IGNITER REQUIREMENTS FOR A MAJOR OIL SPIL FROM A VESSEL IN THE CANADIAN ARCTIC

EE-56

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Igniter Requirements

for a

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Summary

An estimate of the number of oil spill igniters needed to successfully burn the oil released in ice from a major tanker accident in the Arctic has been made. For oil discharged from a tanker that remains stationary after the accident, about 2,500 igniters will be required. However, up to 30,000 igniters may be needed to burn the oil spilled from a moving tanker. It thus seems appropriate for oil spill control purposes that, when possible, a damaged vessel remain stationary while oil is being spilled.

A survey of 10 explosive manufacturers was conducted to assess their willingness and ability to produce both or either of the "DREV" and "Dome" igniters, products recently designed and developed to the prototype stage. Half of the companies contacted expressed an interest in producing one or both of the igniters. The production capacities of these companies varied but some common production problems emerged from the survey.

1) It will generally be necessary to fund a pre-production effort some 3 to 12 months prior to the establishment of a full-production capability.

2) The delivery of raw chemicals for the production of the solid propellant components of the igniters would likely take 2 to 3 months. This eliminates the possibility of producing even a small number of igniters on short term notice unless raw materials are purchased beforehand and stockpiled.

3) Once the raw materials are on hand the igniter production rate is controlled by the specialized mixing and curing stages of the propellant formulation process. The number of igniters which can be produced per batch is controlled by the limited size of the available mixers. The best production rates quoted were 6000 per month for the Dome igniter and 3000 per month for the DREV unit.

It is evident from the results of the survey that immediate igniter demands cannot be met unless stockpiles are kept of either the raw materials or the finished product. Even with raw materials on hand and more than one manufacturer involved, large quantities of igniters (up to 30,000) will take several months to produce. If a spill were to occur late in the winter, time would not be available to manufacture the igniters prior to spring break up.

Even if igniters are available the success of a land-based operation is not guaranteed. The limited range of the helicopters suitable for the deployment of igniters may not permit them to reach the spill site from a land base. This is of particular concern off Baffin Island where the shipping lanes are far offshore and in Viscount-Melville Sound where suitable operations bases are not plentiful. The use of a suitably equipped vessel as a base of operations for the helicopters should be investigated for those instances where land bases are not viable.

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1. INTRODUCTION

The research and development efforts of both Environment Canada and Dome Petroleum Ltd. have resulted in the design of two successful helicopter-deployable oil pool igniters which are the subject of this report (Meikle, 1981; Pistruzak, 1981; Twardawa and Couture, 1983; Twardus, 1978). Field and laboratory testing have shown that these incendiary devices perform their intended tasks very well but they can only be established as viable operational tools for major spills by performing further engineering studies. Among others, the number of igniters needed, feasible igniter supply and manufacturing arrangements, and logistical support requirements for the complete burning operation must be identified. This report addresses these three factors for a major oil spill originating from an ice breaking crude carrier in the Canadian Arctic. The objective is to assist in the development of a reliable capability to use igniters for these and other such potential spills in Canada.

2. ACCIDENT SCENARIOS

This igniter study concentrates on a hypothetical tanker accident involving one of the proposed ice-breaking tankers currently being considered for Arctic service (S. L. Ross, 1982). The focus of the work is on the use of igniters to remove spilled oil that has been contained by an ice cover. A discharge in the open water season is not considered.

For the purpose of this study it is assumed that 35,000 m^3 of oil is discharged over a 24-hour period in a complete ice cover. The manoeuvering of the ship after the accident will dramatically affect the final distribution of oil in, under and on the ice. Because of this, three possible scenarios are considered, as follows.

2.1 Scenario #1: Vessel Steams on

The most likely procedure after an accident of this type would be for the tanker to move on towards a safe port once the extent of the damage had been assessed and the necessary repairs or precautions taken. By steaming on, the captain prevents the ship from becoming ice-fast and immobile. An Arctic tanker moving through relatively thick (1 to 4 metres) first-year ice will break the ice with its bow. Because of the large draft of these proposed tankers, relatively large sheets of ice will tilt to a vertical attitude and pass alongside the ship (Gallant, 1983). The resulting ship track will be approximately the width of the tanker and contain these relatively large sheets of broken ice mixed with the usual smaller ice pieces. Oil spilled during this type of movement will become either trapped under the relatively large pieces of ice or on the water between the ice chunks. The considerable turbulence created by the propellers coupled with the oil's natural buoyancy will limit the amount of oil trapped under the ice.

Assuming a vessel speed of about 6 knots (11 km/hr), a uniform oil discharge, and a ship track width of 60 metres an oiled area of about 1600 hectares could result from a 24 hour spill and the average oil coverage in the ship track would be about 0.002 m^3/m^2.

2.2 Scenario #2: Vessel Grounds - Backs off - Remains

The tanker could be holed by a grounding, back off the obstacle and discover that continued progress is unwise or impossible due to propulsion or ballast problems. During these manoeuverings the vessel could conceivably break up an ice area approximately 3 ship lengths by one ship length (1200 m x 400 m). The oil released initially would make its way to the surface between relatively small ice pieces. After a short period the surface would begin to freeze over and the oil would subsequently be trapped in the gradually thickening ice in the vicinity of the vessel. The oil would likely be confined to the initially broken area by ice ridges created at the boundaries. The average under-ice oil thickness (or coverage) for the spill would be approximately .07 m^3/m^2.

2.3 Scenario #3: Vessel Grounds and Remains

The grounding of the tanker could be so severe that it might not be able to free itself. The tanker would simply remain stationary and release oil while becoming ice-fast. In a release of this kind most of the oil would be released under the ice sheet and spread out and away from the source.

Generally the minimum thickness to which crude oil spreads under an ice layer is about 1 cm (NORCOR, 1977) and this thin layer is likely only for very smooth ice sheets. Depressions in the ice result in the pooling of oil to much greater average thicknesses. Studies have indicated that depressions in thick ice are approximately 10 to 20% of the mean ice thickness (NORCOR, 1977). For 3-metre thick ice approximately 30 centimetre undulations could exist with depressions accounting for half of the under ice area.

If it is assumed in this scenario that the oil pools in sinusoidal depressions to a thickness of 15 cm, then the 35,000 m^3 of oil would spread out over approximately 50 hectares. The average under-ice oil thickness for the spill would thus be about 7.5 cm.

Because the oil distributions of scenarios #2 and #3 are very similar they will be discussed jointly as stationary releases for the remainder of the report.

3. NUMBER OF IGNITERS NEEDED IN A SPRINGTIME CLEANUP OPERATION

3.1 General Oil Behaviour

During the spring thaw, melt pools are formed on the ice surface. Oil reaches these pools either through the melting of the surface ice layers which exposes oil near the surface or by the upward migration of the oil from pockets deep in the ice layer via a network of brine drainage channels. Several detailed accounts of these processes are available in the literature (Dickins and Buist, 1980; NORCOR, 1977; S. L. Ross, 1982).

Considering the oil released in the scenarios developed for this report, the oil of scenario #1 would be exposed by the ablation process whereas that of scenario #3 would reach the surface primarily via the brine channel route. Because the oil of scenario #2 would be released in areas of rapidly growing ice, both processes would likely act to expose the oil. In any event, for all three scenarios the oil would reach the surface melt pools, float and be concentrated by wind herding.

The number of igniters needed to set fire to this surfaced oil is a function of the final distribution of melt pools and oil pools. This distribution is a function of the ice conditions, the characteristics of the oil released and wind conditions and hence is difficult to estimate. Nevertheless, on the basis of certain assumptions and deductions, the oil pool distributions and thus the igniter requirements, for each of this study's scenarios, can be approximately determined. This is done in the following section using the results of the experimental oil spills in ice conducted at McKinley Bay (Dickins and Buist, 1980) and Balaena Bay (NORCOR, 1975).

3.2 Numbers of Igniters

3.2.1 Based on Experimental Results

Oil pool sizes, thicknesses and numbers were recorded for the various under-ice oil releases conducted at McKinley Bay. Table 1 summarizes the initial oil release conditions and the resulting on-ice oil distributions from these spills. These findings indicated that from 11 to 77% of the surfaced oil was in pools 10 m^2 in area or larger (the minimum size considered as an appropriate target for the igniter). The number of these 10 m^2 or larger pools ranged from only a few per hectare for the December and May discharges up to 10 for the April release. The initial under ice oil coverages for these experimental spills was very similar to that which would result in scenario #1, the steam-on scenario (.002 m^3/m^2). However, the December and May discharges cannot be considered representative of a steam-on tanker release. The oil of the December test did not form pools due to the method of oil release (droplet form) and the smooth ice conditions present during the discharge. The oil discharged in May did not have sufficient time to migrate to the surface prior to break-up and therefore only a small percentage of the oil was on the surface during the survey of the oil pools. Most of the oil from the April release, however, surfaced and pooled prior to break-up. The 10 pools, 10 m^2 or larger, recorded from this spill will thus be considered as representative of the minimum number which would result from a steam-on tanker release. Therefore, at least 10 ignitions per hectare would be needed to ignite these pools.

The Balaena Bay experiment involved initial under-ice oil thicknesses an order of magnitude higher than both the McKinley experiment and what could be expected in scenario #1. The resulting oil pools were much thicker and more numerous than those from the McKinley study. A count of the oiled areas at the Balaena site which would be suitable for an igniter drop can be made from Figure 1. About 25 igniters would be needed to successfully burn the oil in this one hectare site. This suggests that at an extreme upper limit 25 igniters per hectare could be needed for scenario #1.

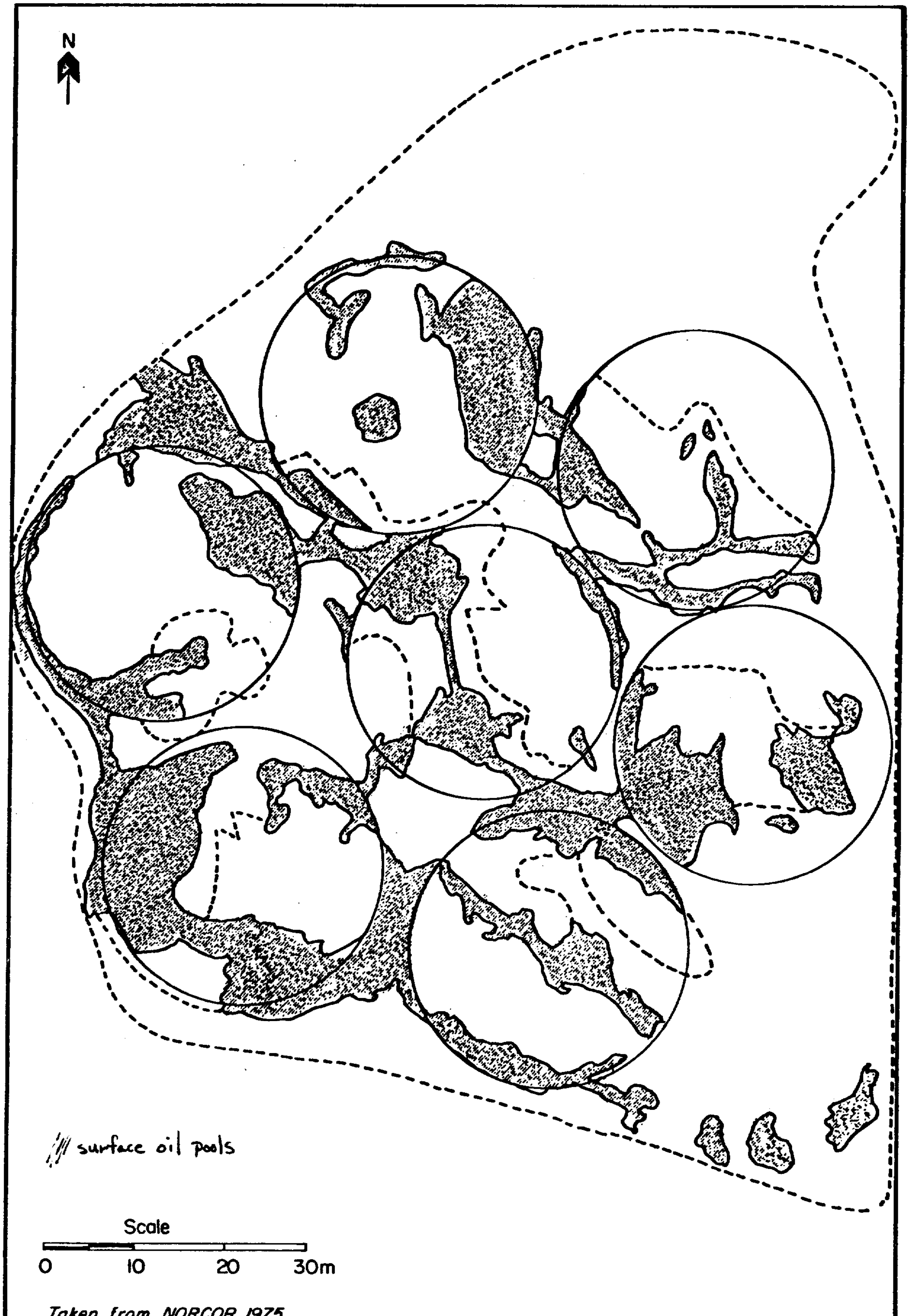
TABLE 1

OIL POOL DISTRIBUTIONS AT MCKINLEY BAY

Release Conditions				Resulting Springtime Oil Pool Distribution				
Time of Release % of released oil on surface at time of survey	Area of Oil Coverage Under Ice (ha)	Approx. Area of Oil Coverage on Ice (ha)	Under Ice Oil Coverage (m^3/m^2)	number of pools per hectare / % of measured surface oil in these pools				
				Oil Pool Size Ranges (m^2)				
				All Pools	1-20+	5-20+	10-20+	20+
December (85%)	0.79	.79	.001	41 *20%	29 19%	11 14%	5 11%	0 0
April (80%)	0.28	1.0	.003	46 100%	37 94%	17 86%	10 77%	1 50%
May (30%)	0.79	1.0	.001	24 100%	15 95%	5 77%	3 70%	1 55%

* Majority of oil was not present in pools but was in droplet form on the ice surface.

FIGURE 1
BALAENA BAY
TEST SITE APPEARANCE - JUNE 7.



Taken from NORCOR, 1975.

In summary, the experiments conducted at McKinley Bay and Balaena Bay indicate that between 10 and 25 igniters per hectare would be needed to ignite the majority of the surface oil resulting from a spill similar to scenario #1. For the purpose of this report 15 igniters per hectare will be considered as the number needed for a spill of this type.

