cleaned up by repeated burns.

Date of Spill: June 6, 1970.
Location: Athabasca River, Alberta, Canada.
Cause and Extent of Spill: 17,000 bbl of oil spilled onto the river bank from a break in a 16-in. pipeline. Oil in the river was carried rapidly downstream to the Athabasca Lake.
Environmental Conditions: 45-mph winds.
Cleanup Procedures: Booms - booms were set up to prevent the flow of oil into the Slave River system. Skimmers - a "slick-licker" was brought in but not used for lack of a suitable mounting craft and because of high winds. Winds dispersed the spill within 2 days.

Date of Spill: July 1970.
Location: Oslofjord, Norway.
Cause and Extent of Spill: Deteriorating fuel tanks of a German cruiser that had sunk on April 9, 1940, in about 33 ft of water released oil into Oslofjord. The tanks contained about 1,800 metric tons of oil.
Environmental Conditions: None given.
Cleanup Procedures: None given.

Date of Spill: Sept. 7, 1970.
Location: 47°22'N, 63°20'W in the Gulf of St. Lawrence near Prince Edward Island.
Cause and Extent of Spill: The oil barge Irving Whale sank in 75 m of water. It carried approximately 4,000 tons of Bunker C fuel oil (pour point 12°C). Within 3 days, leaking oil formed lenses occupying an area 30 km long and 15 km wide.
Environmental Conditions: Water temperature was 12°C at the surface and 0°C at 75 m under the surface. Four days after the sinking, a storm caused winds of 10 m/sec.
Cleanup Procedures: Booms - booms were used to protect harbors and shore; a boom around the barge sank after 4 days of high winds and heavy seas. Absorbents - peat moss was spread on the bands of oil. Dispersants - limited amounts of dispersants were used. High winds and waves caused by the storm broke up the oil slick. Weathered oil lumps, which later washed up on beaches, were easily removed with forks and shovels.

U. S. Coast Guard Oil-Spill Test Program

Date of Spill: Summer 1970.
Location: Point Barrow, Alaska.
Cause and Extent of Spill: The U. S. Coast Guard conducted tests to study the behavior of oil in the arctic and possible cleanup procedures. Approximately 55 gal of North Slope crude oil was used in each of several tests.
Environmental Conditions: Ice temperature - 0.3°C. Water temperature - 1° to 2°C. Air temperature - 1° to 4.8°C.
Cleanup Procedures: Burning - fresh and 6-day-old crude oils ignited and burned well both on water and on ice; no difference in ignition and burning was noted when either a glass bead or fumed silica burning agent was used. Absorbents - peat moss and straw were effective absorbents, with peat moss showing greater absorption both in water and on ice; however, straw was much easier to handle. Dispersants - chemical dispersants tested were judged impractical because conditions made it difficult to supply adequate mixing energy.

Date of Spill: Jan. and Feb. 1972.
Location: Port Clarence Bay, Alaska.
Cause and Extent of Spill: Further U. S. Coast Guard tests. Approximately 55 gal of North Slope crude oil was used in each of the tests.
Cleanup Procedures: Burning - 24-hour-old crude oils burned well on both snow and ice without the use of burning agents; approximately 70 percent of the oil

on snow and 90 percent of that on ice was destroyed by burning; fires were extinguished when winds increased above 14 knots.

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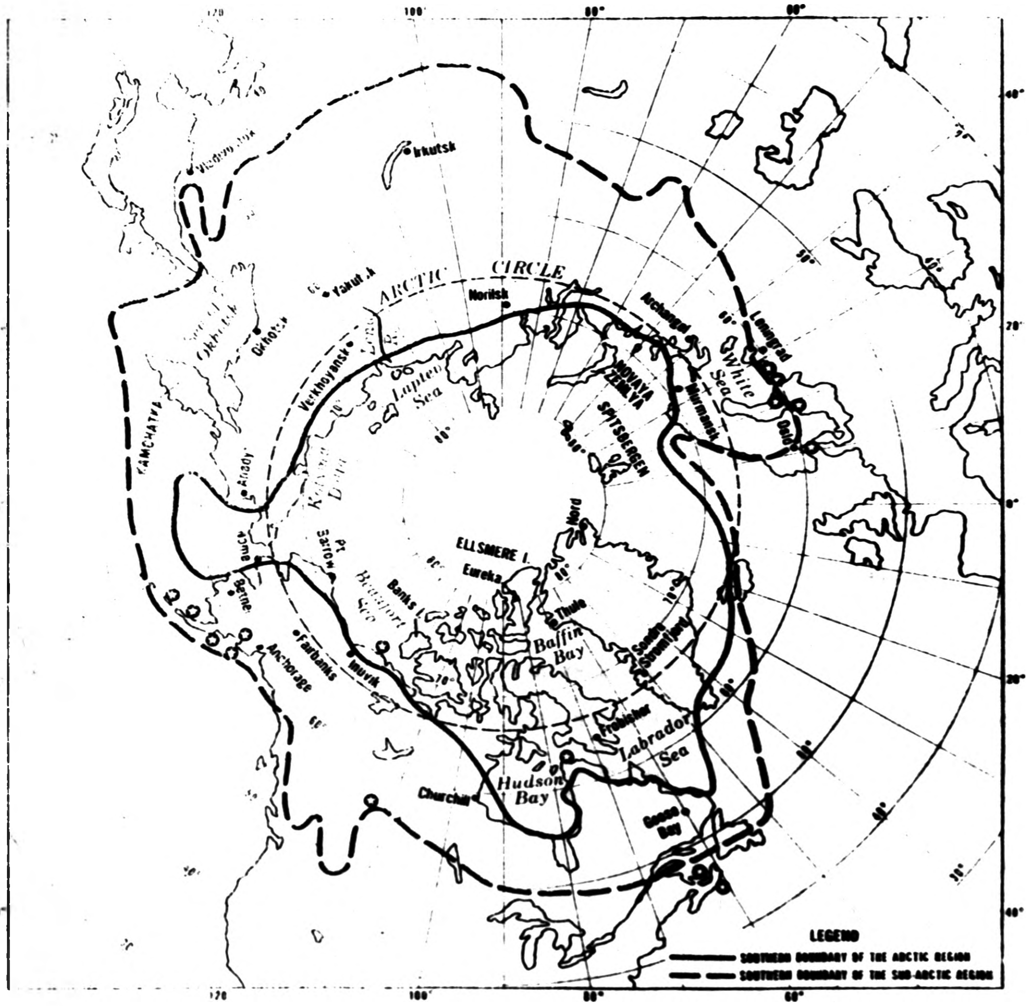

Figure I NORTH COLD REGIONS: POLAR LIMITS AND ZONES.

FIGURE II - CONTAINMENT, COLLECTION AND DESTRUCTION METHODS