3.2.2 Based on Likely Oil Behaviour

Large releases of oil in ice similar to the "stationary release" scenarios have not been studied experimentally. Therefore, it is necessary to estimate the number of igniters which might be needed on the basis of an understanding of the likely behaviour of the oil.

The oil from a large stationary tanker release would likely be present under the ice in thicknesses greater than 7 cm (See Sections 2.2 and 2.3). In the spring the oil would migrate through the ice to the surface from these thick oil pockets (as discussed in section 3.1). Regardless of the oil quantities present, a melt pool distribution similar to the McKinley or Balaena Bay sites could be expected. These two studies demonstrated that larger under-ice oil coverages result in more ignitable pools prior to break up. This can be attributed to the fact that more oil is available to feed into the melt pools and therefore more large oil pools (greater than 10 m^2) can form. The Balaena Bay results indicate that 25 igniters per hectare would have been required for such a discharge; however, if more oil had been present during this experiment more large pools could possibly have formed, and hence additional igniters would have been required to burn these pools.

In the extreme case of the stationary tanker release all of the melt pools will be entirely covered by oil and the oil will then build to thicknesses greater than that achieveable by wind herding. The number of igniters needed for such an operation is therefore limited by the number of melt pools present. However, no suitable information on melt pool distributions is available to enable one to predict the maximum number of igniters required under such conditions.

3.2.3 Based on Igniter Spacing

Because the oil is confined to a relatively small area of ice and is highly concentrated, a reasonable number of igniters might better be identified by reviewing the operational problems associated with the close spacing of igniter drops.

As more igniters are dropped per hectare the average spacing between igniters on the surface necessarily becomes smaller. Figure 2 illustrates the approximate spacing which would result from various drop rates if a uniform spacing between igniters is assumed. It is apparent from this curve that at values greater than about 40 igniters per hectare the decrease in distance between igniter spacing is not pronounced. From an operational standpoint about 40 igniters per hectare would then seem to be an efficient number to deploy for heavily oiled areas. This number also seems reasonable in reference to the Balaena Bay experiment. In Figure 3 the uniform 15-metre igniter spacing (40 igniters/hectare) has been super-imposed on that spill's oil pool distribution. No attempt has been made to align the igniter locations with oil pools. The figure is intended to illustrate that the value of 40 igniters per hectare provides an adequate coverage of the area and that in all likelihood an efficient burn could be achieved with this number of igniters regardless of an increase in oil pool numbers. If the pool numbers increased substantially, more interconnections would have to occur thus reducing the number of igniters needed. It is also unlikely that a much closer spacing of igniters could be achieved since smoke from initial ignitions would hide pools in the general vicinity making additional nearby drops impossible.

It is interesting to note that the 15 igniters per hectare chosen for the steam-on scenario results in an average igniter spacing of about 25 metres, as shown in Figure 2. Therefore, even with this reduced number of igniters, the large 1600 hectare oiled area of scenario #1 would see a relatively close spacing between igniter drops.

FIGURE 2
APPROXIMATE IGNITER SPACINGS VS NUMBER DROPPED / HECTARE

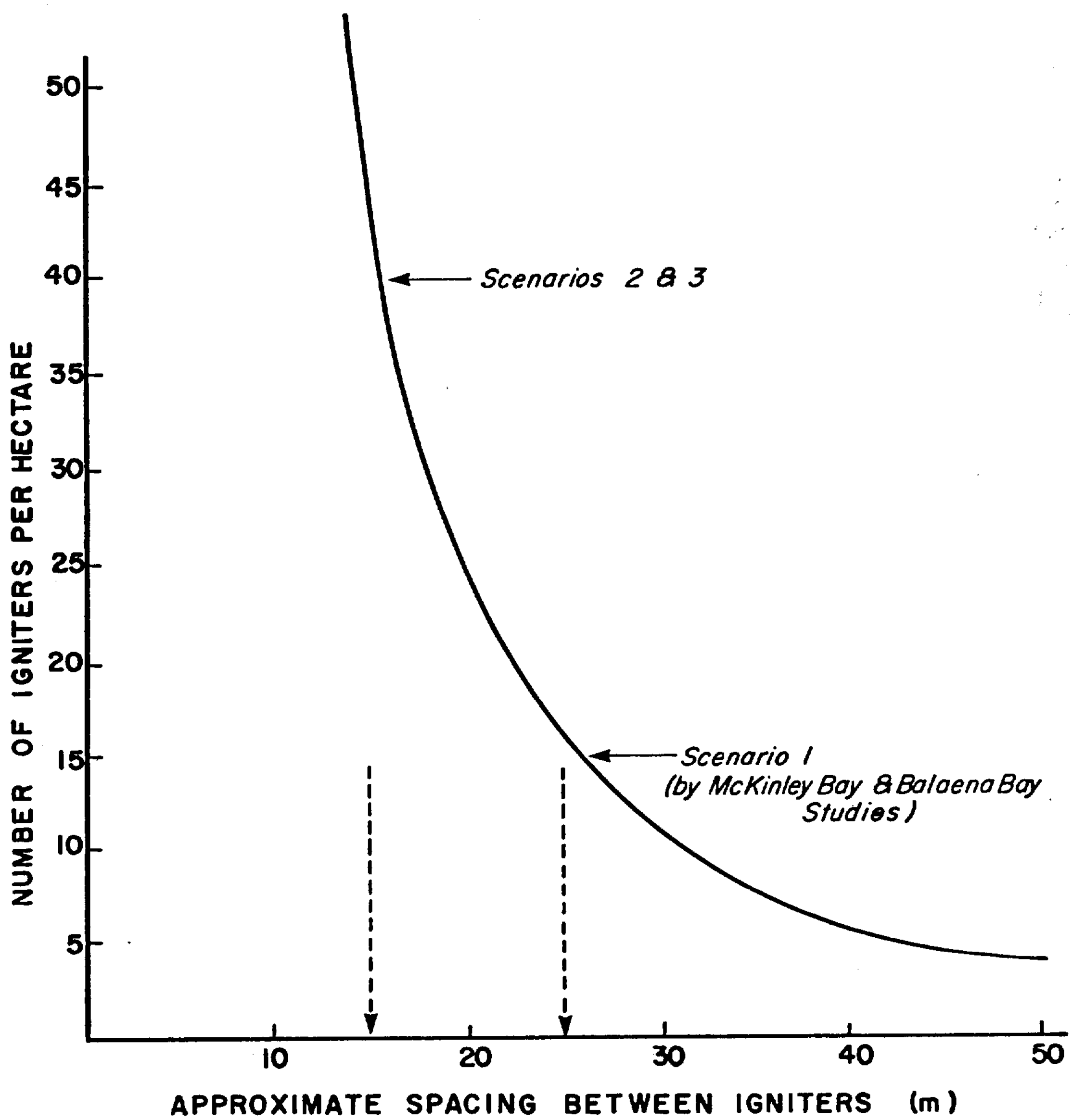
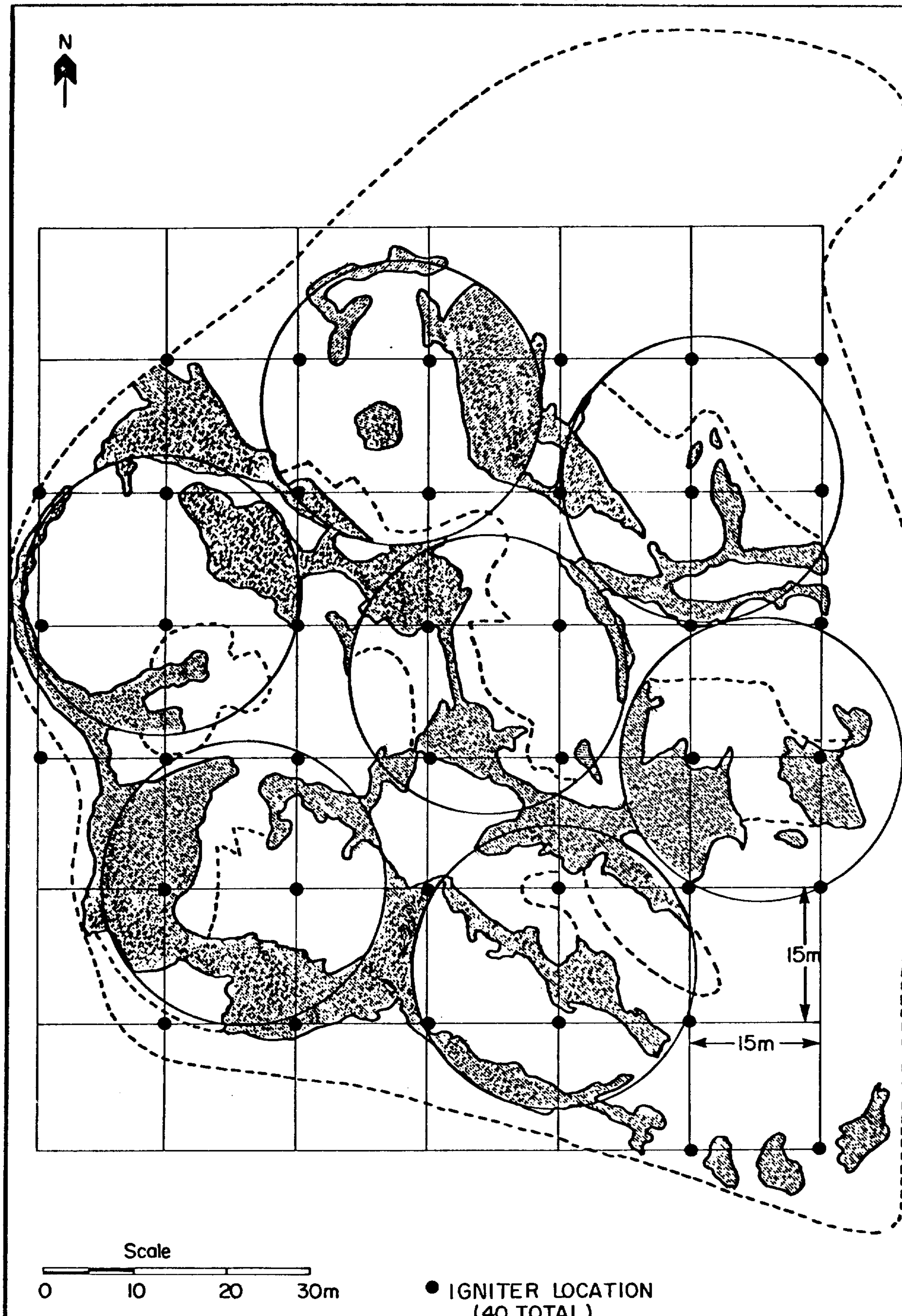


FIGURE 3

BALAENA BAY TEST SITE
SUPERIMPOSED BY 15m IGNITER SPACING (40/ha)



Taken from NORCOR, 1975

In summary, for the purposes of this report 15 and 40 igniters per hectare will be considered necessary for the efficient ignition of the steam-on and stationary tanker oil releases, respectively. For the steam-on condition a total of 30,000 igniters would be needed for each spill (15 igniters/ha x 1600 ha - .8 igniter efficiency). The stationary releases would require approximately 2500 igniters per incident (40 igniters/ha x 50 ha - .8 igniter efficiency). These numbers will be used in evaluating the logistics for an Arctic operation and the potential manufacturing sources for the igniters.

It should be noted that the rate of oil outflow during a steam-on oil spill could dramatically alter the number of igniters required for burning. A uniform discharge of 35,000 m^3 of oil over 24 hours was assumed in this report. A parallel study (S. L. Ross, 1983) investigates the effect that puncture size and oil outflow rate have on the number of igniters needed. This study has revealed that, for large punctures (greater than 0.5 m^2), the bulk of the oil is released within the first few hours of the accident. This type of damage would therefore result in a much smaller burnable oiled area and a corresponding decrease in the number of igniters necessary. It is possible, however, to have oil leak from a very small fracture over an extended period and still have burnable pools. The contaminated area would not be as heavily oiled as in the case of a 24-hour release of 35,000 m^3 of oil but a similar number of igniters would likely be needed to burn the oil.

4. IGNITER SUPPLY AND MANUFACTURING

4.1 Igniter Supply

Two possible options exist for the supply of igniters in the event of a spill. They could be produced by the manuacturers "as needed" or provided from a stockpile of igniters. Stockpiling is the preferred method from the production standpoint as this allows for a much more relaxed manufacturing schedule. However, response organizations would generally prefer to have the igniters supplied on demand to reduce shelf spoilage, storage costs, etc. The number of igniters needed for a spill, the time available to produce and transport them to the spill site, the cost of production, and the possible production rate of the igniters must be considered when evaluating the merits of the two methods. The basic question which must be answered is whether a stockpile of igniters is necessary or if a production/supply arrangement on an "as-required" basis is feasible and suitable.

The previous chapter has identified the numbers of igniters needed for various spill situations. The time available for their production depends upon the time of year of the accidents. An early release guarantees that the oil will be deposited under a thin layer of ice and that it will be exposed early during the spring melt by ablation or by a short migration to the surface. The timing of this spill is such that up to 8 months of preparation time is made available for the manufacture of igniters, establishment of operational bases and the shipment of goods to the north.

The discharge of oil late in the year would result in only a fraction of the oil making its way to the surface prior to breakup assuming the oil was originally deposited under thick ice layers. In this case only a short period would be available to prepare for the igniter operation. The extreme version of this case could involve a spill during breakup itself and the immediate need for igniters.

With these factors in mind, existing manufacturing companies were surveyed to establish their ability to produce igniters under various demand conditions.

4.2 Igniter Manufacturing

A total of 10 potential manufacturers of igniters were questioned with regard to their willingness and ability to produce both the Dome and DREV* igniters. Table 2 lists the companies which were approached. The following three igniter-demand scenarios were presented to the manufacturers.

Production Scenario 1: 2500 igniters are required in the 3 month period after an accident has occurred. The accident could occur this year or during any year in the future.

Production Scenario 2: 30,000 igniters are required for stockpiling and are produced steadily over a five year period. The start of production would be specified by the buyer and not be tied to the occurrence of an accident.

Production Scenario 3: 30,000 igniters are needed within 5 months after an accidental spill. The exact year of the spill is again unknown.

The manufacturers were then asked to answer the following questions for each scenario.

1. Would your company be willing to be prepared to produce the igniters under the demand structures which are indicated? For example, production scenarios 1 and 3 identify situations where a production capability and expertise would somehow have to be maintained during potentially long periods of no demand so that high production rates could be met in the future. For the products which we have specified, would this pose significant problems for your company?

2. Could you produce the specified number of igniters in the time period identified? If so, at what approximate cost per igniter? If not, briefly why not?

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*Defence Research Establishment Valcartier

TABLE 2

List of Companies Canvassed for Information

Company Name	Address	Phone Number	Contact
ABA Chemicals Ltd.	P.O. Box 908 Guelph, Ontario N1H 6M6	519-823-1465	John Edwards Frank Maine
Bristol Aerospace Ltd.	P.O. Box 874 Winnipeg, Manitoba R3C 2S4	204-775-8331 telex 07-57774	W. Voort
Canadian Arsenals Ltd.	5 Montee Des Arsenaux Ville de Le Gardeur, Quebec J5Z 2B4	514-581-3080	Laurent Bergeron
CIL Inc.	Explosives Division P.O. Box 10 Montreal, Quebec H3C 2R3	514-467-3375	Mr. Guertim
DuPont Canada Inc.	Box 2200 Streetsville Postal Station Mississauga, Ontario L5M 2H3	416-821-3300 telex 06-22304	D. W. Briden
Energetex Engineering	P.O. Box 744 Suite 9 498 Albert Street Waterloo, Ontario N2J 4C2	519-743-7191	Ed Twardus
Expro Chemical Products Inc.	P.O. Box 5520 Valleyfield, Quebec J6S 4V9	514-371-5520 telex 05-27355	R. D. Heddle R. Christen
HANDS Fireworks Inc.	221 Nipissing Road Milton, Ontario L9T 1R3	416-878-2831	R. F. (Bud) Little
Morton Thiokol Inc.	P.O. Box 241 Elkton, Maryland USA 21921	301-398-3000	Arnold Irwin X331
Valcartier Industries Inc.	P.O. Box 790 Courcelette, Quebec GOA 1R0	418-844-3711 514-653-4406 (Montreal)	Bill Friend Ivan Grenier

3. If the 30,000 igniters of production scenario #3 cannot be produced in such a short period what is your best estimate of the maximum number of igniters which you could make at a "reasonable" cost; reasonable being defined as not more than twice the unit cost estimated for production scenario #2.

In response to these questions the manufacturers were asked to assume that they had licenses to manufacture the products. However, all other government restrictions concerning the handling and manufacture of explosives were to be considered in their analysis.

A summary of the responses by the manufacturers is included as Table 3. A copy of each response is provided in Appendix A. Because the replies of the manufacturers generally carried conditional requirements this table should be interpreted carefully. The major results of the survey are summarized in the following points.

1. A pre-production preparation would have to be funded from 3 to 12 months prior to the first order of igniters for most manufacturers. A longer preparation time may be required if licensing difficulties were encountered. Energetex Engineering could start production of the Dome Igniter immediately. These pre-production costs could exceed 1/4 of a million dollars.

2. Stockpiles of chemicals and/or igniter hardware would have to be maintained by any manufacturer in order that the 3 month deadline of production scenario #1 could be reached. A delay of from 2 to 3 months is likely in the shipment of chemicals needed for the igniters. Only Morton Thiokol expressed that they maintain sufficient chemical stock on hand to meet these immediate production requirements. However, they considered that the hardware needed in the igniter assembly would have to be stockpiled for them to meet this immediate need.

3. For those companies willing to produce the igniters all could meet the demand structure of production scenario #2 with no difficulty and without requiring raw material stockpiles.

TABLE 3

Company Responses : Production Capability and Igniter Costs ($1983)

Company Name	Production Scenario #1 2500 igniters in 3 months #/cost CDN		#2 30,000 igniters in 5 years #/cost CDN		#3 30,000 or Maximum Prod. in 5 months #/cost CDN		Additional Comments
	Dome	DREV	Dome	DREV	Dome	DREV	
ABA Chemicals	NWP+	2500 $100	NWP	30000 $100	NWP	4000 $100	They would need 3 to 6 months pre-production preparation. The need for raw material stockpile not reported.
Bristol Aerospace	NWP	*	NWP	30,000 $80 - $100	NWP	2800** $80 - $100	*3 months lead time needed for chemical delivery. If chemicals stockpiled (at buyers expense) 350 units/week could be produced with little delay and 2500 could be made in 3 months. **if stockpiles available could produce 7000 in 5 months. It is assumed that a preproduction run and standby equipment would be sponsored by ultimate buyer due to short time response required
Canadian Arsenals Ltd.		No Reply					
CIL Inc.		No Reply					
Dupont Canada Inc.	NWP	NWP	NWP	NWP	NWP	NWP	
Energetex Engineering	NWP	NWP	30,000 $40	NWP	NWP		Maximum production possible 450/week igniter cost not greater than $80 each.

+ NWP - not willing to produce

TABLE 3 (cont'd)

Company Responses : Production Capability and Igniter Costs ($1983)

Company Name	Production Scenario #1 2500 igniters in 3 months #/cost CDN		#2 30,000 igniters in 5 years #/cost CDN		#3 30,000 or Maximum Prod. in 5 months #/cost CDN		Additional Comments
	Dome	DREV	Dome	DREV	Dome	DREV	
Expro Chemical	NWP	NWP	NWP	NWP	NWP	NWP	Don't handle these types of pyrotechnics
HANDS, Fireworks	1250* $67	2500+ $113	30,000 $65	30,000++ $112	18,000** $62	7500+++ $107	Dome Igniter 2 month lead time for components necessary *If stockpiles for 2500 units available, 3 month production is possible in scenario #1. Otherwise 4 months needed for 2500 **If stockpiles for 1200 units available 5 month production of 30,000 is possible Pre-production runs and minor equipment costs are additional expenses DREV Igniter - Minimum 6 month pre-production lead time needed with capital outlay by purchaser of $226,000 + If materials on hand the 2500 units can be produced. ++ No stockpiles needed but capital outlay and standby charges would apply. +++ If stocks for 7500 units on hand a maximum of 13,500 units could be made. Initial capital outlay still applies. Prices include F.S.T. and shipping.

TABLE 3 (Cont'd)

Company Responses : Production Capability and Igniter Costs ($1983)

Company Name	Production Scenario #1 2500 igniters in 3 months #/cost CDN		Production Scenario #2 30,000 igniters in 5 years #/cost CDN		Production Scenario #3 30,000 or Maximum Prod. in 5 months #/cost CDN		Additional Comments
	Dome	DREV	Dome	DREV	Dome	DREV	
Morton Thiokol Inc.	2500 $65	2500 $75	30,000 $42	30,000 $54	15,000	15,000	Purchaser would have to fund tool up and demonstration effort 9 to 12 months in advance of capability. Need for stockpiles not expressed.
Valcartier Industries	No Reply						

3. None of the manufacturers could produce 30,000 igniters in 5 months. With chemical stockpiles on hand Bristol Aerospace could produce about 7,000 DREV igniters. Hand Chemical could produce 18,000 Dome igniters in 5 months (30,000 with stockpiled chemicals for 12,000 units) and 7500 DREV igniters (13,500 if stockpiles of chemicals for 7500 were maintained). Morton Thiokol could produce about 15,000 of either igniter in this time.

4. The predicted cost of the igniters varied with manufacturer and with scenario. The Dome igniter is generally less expensive to produce. Under the rushed demand of production scenario #1 the cost of the Dome igniter ranged from $65 to $67 per unit. The DREV igniter would cost between $72 and $113. For production scenario #2 the Dome version would cost between $40 and $65, the DREV between $54 and $112. A similar cost breakdown for production scenario #3 could be expected. Only Morton Thiokol indicated a significant price reduction for higher production situations.

In summary, an urgent demand for even 2500 igniters could not presently be met without pre-production testing and raw chemical stockpiling by the manufacturers. It would therefore seem reasonable to stockpile at least this number of completed units for spills which would require immediate attention. Maximum production rates by individual manufacturers are between 350 to 750 units/week for the DREV and 450 to 1500 units/week for the Dome igniter. A combination of all 5 of the manufacturers' outputs for about 3 months would therefore be needed to meet the requirements of a steam-on tanker release late in the season. Each of these manufacturers would require extensive pre-production preparation. A stockpile of 30,000 finished igniters would be the only feasible method of supplying this number of units in a short time.

5. FACTORS AFFECTING IGNITER OPERATION

Assuming that sufficient quantities of igniters can be manufactured to deal with a potential spill of oil in Arctic ice, the actual success of the countermeasure operation will depend upon many related factors. The general igniter deployment operation from a land base will involve the following major steps regardless of the method of supplying igniters (i.e. stockpile or "as-needed" production).

i) The transport of igniters, helicopters and manpower to a major northern base from a southern stockpile or southern manufacturing location,

ii) The transfer of goods (igniters, helicopters, fuel, etc.) and manpower from the major base to the nearest operations base (if it is not one of the major settlements) by smaller aircraft, and

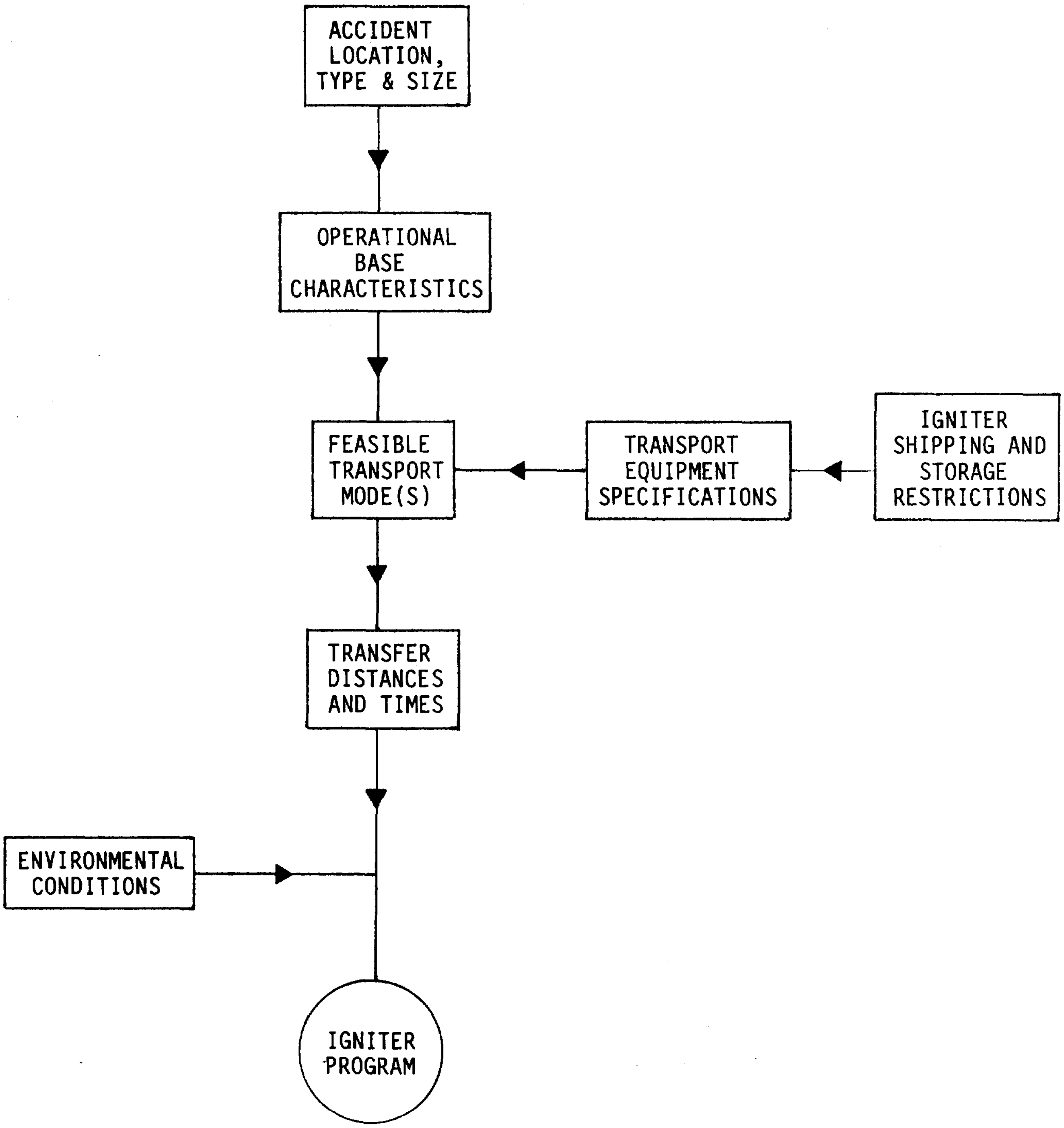
iii) The deployment of igniters from this nearest suitable base of operation via helicopters.

If the igniters are stockpiled in a southern centre (for reasons of convenience, security or extending their shelf-life) or if they are supplied on an as-needed basis from a southern manufacturer all three of the igniter transfers may have to be made in a very short time.

The stockpiling of the igniters in a central northern location, such as Resolute, would eliminate one stage of the transfer operation at the time of the spill. Igniters could be shipped at convenience to the north by the most economical means and then, at the time of a spill, igniters and other supplies would be moved to a suitable operations base for final deployment.

A summary of the major factors which must be considered when implementing these igniter transfers is presented in Figure 4. Discussions of the influence of these components on the planning and success of the igniter operation follows.

FIGURE 4: FACTORS AFFECTING IGNITER OPERATION



5.1 Accident Location, Type and Size

5.1.1 Accident Location

The proposed shipping routes for Beaufort crude to the east coast can be seen in Figure 5. An accident could conceivably occur at any point along this route. The use of igniters could be a feasible cleanup option along all but the southern-most portions of the route where an ice cover is not present during any time of the year. Potentially large distances could exist between land bases and the spill site and these distances could be greater than the range of suitable helicopters. In particular, Viscount Melville Sound and Baffin Bay/Davis Strait are wide shipping areas with few nearby settlements. In such cases the igniters would be viable only if they could be deployed from a helicopter operating from a suitably equipped vessel or mobile base stationed near the spill site.

5.1.2 Accident Type and Size

As discussed in Chapter 2 the spill could involve a stationary or moving tanker. A wide range of oil discharge volumes, release durations and spill properties are possible as a result of either situation. For simplicity this report discusses only one feasible "worst-case" spill situation for planning purposes. It is important to note, however, that other spill volumes or durations could result in very different igniter requirements, especially for the steam-on condition.

5.2 Arctic Operational Bases

Existing settlements deemed suitable for the deployment of igniters from a land base by helicopters are summarized in Table 4. These centres are located on the map of Figure 6 and were selected primarily because of their air strip facilities and proximity to the shipping route. Table 4 also indicates the potential transport modes which could be used to access these sites.

FIGURE 5
PROPOSED SHIPPING ROUTE FOR BEAFORT SEA, CANADA
(taken from Dome Petroleum, 1982)

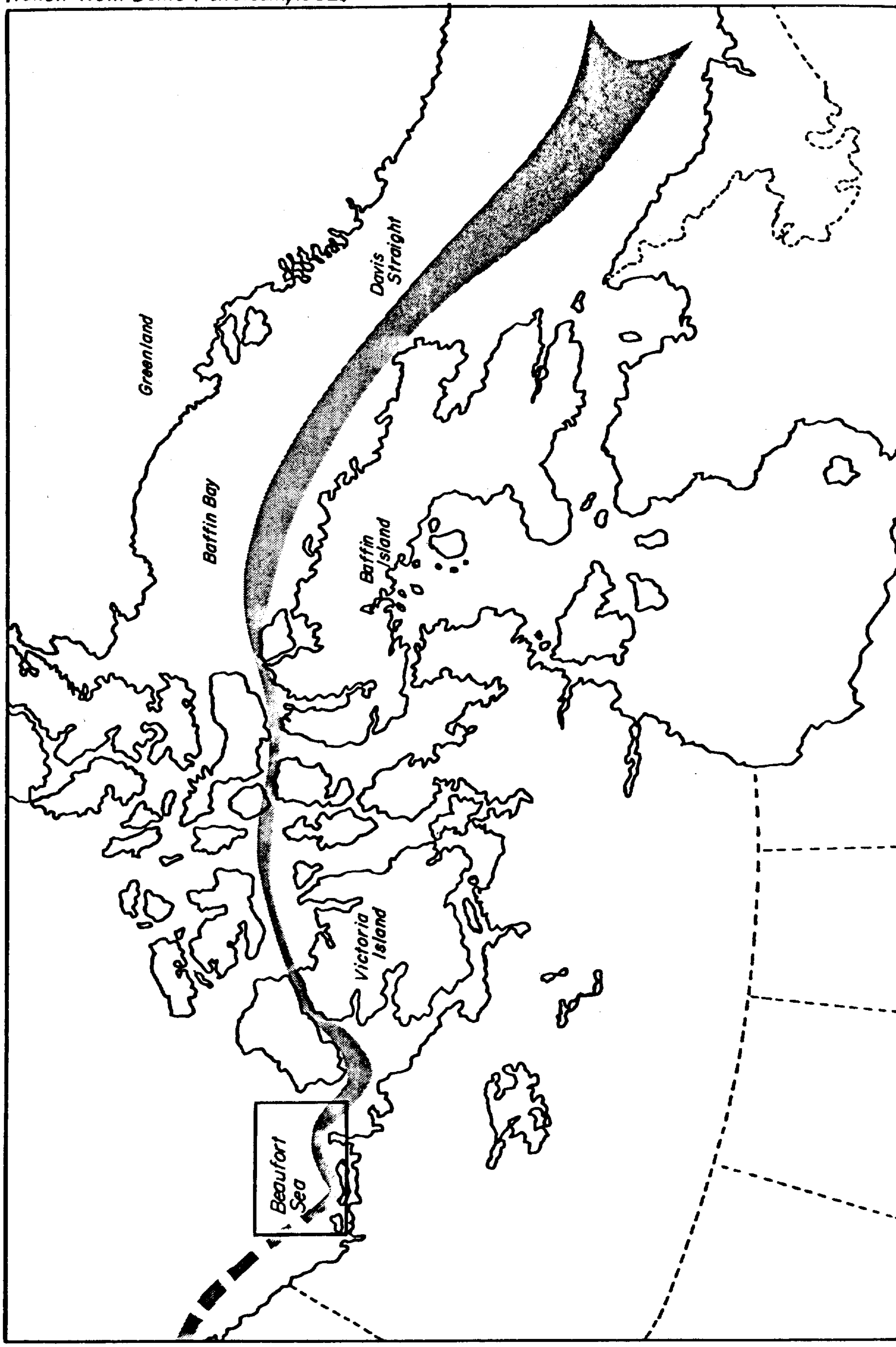


TABLE 4

Probable Operational Bases in Arctic and Possible Access

Operations Base	Access		
	ROAD/RAIL	SEA	AIR
Frobisher Bay		●	⊛
Broughton Is.		●	*
Cape Dyer		●	*
Clyde River		●	*
Pond Inlet		●	*
Nanisivik		●	⊛
Resolute Bay		●	⊛
Rea Point		+	*
Johnson Point		+	*
Inuvik	Year round	+	⊛
Cape Parry		+	*
McKinley Bay	Winter only	+	*
Tuktoyaktuk	Winter only	+	*

Legend

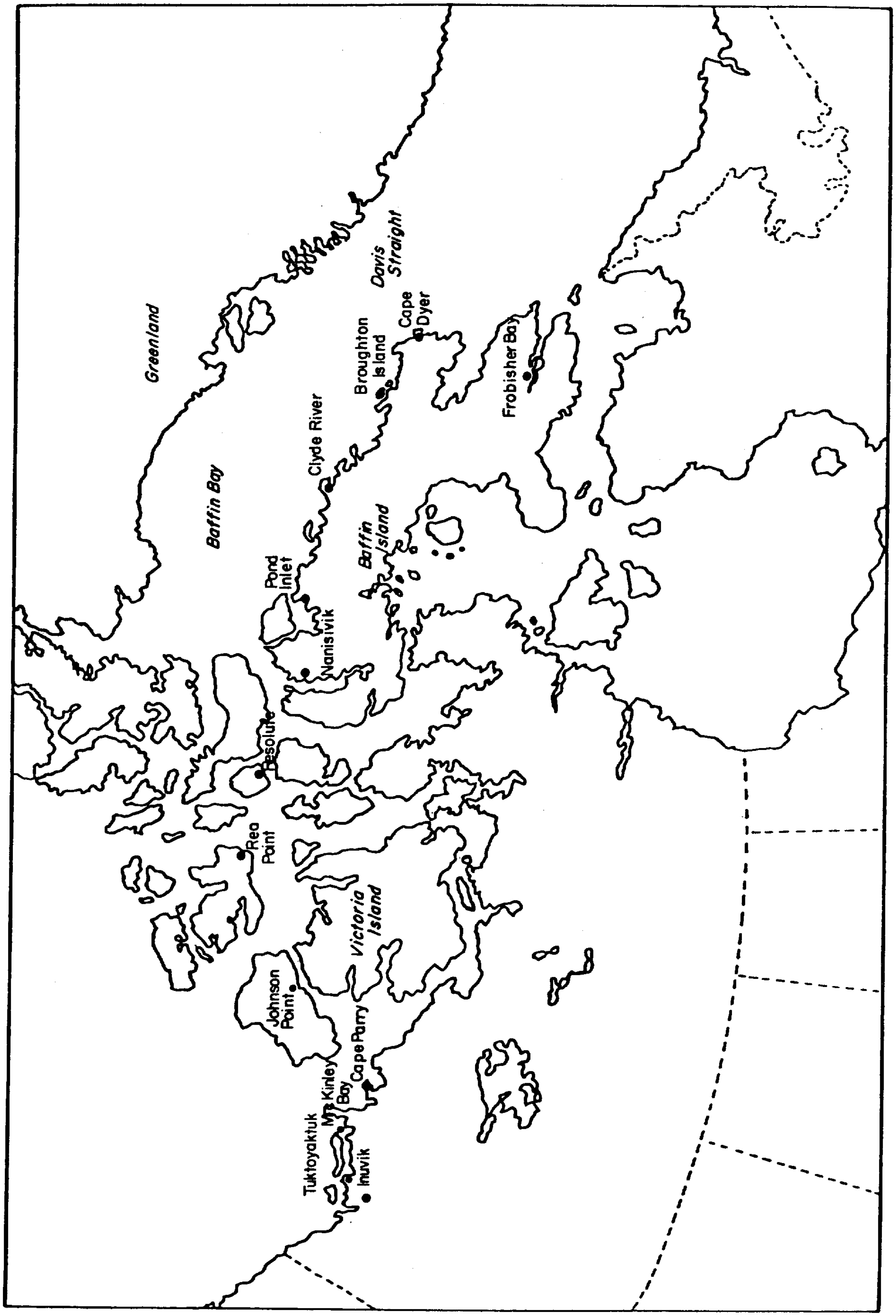
● CCG resupply operation

\+ Northern Trans. Co. Ltd. barges

* minor air support/air strip

⊛ major air support

FIGURE 6
OPERATIONS BASE LOCATIONS



Road access is available only to the Beaufort sea area. Roads are open year-round to Inuvik and ice road links are present between Inuvik, Tuktoyaktuk and McKinley Bay in the winter.

Regular shipping by sea to the eastern centres is prevalent during summer resupply operations which are managed by the Canadian Coast Guard. Both fuel and bulk goods are transported in these operations during the months of July, August and September. Activity in the Western Arctic is serviced by an extensive barge operation during the summer months via the Mackenzie River. National Transportation Company Ltd., a crown corporation, is responsible for these shipments to the delta and outlying and Western Arctic communities.

A very general classification of the airstrip facilities at each of these bases is also presented in Table 4. The major air strips have significant communications, accommodations and goods-handling infrastructures whereas the minor strips have adequate runways but are lacking much of the support capability. A more specific breakdown of the air support at each of these centres is presented in Table 5.

Parachute and low level drops of igniters and supplies could be made at remote points nearer the spill site. However, the need for extensive helicopter refueling and maintenance, crew accommodation, etc. could complicate such a program to a degree that it would no longer be a practical operation; especially when one considers the short time frame in which the work must be carried out.

Another possible alternative to the land based igniter operation could be the use of the damaged oil tanker or another icebreaking ship or tanker as an operational platform. This would eliminate many of the problems associated with the igniter transfer logistics, housing, etc. The vessel could be positioned very near the spill location and a helicopter flown from its deck for the igniter drops. This alternative is not discussed in this report as it is the subject of another Environment Canada study (S. L. Ross, 1983). Mobile bases of the type used by the Canadian Forces are an alternate to the use of a vessel, and have many of the same capabilities and drawbacks.

TABLE 5

AIRPORT OPERATIONAL CHARACTERISTICS*

Name	Coordinates		Runway					Navigation Aids								Fuel Available				Services				Accessibility			
	N	W	Asphalt	Gravel	Length (m)	All Weather	All Season	VOR	TRACAN	NDB	VDF	VHF	UHF	ILS	VFR	100	115	JP1	JP4	Min Main.	Min Repair	Maj Repair	Hanger	Port	Community	Winter Road	All Weather
Frobisher Bay	69°45'	68°33'	x		2,750	x	x	x		x		x		x		x		x	x	x	x		x	x	x		
Broughton Is.	67°33'	64°02'		x	1,070	x	x			x			x					x						x	x		
Cape Dyer	66°36'	61°35'		x	1,525		x			x		x	x				x		x				x	x	x		
Clyde River	70°29'	68°31'		x	1,070					x		x			x									x	x		
Pond Inlet	72°41'	78°00'		x	1,220		x			x		x			x									x	x		
Navisivik	72°58'	84°32'		x	1,615					x		x			x									x	x		
Resolute Bay	74°43'	94°57'		x	1,980	x	x	x	x	x	x	x		x		x		x	x	x	x	x	x	x	x		
Rea Point	78°21'	108°43'		x	1,920	x	x	x		x		x						x		x			x	x	x		
Johnson Point	72°46'	118°30'		x	1,645					x		x															
Cape Parry	70°10'	124°42'		x	1,525	x	x			x		x	x				x		x			x	x	x	x		
Atkinson Point	69°56'	131°25'		x	762										x												
Tuktoyaktuk	69°26'	133°07'		x	1,075	x	x			x		x											x	x	x	x	
Inuvik	68°18'	133°43'	x		1,830	x	x	x		x		x		x		x		x	x	x	x		x		x	x	
Whitehorse	60°43'	135°04'	x		2,190	x	x	x	x	x	x	x	x	x		x			x	x	x		x				x
Yellowknife	62°28'	114°26'	x		2,290	x	x	x		x	x	x	x	x		x	x	x	x	x	x	x	x				x
Hay River	60°50'	115°47'	x		1,830	x	x			x		x		x		x		x	x	x							x

(* derived from DeLeuw Cather, 1978)

5.3 Feasible Igniter Transport Modes

The general transportation options available to the north have been identified. Government restrictions on the handling and shipment of explosives by these various options and the capacities and speeds of the methods will now be reviewed.

5.3.1 Shipping and Storage Restrictions for Igniters

Canada is presently converting its explosives classification and regulation system to an international format. Under the old Explosives Act the DREV igniter was formally classified as a Class 7 (fireworks class), Division 2 (manufactured fireworks), Subdivision 5 (high hazard, practical use) explosive. Under the United Nation's based system the igniter will likely be identified as a Class 1 (explosives code within the Dangerous Goods grouping), Division 3 (pyrotechnic device), group g material (Twardawa, 1981). The Dome igniter should be similarily classified. The shipment of such a product by land or sea is not restricted under these guidelines but the transport of them as cargo on commercial passenger aircraft is prohibited. The igniters can be transported by aircraft chartered from qualified airlines.

The storage of igniters must comply with the following simple guidelines.

1. They must be housed in a securely locked area with no other flammable materials.

2. The interior of the lock-up must be non-sparking.

3. The lock-up must be clearly identified as a fireworks storage area on its exterior.

These restrictions should present no major difficulties even in Arctic regions. Standard shipping containers lined with plywood, locked and marked, would make suitable storage areas. Any available warehouse or storage space properly prepared would also be acceptable.

5.3.2 Transportation Equipment Specifications

As discussed, 2,500 to 30,000 igniters might be needed to successfully deal with a tanker accident in the Arctic. In order to evaluate shipping requirements the approximate volumes and weights of the igniters must be identified. Table 6 provides a breakdown of this information. It is seen that while the igniters are similar in size the DREV igniter is 4 times as heavy as the Dome version.

Land Transport

Standard tractor trailers or smaller vans could be used to move the igniters by land. The volume of a standard trailer will restrict the number of Dome igniters which can be transported. Weight will likely limit the number of DREV igniters which can be carried. These trailers have 2880 ft^3 or 81.5 m^3 of storage space and can carry in excess of 45,000 pounds. A total of 11,500 igniters could be placed in each trailer. A full load of Dome igniters would weigh only 11,500 lbs; the DREV igniters would weigh 51,750 lbs which exceeds the load carrying capability of some transports. In either case, however, 3 transport trucks would be adequate to move 30,000 igniters.

The 2,500 igniters could be handled in one shipment by a smaller moving van with no difficulty.

The transport of the igniters by train from a manufacturer to a marine port (such as Hay River or Montreal) is another possible option. Box cars are approximately 40 ft x 10 ft x 10 ft (4000 ft^3) and can handle loads in excess of 100,000 lbs. As an example of the type of shipment which might be made via a train, two cars could move 30,000 igniters from Toronto or Montreal to Hay River in about a week. Short haul situations would probably be more easily handled by transport trucks.

TABLE 6

IGNITER WEIGHTS AND VOLUMES

Igniter Type	Volume* per Unit m^3 (ft^3)	Weight* per Unit kg (lbs)	Volume per 2,500 m^3 (ft^3)	Weight per 2,500 kg (lbs)	Volume per 30,000 m^3 (ft^3)	Weight per 30,000 kg (lbs)
DREV	0.007 (0.25)	2. (4.5)	17.5 (625)	5,000 (11,250)	210 (7,500)	60,000 (135,000)
DOME	0.007 (0.25)	0.5 (1.0)	17.5 (625)	1,250 (2,500)	210 (7,500)	15,000 (30,000)

* approximate packaged volumes and weights per igniter

Marine Transport

As outlined in section 4.2 Arctic communities are serviced yearly by marine resupply operations. The eastern Arctic, extending as far as Resolute, is managed by the Canadian Coast Guard. A Montreal based firm packages all bulk goods in a palletized format for shipment to the north during the months of July, August and September. All communities which have previously been identified as potential operational bases are served by this program.

Resupply in the western Arctic is handled by the Northern Transportation Co. Ltd. via barges which originate at the railhead at Hay River and utilize the Mackenzie River. A palletized packing/handling procedure would also be suitable for these vessels. The igniters could be shipped by rail or transport trucks to Hay River for final transfer by barge to the delta.

The major drawbacks of the marine transport mode are its seasonal nature and slow response time. Economical marine shipping to the north is feasible only in the open water season and these transfers take several weeks to complete.

Air Transport

By far, the fastest and most straightforward method of getting goods into the Canadian Arctic is by cargo aircraft. The most popular airplanes used in commercial Arctic ventures at present are summarized in Table 7 under various type classifications. In the heavy cargo class the Lockheed Hercules has the obvious advantages of shorter runway requirement, heavier payload and better fuel consumption when compared to the Boeing 737 but it is used almost exclusively by the military with only a few in service in commercial airlines (DeLeuw Cather, 1978). The Boeing 737 is popular among the Arctic commercial airlines, has greater range than the Hercules but is able to land only at the major airstrips in the Arctic due to its minimum runway requirement (1830 m or 6000 ft). See Table 7.

TABLE 7

AIRCRAFT CHARACTERISTICS+

Type	Name	Model	Fuel					Consumption gal/hr	Runway Requirements m(ft)				Freight		Range Loaded km (mi)	Cruise Speed km/hr(mi/hr)	Comments
									Normal		Emergency		Payload	Cargo Volume			
			100	115	JP1	JP4	JP5		Paved m(ft)	Gravel m(ft)	Paved m(ft)	Gravel m(ft)	kg (lbs)	m^3 (ft^3)			
Heavy Transport	Boeing 737	200			x	x		725	2750 (9000)	2750 (9000)	1830 (6000)	1830 (6000)	15,900 (35,000)	140* (5000*)	4500 (2800)	925 (575)	-sees heavy commercial use
	Lockheed Hercules	L100-30			x	x		680	1524 (5000)	1524 (5000)	1220 (4000)	1220 (4000)	22,675 (50,000)	170* (6000*)	3221 (2000)	580 (360)	-primarily owned by military
Medium Transport	Douglas	DC 3	x					80	1040 (3400)	1040 (3400)	760 (2500)	760 (2500)	2720 (6000)	53 (1872)	900 (560)	225 (140)	-popular medium transport plane
	DeHavilland Buffalo	DHC 5			x	x		230	915 (3000)	915 (3000)	460 (1500)	460 (1500)	4540* (10,000*)	42 (1500)	1600 (1000)	400 (250)	-military only
Helicopters suitable for igniter drops	Sikorsky	S61L				x	x	140					1090 (2400)	84 (1200)	1000 (625)	219 (136)	
		S76				x	x	100*					550 (1200)	6 (210)	1000 (625)	232 (144)	
	Bell 212	CH 135			x	x		84					2270 (5000)	6 (220)	420 (261)	230 (142)	-range extender package available
	Aerospatiale	SuperPuma			x	x		153					2720 (6000)	11 (400)	700 (400)	280 (170)	-availability unknown
	Boeing Vertol	Chinook			x	x	x	325					9525 (21,000)	40 (1400)	370 (230)	300 (190)	-military only -downwash may be excessive
															2000 (1300)		-no payload

(+ adapted from DeLeuw Cather, 1978 and James' All the World's Aircraft)
* estimates

The Douglas DC-3's specifications, availability and reliability make it a good choice for the movement of materials from the major northern centres to the outlying operations settlements. The DeHavilland Buffalo is another excellent medium transport aircraft but in Canada these are operated exclusively by the Canadian Armed Forces.

Several helicopters would be suitable for the deployment of igniters based on their range and cargo specifications. A partial list of suitable helicopters is included in Table 7 but these larger helicopters are not often readily available due to their limited supply and in some cases are available only through the military. In any case, the downwash of very large helicopters at low levels may cause movement in the surface oil thus making them unsuitable for igniter drop operations. A fine balance between the availability, size, range and functional characteristics of the helicopter must be considered in the selection process.

It is not possible to rely on the use of Canadian Armed Forces personnel and equipment in planning for future oil spill countermeasures. Military assistance to non-defence agencies is provided for only on the basis of individual circumstances or requests from federal ministers or provincial premiers, etc. (DND 1981). It is noted, however, that the Armed Forces has an excellent capability in the areas of both cargo shipment and helicopter support and their expertise may be made available during emergencies.

5.4 Transfer Distances and Times

5.4.1 Movement of Igniters to the North

The most suitable means for transferring the igniters north depends upon the supply method. If a northern stockpile is established prior to an accident the time required to deliver them is not important and the most economical method is preferred. This would likely be by the regularly scheduled sea lifts. These could take several weeks to complete after accounting for the time to transport the goods to the dock site. The sea lift option must be ruled out if the igniters are to be delivered to the spill from a southern stockpile or if they are to be produced as needed since the transfer would have to be made in the winter*. A spill late in the season would also rule out land transport to the Beaufort sea area. Igniters could be moved via transport trailers to the western Arctic only if a few weeks were available from the time of the accident to breakup. For all other parts of the Arctic and for quick delivery to the Beaufort, chartered cargo aircraft delivery is the only method available. Igniters could be transported from any major southern Canadian location with regular connections to the Arctic within a maximum of 2 or 3 days. Thirty-thousand igniters could be moved in only two or three flights depending on the igniter type. While this method would be the fastest and probably the most reliable, it would be by far the most costly.

5.4.2 Supply of Operation Bases

In many instances igniters will have to be transferred from a major northern base to a small settlement near the spill. The transfer distances and flight times between these locations must be known in order to plan the logistics of the entire operation. Table 8 summarizes this information for the operations bases identified in Section 4.4. The flight times noted are approximate and, when planning an operation, factors such as ground delays, weather conditions, equipment maintenance and crew changes all have to be taken into consideration. Five full flights would be needed to transfer 30,000 Dome igniters by DC-3 aircraft. Because of their additional weight, 20 flights would be needed to move 30,000 DREV units. See Tables 6 and 7.

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*If another ice-breaking vessel were to be used as an operations platform they could be transported on board. However, time would have to be available for the vessel to reach the spill site prior to break up.

TABLE 8

TRAVEL DISTANCES AND TIMES

Location	Main Base to Ops Base (by medium cargo aircraft)		Ops Base to Spill Site (by helicopter)					
	Distance (km)	Flight Time (hrs)*	Distance One Way+ (km) Min.		Max.	Round Trip Time** (hrs) Min.		Max.
Frobisher Bay	---	---	350	to	450+	3	to	4
Cape Dyer	450	1 to 2	100	to	350+	1	to	3
Broughton Is.	450	1 to 2	125	to	350	1	to	3
Clyde River	720	1.5 to 3	150	to	380	1.25	to	3.5
Nanisivik	---	---	100	to	250	1	to	2.25
Pond Inlet	225	.5 to 1	150	to	350	1.25	to	3
Resolute Bay	---	---	50	to	150	.5	to	1.25
Rea Point	320	1 to 1.5	50	to	225	.5	to	2
Inuvik	---	---		---				
Johnson Point	725	1.5 to 3.	10	to	225	.1	to	2
Cape Parry	400	1 to 2.	50	to	175	.5	to	1.5
McKinley Bay	200	.5 to 1.	50	to	150	.5	to	1.25
Tuktoyaktuk	120	.5	50	to	150	.5	to	1.25

* depends on aircraft used
** based on 225 km/hr cruise speed
\+ depends on actual shipping route and location of spill relative to site

5.4.3 Deployment of Igniters

The final deployment of igniters involves four steps: the helicopter flight from the airstrip to the spill site, the location of suitable targets, the igniter drops and the return flight. The igniter drops cannot be made more frequent than about 3 every 2 minutes so the more time that is available for deployment the more effective each helicopter sortie will be. One of the most critical factors affecting a land-based operation is therefore the transit time or distance between the land base and the spill site. Every additional minute in transit diminishes the possibility of an oil pool ignition. The maximum flight times for the suitable helicopters are between 2 to 4 hours (this varies with helicopter, cargo weight and flight characteristics). As can be seen from Table 8 there are many areas along the shipping route where the helicopter will have little or no time to deploy igniters once it reaches the spill. For these instances a land based igniter operation is not feasible. The eastern extreme of the Baffin Bay-Davis Strait shipping lane is the most notable of these areas.

The feasibility of using igniters will have to be determined for each spill situation because of the wide range of transit distances and possible igniter numbers which will be needed. The following two brief scenarios are provided to give an indication of the magnitude of possible operations.

Oil is spilled within a 1 hour round trip distance of a land base from a moving tanker. Thirty thousand igniters are needed to ignite the oil. A three hour flight duration by the helicopter is assumed and 5 flights per day are considered possible. In the two hours available for dropping igniters, 180 units would be deployed (3/2 minutes). A total of 167 sorties (30,000/180) would be needed to drop the igniters. Given that a 1 week period was available for dropping the devices, a total of 5 helicopters would be needed to carry out these sorties ($167 \div 7 \div 5 = 4.8$). This does not account for the possibility of bad weather or equipment failure hampering the program.

A second scenario could involve a stationary release of oil within a 2 hour round trip of a land base. This spill would require about 2500 igniters. Assuming that 1 hour is available for the igniter drops, 5 sorties are possible per day per helicopter and 3 igniters are dropped every 2 minutes, one helicopter could drop the igniters in less than 6 days (2500 igniters ÷ 90 igniters per sortie per helicopter ÷ 5 sorties per day = 5.6 days)

It is evident from these two scenarios that a wide range of helicopter numbers and support logistics requirements could be needed for an igniter operation depending on the accident conditions. The decision by the concerned agency to use igniters at a specific spill can only be made after reviewing these accident-specific conditions.

5.5 Environmental Conditions

The igniter drop operation is a fair weather program by necessity. Excellent visibility is needed to enable the crew to spot the appropriate oil pools; clear, stable flying conditions are necessary to permit the helicopter pilots to find and hover over these targets. Poor weather could also hinder the movement of supplies to the spill site. The igniter drops should begin no more than about a week prior to break up to achieve maximum efficiency and therefore the weather conditions during these periods are critical. Ice-breakup occurs anywhere between April and August in the different regions of the Arctic. Figure 7 provides a summary of the ice conditions along the shipping route. The exact timing of final break up will vary from year to year as well as from place to place and will therefore have to be monitored for each individual spill.

Between 18 and 24 hours of daylight will be available each day for an igniter operation based on an April to August break up period and a spill latitude between 70 to 75^{o}. (See Figure 8). Daylight hours do not guarantee a successful operation, however, since other factors such as fog can reduce visibility. Figure 9 demonstrates the probabilities of flight limits which have been recorded at settlements along the proposed tanker route.

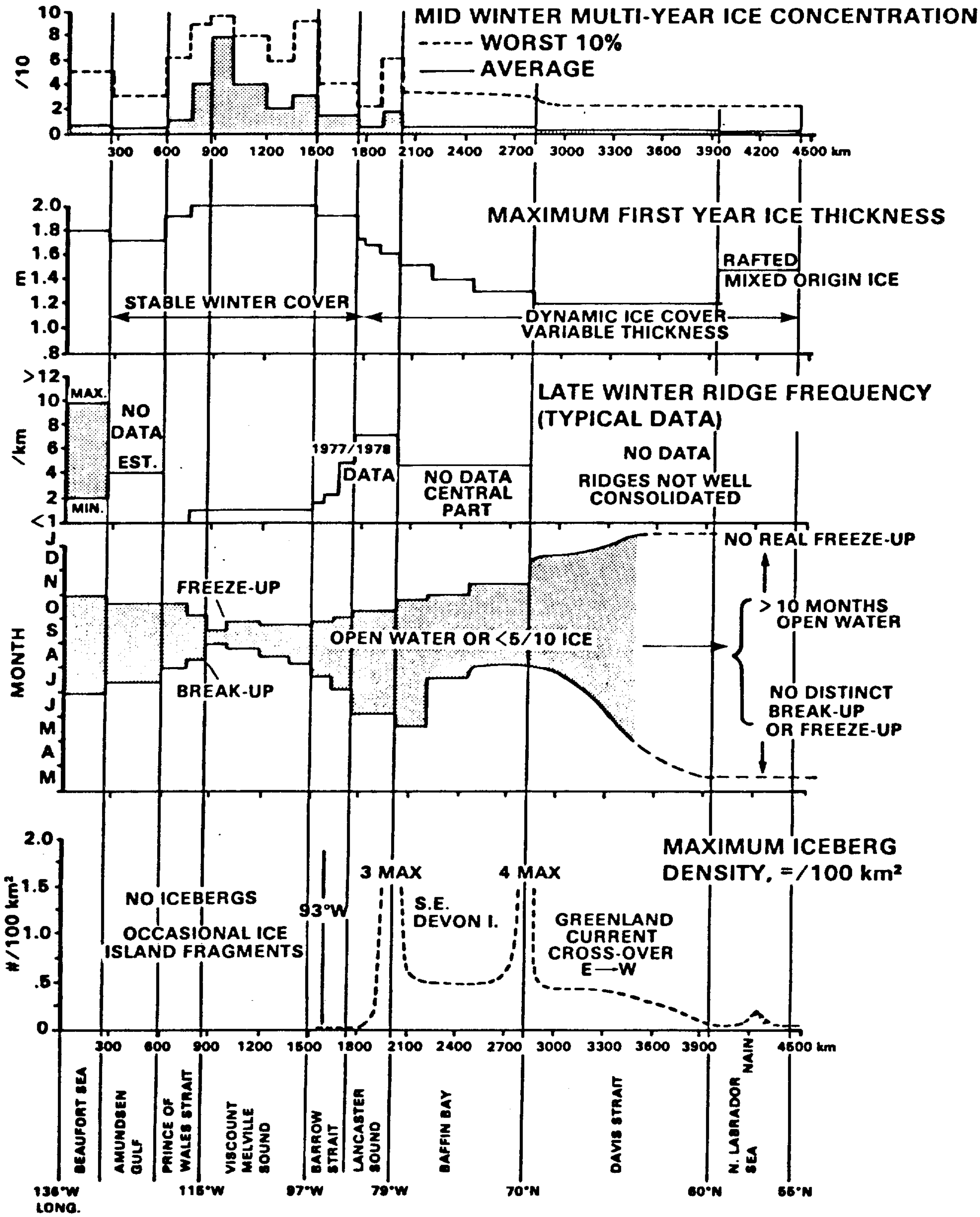


FIGURE 7: ICE CONDITIONS ALONG ARCTIC SHIPPING ROUTE

(from Dome Petroleum, 1982)

In general, at least 70 to 80% of the time visual flight is possible along the route in the months of April to August. The possibility of poor weather during an operation does exist, however, and should be accounted for in the preliminary planning for both the igniter drops and resupply operations at each specific spill location.

The average air temperatures which could be expected during igniter operations in the various parts of the Arctic are indicated in Figure 10.

While many other environmental factors will have to be considered during a burning operation, such as storms, winds, etc., they are not as easily predicted on a pre-spill basis.

FIGURE 8
DAYLIGHT HOURS AVAILABLE FOR IGNITER OPERATION

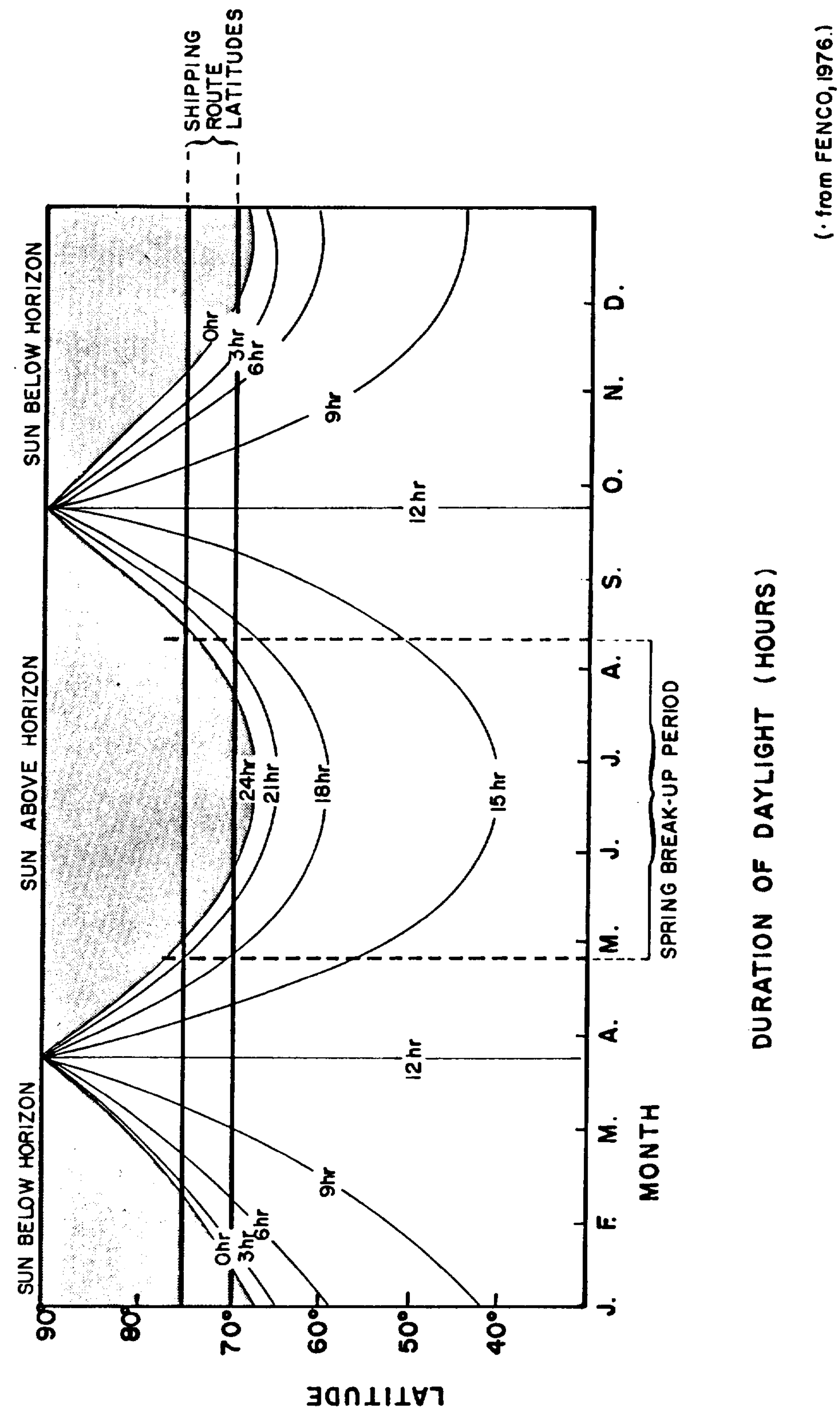
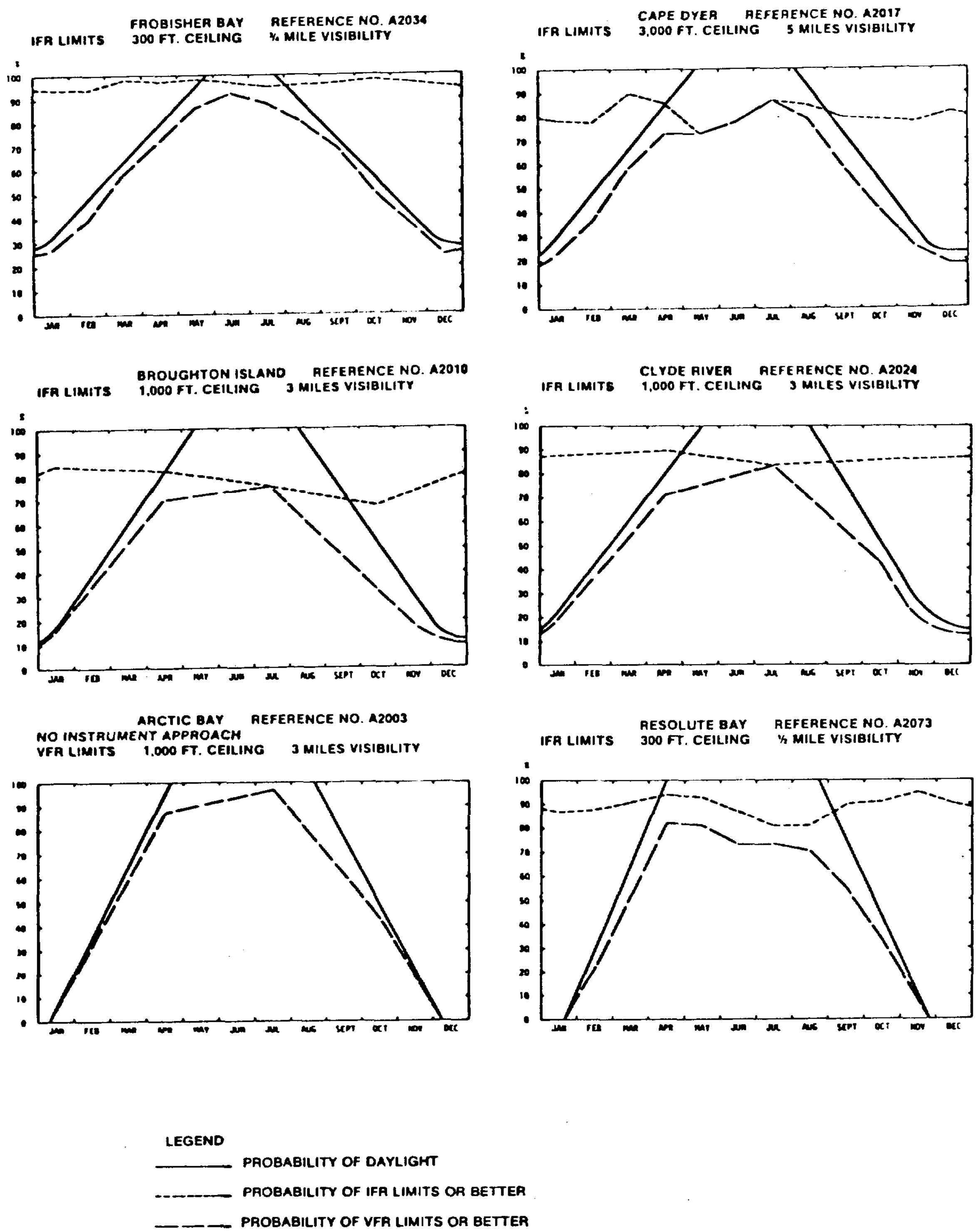
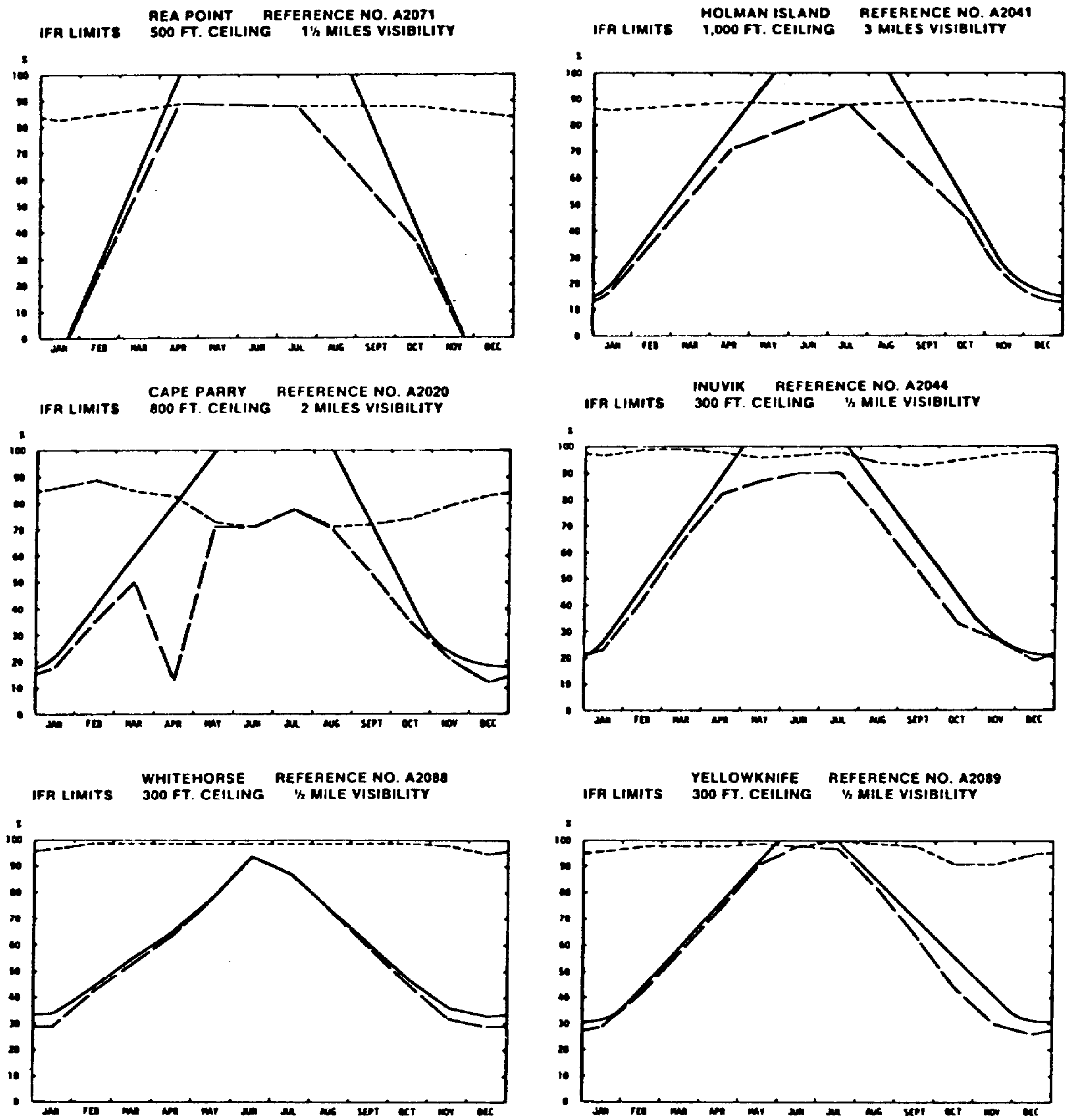


FIGURE 9: FLIGHT PROBABILITIES ALONG TANKER ROUTE



(from DeLeuw Cather, 1978)

FIGURE 9: con't



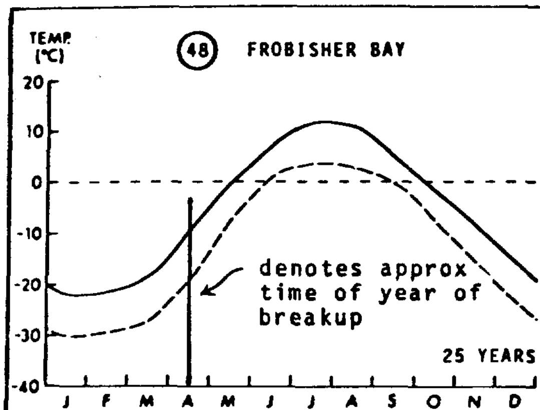
LEGEND

———— PROBABILITY OF DAYLIGHT

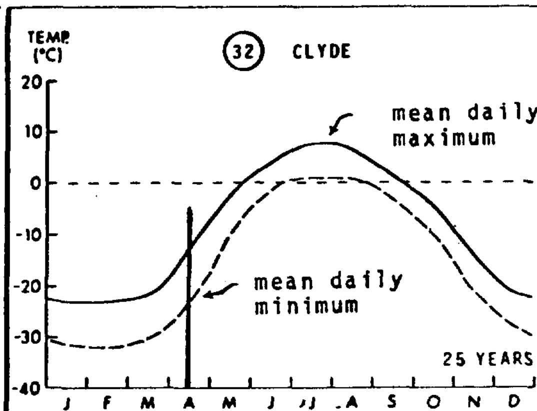
--------- PROBABILITY OF IFR LIMITS OR BETTER

— — — PROBABILITY OF VFR LIMITS OR BETTER

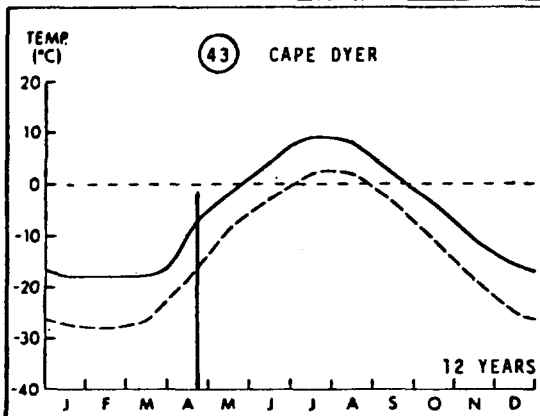
FIGURE 10: AIR TEMPERATURES ALONG TANKER ROUTE



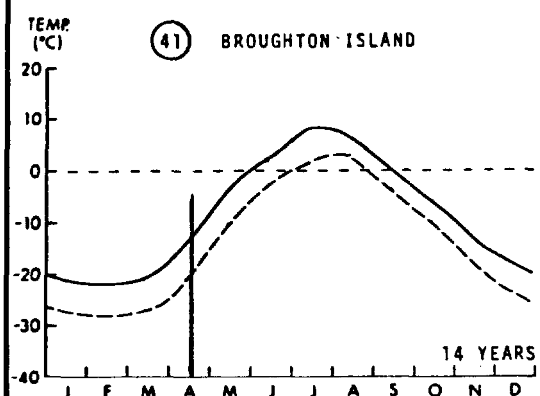
J	F	M	A	M	J	J	A	S	O	N	D
4	4	4	5	13	22	24	23	17	7	6	3
-45	-46	-44	-34	-26	- 8	- 3	- 1	-13	-22	-36	-42



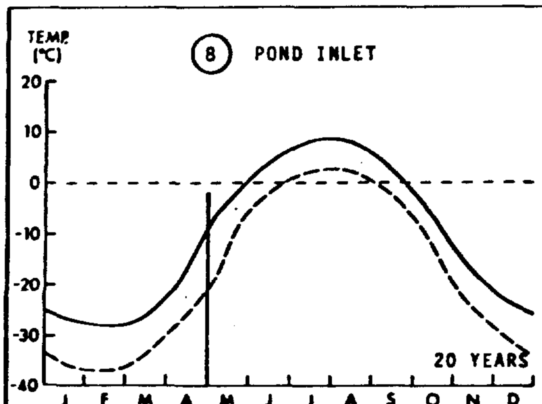
J	F	M	A	M	J	J	A	S	O	N	D
0	3	- 2	7	9	15	22	20	13	6	7	0
-46	-44	-43	-41	-27	-12	- 6	- 6	-16	-26	-35	-44



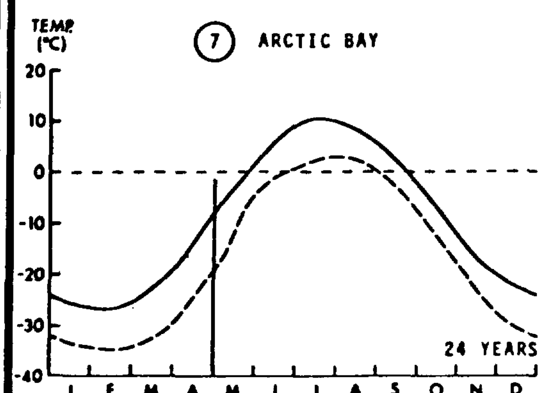
J	F	M	A	M	J	J	A	S	O	N	D
- 1	2	1	3	8	13	19	19	16	8	3	6
-43	-42	-47	-33	-28	-14	- 4	- 5	-19	-25	-39	-44



J	F	M	A	M	J	J	A	S	O	N	D
0	1	- 2	6	7	15	18	18	14	7	3	5
-42	-40	-39	-33	-26	-12	- 6	- 6	-12	-21	-31	-37

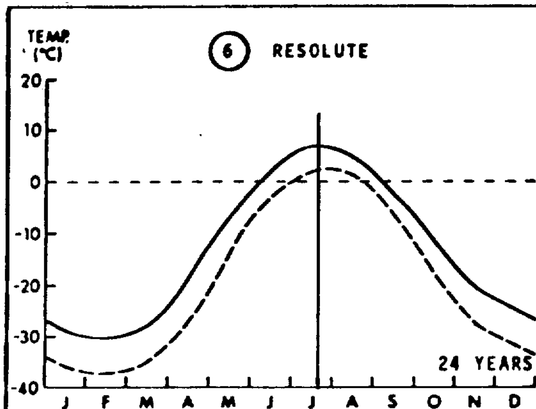


J	F	M	A	M	J	J	A	S	O	N	D
0	2	0	6	9	17	20	17	16	7	4	0
-49	-53	-48	-42	-32	-12	- 6	- 3	-18	-29	-46	-47

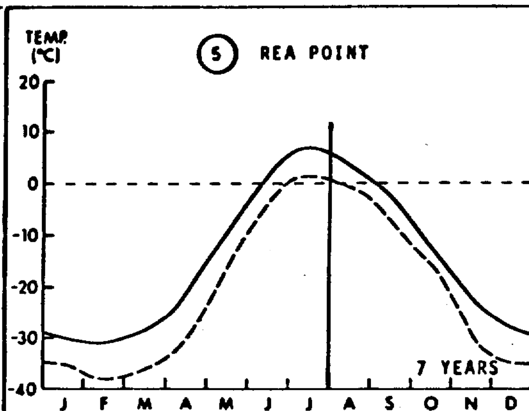


J	F	M	A	M	J	J	A	S	O	N	D
4	2	1	2	11	17	24	18	13	7	2	1
-47	-49	-45	-43	-28	-12	- 6	- 4	-15	-32	-41	-46

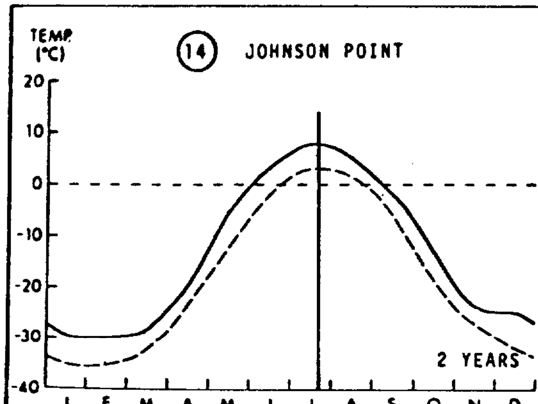
FIGURE 10: con't (from Fenco, 1978)



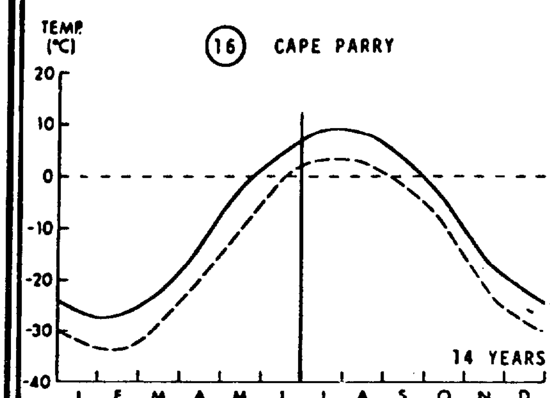
J	F	M	A	M	J	J	A	S	O	N	D
- 5	- 4	- 7	- 1	4	14	18	15	9	0	- 3	- 8
-52	-51	-52	-42	-29	-13	- 3	- 8	-21	-35	-43	-46



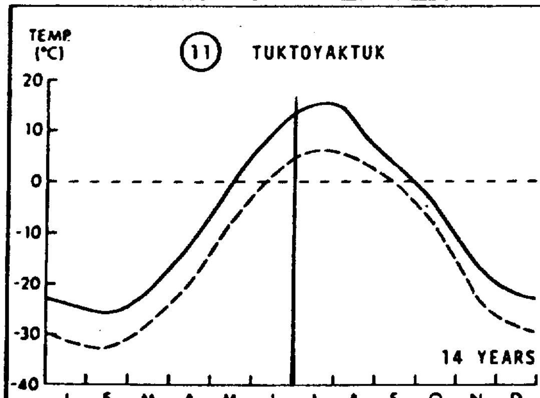
J	F	M	A	M	J	J	A	S	O	N	D
-10	-16	-16	-3	3	18	17	16	7	0	-2	-15
-52	-49	-48	-41	-29	-16	-6	-7	-20	-32	-43	-47



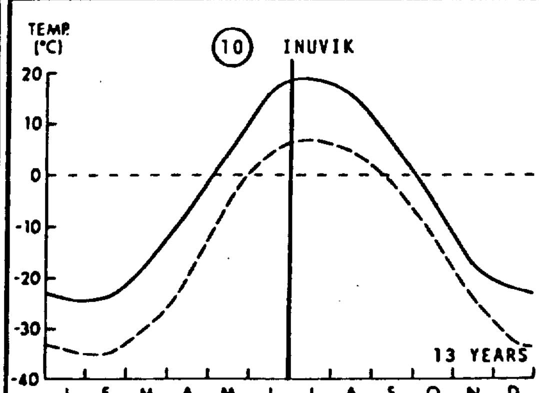
J	F	M	A	M	J	J	A	S	O	N	D
-7	-10	-17	-3	4	15	17	16	7	0	-7	-8
-54	-44	-46	-38	-23	-14	-1	-5	-16	-32	-43	-44



J	F	M	A	M	J	J	A	S	O	N	D
- 3	- 8	- 5	3	11	17	23	21	18	6	3	- 4
-42	-47	-43	-38	-28	-11	- 3	- 4	- 8	-22	-37	-41



J	F	M	A	M	J	J	A	S	O	N	D
- 4	- 3	1	6	19	27	28	30	22	10	6	- 2
-45	-50	-42	-38	-27	-11	- 2	- 2	-11	-31	-39	-44



J	F	M	A	M	J	J	A	S	O	N	D
2	3	6	13	23	32	31	29	26	15	11	- 1
-52	-57	-51	-44	-28	- 6	- 3	- 6	-19	-35	-46	-50

6. CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

6.1.1 Igniter Requirements

A large release of oil from a stationary tanker will require about 40 igniters per hectare of oiled ice for an effective burning operation. For a substantial discharge of oil from a moving tanker about 15 igniters per hectare will be needed to burn the major oil pools. Therefore, based on the spill scenarios selected for this study about 2500 igniters would be needed to burn the oil from a large stationary tanker spill. Up to 30,000 igniters could be needed to ignite the oil from a large release of oil from a moving tanker.

6.1.2 Igniter Production

The acquisition of the necessary chemicals for the igniter production will likely take 2 to 3 months. Hardware items could have similar supply delays. Unless these raw items were stockpiled, at the buyer's expense, production of igniters could not commence until 2 to 3 months after an order was placed.

Once the materials are on hand the limiting steps in the production process are the mixing and curing stages of the formulation process for solid rocket propellant. The specialized mixers used in this process are small; therefore significant time is needed to produce large quantities of igniters (i.e. 30,000). Since the Dome igniter uses much less of this fuel it can generally be produced at a higher rate than the DREV unit. Of the manufacturers surveyed, a maximum production of about 6000 units (Dome) per month was identified as possible once raw materials were on hand (3000/month for the DREV).

All of the manufacturers, except Energetex Engineering, would require that a pre-production run be funded anywhere from 3 to 12 months prior to the first full-scale production order.

Because of the raw material supply delays and limited production rates a short term supply of even 2500 igniters is not possible. Igniters will therefore have to be stockpiled to handle any major spill which occurs late in the winter (i.e. up to 3 to 4 months prior to breakup). The 30,000 igniters needed for an oil release from a moving tanker could not be made by any one manufacturer even if it occurred very early in the year and 8 months were available to produce the units. The stockpiling of igniters would seem to be the only way to ensure that sufficient igniters are available for clean up in the spring.

6.1.3 The Igniter Operation

The Arctic settlements in the north considered suitable for land based operations along the proposed shipping route are Frobisher Bay, Broughton Is., Cape Dyer, Clyde River, Pond Inlet, Nanisivik, Resolute Bay, Rea Point, Johnson Point, Inuvik, Cape Parry, McKinley Bay, and Tuktoyaktuk. The larger of these settlements would serve as intermediate links between the south and the small settlements near the spill site.

While land and sea shipment of igniters pose no difficulties both methods are relatively slow and seasonal and land access is available only to the southern Beaufort Sea area. Chartered cargo aircraft is the only viable shipment mode for the fast movement of igniters from the south to northern spill sites.

As examples of the capacities of various transport modes, 30,000 Dome igniters could be moved in 3 transport trucks, 2 train cars, 2 Boeing 737 aircraft or 5 Douglas DC 3 cargo planes. Because of the heavier weight of the DREV igniter, 3 Boeing 737's and 22 DC-3 shipments would be needed to move 30,000 units.

The igniters must be stored in locked spark free enclosures absent of other flammable materials. The storage location must also be clearly marked as a fireworks storage area.

The major drawback of a land based helicopter operation is the transit time to and from the spill site. The available flight time of suitable helicopters limits the time which can be used for the actual igniter deployment. The shipping lanes off Baffin Island are so far offshore that most helicopters do not have the range to fly a sortie to these locations.

Depending on the accident location and the size of the spill, from 1 to more than 5 helicopters may be needed to deliver the igniters to the spill spite during a spring operation.

Since the igniters would be dropped during the spring melt the prevailing environmental conditions should not hamper the operation excessively. Sufficient daylight will be available at this time of the year (from 18 to 24 hours) and the probability of good flight conditions is high (70% to 80%).

6.2 Recommendations

1) About 2 years prior to the use of tankers in the Arctic, pre-production efforts should be funded to ready suitable manufacturers. About 1 year from the start of shipping, production of a stockpile of igniters should begin to ensure that immediate demand situations can be met.

2) The use of the damaged tanker, or another suitable ice breaking vessel, as a platform of operation for the deployment of igniters in areas far offshore should be investigated.

3) The feasibility of instructing the tanker's captain to remain stationary, if safe to do so, or at least to manoeuver in a confined area during the release of oil in ice should be investigated. The logistics and probability of success of a springtime igniter clean up operation would be enhanced greatly if this could be achieved. The safety of the crew would obviously be given priority over such actions.

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Appendix A: Company Responses

bristol aerospace limited

P. O. BOX 874, WINNIPEG,
CANADA R3C 2S4
TELEPHONE (204) 775-8331
TWX 610-671-3598
TELEX 07-57774 - 07-57804

Our Ref. C6.4.1

February 2, 1983

Environment Canada,
Environment Emergencies Branch,
346 Frank Street,
Ottawa, Ont.
K2P OY1.

Attention: Mr. R. C. (Randy) Belore

Dear Sir:

We have now had an opportunity to study the information on incendiary devices for in situ combustion of oil provided in your letter of December 14, 1982 and find that the unit identified as the DREV igniter is well within the manufacturing capability of the Bristol Aerospace Ltd., Rockwood Propellant Plant. Although the Dome Petroleum Ltd. igniter appears to be an equally simple and no doubt cost effective solution, the fact that it involves the use of gelled kerosene makes it incompatible with the materials and processes associated with our propellant manufacturing operation.

Concentrating on the DREV design then we have identified at least three possible methods of manufacture. These are:

1. Cast incendiary composition into cardboard cylinders and then bandsaw and groove the disc to the appropriate configuration.

2. Cast the incendiary composition into reusable molds configured to the final shape of the main charge.

3. Preassemble the plywood layers and foam separator and cast the incendiary composition into the remaining cavity.

The first approach will involve designing special purpose equipment so that the cutting operations can be performed remotely while the second method involves manufacture of relatively expensive molds. To avoid these capital and tooling related expenses, we have assumed that the third method (while perhaps requiring some design changes to that shown on the sketch in Attachment A) would represent a feasible manufacturing approach. On this basis then we have developed some ROM costs and using the quantities identified in your letter consider that the unit price would be of the order of $80.00 to $100.00.

With regard to the three scenarios you have outlined, it is important to note that our plan has assumed that we would produce this device using a mixer capable of processing approximately 200 lbs. of incendiary composition (or the equivalent of 40 units) and under the best circumstance we might expect to be able to cast about 350 units per week. The lead times for the chemicals and inert materials should not represent a significant problem with the possible exception of the hardware and pyrotechnics components associated with the firing mechanism. You should allow 8 to 10 weeks delivery for the chemicals and consider stockpiling the firing mechanism so as to minimize the production lead time. Under these circumstances then and assuming a production cycle time of 2 weeks, you might expect 2,500 units to be produced in about 20 weeks with delivery beginning at week 12 at the rate of 350 units/week. The 30,000 units would require close to two years to produce.

It is worth noting that because of our current and anticipated rocket motor production action, we have proposed using our 200 lb. mixer for Scenario 1 and 3 as it represents equipment which is normally idle except for those infrequent occasions when it is required for sub-scale propellant formulation activity. Clearily the desirable manufacturing plan from the producers viewpoint is Scenario 2 where the units are produced steadily over a five year period. In this instance it would be possible to schedule the activity into one of two 2,000 lb production scale mixers where it would be possible to process approximately 400 units/batch. This approach would involve processing 15 batches per year and would represent approximately 4% of the theoretical maximum capacity of the mixers.

As you can appreciate this information is based on the limited data provided in your letter and before a more detailed response can be provided it would be necessary to acquire more specific design information so that we can properly assess the feasibility of our manufacturing plan. We would expect that the next stage would involve a demonstration of the production method in order that tooling, ancillary equipment and handling equipment requirements could be determined. Once this has been established, we would expect that in order to accommodate the short time response suggested by Scenario 1 and 3 the necessary funds to fabricate these production support items would be made available so that we could be in a state of readiness should the need arise.

We trust this answers the questions raised in your letter of December 14, 1982 and if we can be of further assistance please let us know.

Yours very truly,

BRISTOL AEROSPACE LIMITED

W. Voort
Programme Manager
CRV7 Weapon System

WV:kjl

Copy sent to:

Mr. H. Whittaker,
Process Development Engineer
Environment Canada,
Environment Emergencies Branch,
15th Floor, Place Vincent Massey,
HULL, Quebec.
K1A 1C8

DU PONT CANADA

DU PONT CANADA INC.
BOX 2200 · STREETSVILLE POSTAL STATION
MISSISSAUGA, ONTARIO L5M 2H3
TELEPHONE (416) 821-3300 · TELEX 06-22304

February 14, 1983

Mr. R.C. Belore
346 Frank Street
Ottawa, Ontario
K2P 0Y1

Dear Mr. Belore:

REFERENCE: 1983 DECEMBER 14 LETTER FROM
H. WHITTAKER, ENVIRONMENT CANADA TO J. DOYLE
DU PONT CANADA INC. - IGNITERS

We have looked at the specifications of the DREV and Dome Petroleum Igniter and must advise that we would not be in a position to manufacture the igniters in Du Pont Canada Inc.

We have asked E.I. du Pont de Nemours & Company in Wilmington, Delaware if they would be interested in manufacture of the items. We have not heard back from them as yet but will advise you when we have done so.

Thank you for your interest in our Company.

Yours very truly,

DU PONT CANADA INC.

D.W. Briden

D.W. Briden
Technical, Planning
and Manufacturing Manager
Explosives Division

DWB/df

DU PONT
CANADA

DU PONT CANADA INC.
BOX 2200 • STREETSVILLE POSTAL STATION
MISSISSAUGA, ONTARIO L5M 2H3
TELEPHONE (416) 821-3300 • TELEX 06-22304

1983 March 23

Mr. R.C. Belore
346 Frank Street
Ottawa, Ontario
K2P 0Y1

Dear Mr. Belore:

REFERENCE: MY MEMO 1983 FEBRUARY 14 ON IGNITERS

Further to my memo we have now heard back from E.I. du Pont de Nemours and Company in Wilmington. They advise that they would not be in a position to manufacture the igniters.

Yours very truly,

DU PONT CANADA INC.

D.W. Briden

D.W. Briden
Technical, Planning
and Manufacturing Manager
Explosives Division

DWB/df

ENERGETEX ENGINEERING
OWNED BY M E T ENGINEERING INCORPORATED

P.O. Box 744, Suite 9, 498 Albert St. (Parkdale Plaza), Waterloo, Ontario N2J 4C2 • Phone (519) 743-7191

January 17, 1983

Mr. R. C. Belore
S.L. Ross Environmental Research
346 Frank Street
OTTAWA, Ontario
K2P 0Y1

Dear Mr. Belore:

This is our response to the letter of December 14 from H. Whittaker of Environment Canada concerning igniters for oil spills in the Arctic. We have given very careful consideration to the three scenarios described in the letter and to the three questions asked of us.

Our answers to these questions all deal only with the Energetex igniter. We have not enough technical information on DREV/ABA igniter in order to reply at this time to your questions. The specific answers are:

1. We would be prepared to gear up to produce igniters in house only under the demand structure of scenario 2. Scenarios 1 and 3 are not feasible for as exactly for the reasons indicated in the question.

2. The numbers of igniters required under scenario 2 could be supplied in the time specified. The approximate cost per igniter in 1983 would be ≈ $40.
We could attempt to supply the numbers of igniters required in scenarios 1 and 3 only on an emergency procurement basis. This would mean that the price would have to be higher than in scenario 2, very much higher in the case of scenario 3, and our ability to guarantee delivery on time would be correspondingly compromised.

3. The number of igniters which could be produced at not more than twice the unit cost of scenario #2 would be 450 per week, i.e. triple the rate of production under #2. This would be achieved by moving to three-shift production in the same facilities.

In answering these questions we have not had to make any assumptions about licensing of the igniters or of the production facilities. We are now fully licensed to produce the Energetex igniters. Our reply is based on zero demand case, from any other sources. However if the demand for oil spill igniters from commercial sources is developed (steady demand) our reply to your letter would be adjusted accordingly.

We would be pleased to discuss this matter further.

Yours very truly,

E. M. Twardus, P.Eng.

EMT/js

CXA Ltd in Gravensbury

PRODUITS CHIMIQUES EXPRO INC.
EXPRO CHEMICAL PRODUCTS INC.

C.P. 5520, Valleyfield, Québec, Canada, J6S 4V9 - Télex : 05-27355 / Tél. (514) 371-5520

December 20, 1982

Mr. H. Whittaker
Process Development Engineer
Environment Canada
Environmental Protection
Environmental Emergencies Branch
15th Floor, Place Vincent Massey
Hull, Québec
K1A 1C8

Dear Mr. Whittaker,

Thank you for your letter dated December 14, 1982, with regards to your investigating methods of cleaning up major oil spills in the Arctic.

We have referred your letter to our Marketing Manager, Mr. R. D. Heddle, who will send you an answer within the next few days.

Yours sincerely,

Valerie Barbar

for R. Christen
Operations Manager

RC/vb

cc: R. C. (Randy) Belore
346 Frank Street
Ottawa, Ontario
K2P 0Y1

HANDS Fireworks Inc.
221 Nipissing Road, Milton, Ontario. L9T 1R3
Telephone: (416) 878-2831/Mississauga (416) 826-8428

February 21, 1983.

Mr. R.C.Belore,
346, Frank Street,
OTTAWA, ONTARIO.
K2P OY1

Dear Mr. Belore,

With reference to the letter from Mr. H. Whittaker of Environmental Emergencies Branch dated December 16, 1982, and to our subsequent meeting and discussion, we are able to submit the following basic pricing, delivery constraints and facilities requirements.

Our firm would certainly be interested to produce these items and we do have suitable production facilities which are fully licenced by the Explosives Branch of Department of Energy Mines and Resources. We will deal with the two prescribed units separately giving information and costing for each Scenario in the letter.

A. THE UNIT DEVELOPED BY DOME PETROLEUM.

General : This unit basically consists of mechanical assembly of parts which can be readily purchased and a quantity of gelled Kerosene which must be prepared. Capital equipment and facility outlays are minimal here, with the exception of a mixer for preparation of the starter composition and for preparing the gelled Kerosene.

SCENARIO I: 2500 igniters are required in the 3 months period after an accident has occurred.

1. This could be met provided the equipment was available in place and ready to use.

2. Sufficient stock would have to be on hand for 2500 units as normal lead times for the various components are 2 months. Approximate stock costs would be $75,000.00.

3. If stock is not held, units could only be manufactured and delivered in month 4 after receipt of order.

4. For the initial quantity of 2,500, the cost would be approximately $67.13 each, F.S.T., and shipping included.

Contd. --

HANDS Fireworks Inc.

February 21, 1983.

SCENARIO 2: 30,000 igniters are required for stock-piling and are produced steadily over a 5 year period.

1. A quantity of 6000 per year would be about 2 months production. We would have to start up and close down the production line 5 times. We will have to buy smaller quantity of items therefore not getting any price breaks that would substantially lower the cost. Also, labour rates vary from year to year, increasing as do materials.

2. There is no problem to meet this schedule. The approximate price would be $65.33 each, increasing approximately 6% per year over the 5 year period. F.S.T. and shipping are included.

SCENARIO 3: 30,000 igniters are needed within 5 months after an accidental spill.

1. This could not be met unless all necessary equipment was in place and sufficient stock was on hand for 12,000 units. We would also have to run extra shifts to get sufficient production in the beginning. A rate of 6000 per month on one shift is achievable. Units would be shipped in lot quantities as soon as they were available.

2. The approximate cost for these items would be $62.25 each, F.S.T. and shipping costs included.

In conclusion of Section A, the Dome Petroleum unit, we are in a position to make them. All deliveries given are predicated on the fact that preproduction items would have been produced by ourselves and were acceptable to the user. We would be paid for material brought in advance and stored; we would be paid for equipment purchased. We do not foresee any facility stand by charges being incurred for this item.

All details would have to be cleared re royalties, Patent rights, etc. that may be involved in this technology transfer. There is no cost allowance in our pricing for any costs pertinent to patent, royalties, etc. Most details could be cleared up at the preproduction stage for which there would be a separate cost.

Contd. --

February 21, 1983.

B. THE UNIT DEVELOPED BY DREV.

General: This unit basically consists of a lamination of polystyrene foam pads, plywood, and contains a large disc of special pyro composition which is ignited by a starter mixture which is actuated by an igniter delay system. The complexity here is in the incendiary composition, starter mixture and igniter assembly. We require special mixing equipment, reinforced mixing building and extensive facilities for curing the cast compositions.

The lead times are significant for set up of the facility and equipment purchase. There are considerable outlays of cash required to set up. There will be stand by charges required for the facilities and equipment while waiting for orders. Certain raw materials will also have to be kept on hand.

There are costs involved for tooling for fabrication of the required igniter. The total outlay for equipment, buildings and tooling is required whether we produce 2,500 or 30,000 units.

SCENARIO 1. 2500 Igniters are required in the 3 month period after an accident has occurred.

1. This quantity of 2500 can be produced and shipped provided the following conditions have been met.-

1.1 All equipment has been purchased, is in place, and is proved in during a preproduction run.
1.2 All necessary facilities are in place and proved in.
1.3 All tooling for the Igniter (Injection and compression moulds) have been purchased, proved in, and parts are on hand. There is a 6 month lead time required here.

2. The following costs would have to be expended to have building, equipment and tooling available and in place.-

2.1 Tooling - Injection & Compression moulds for the Igniter	-- --	--	$66,000.00
2.2 Equipment - Mixer, etc.		--	80,000.00
2.3 Mix Building -	--	--	80,000.00
			$226,000.00

3. To have material on hand for fast start up for 2,500 units is approximately $112,000.00

Contd. --

February 21, 1983.

4. The approximate cost per unit for a lot of 2,500 units, F.S.T. and freight included is $113.40 each.

SCENARIO 2: 30,000 Igniters are required for stock-piling and are produced steadily over a 5 year period.

1. The conditions as set forward under Scenario 1 would apply here as regards all capital outlays. See point 2, under Scenario 1.

2. There would be no requirement to hold minimum stocks for fast start up. One years production of 6000 units would take 2.5 months. There would be some stand-by charges involved for the equipment and machinery.

3. The approximate cost per unit, for a quantity of 30,000 units, produced at the rate of 6000 per year, F.S.T. and freight included, would be approximately $112.39 each. We have tried to work out a price that would project us into 1984. After that there would be an approximate 6% increase per year of the above price.

SCENARIO 3: 30,000 igniters are needed within 5 months after an accidental spill.

1. The conditions as set forward under Scenario 1, would apply here as regards all capital outlays. See point 2 under Scenario 1.

2. In order to have 30,000 units in 5 months, we must be able to produce immediately in the first month, 6000 units. Even holding material stocks, this is impossible. Our best reliable production rate will be 3,000 per month. In the first month 1500 alone will be available. There are possibilities to add shifts to produce more, but we are hesitant to do so as the critical operation controlling output is the mixing of the composition, which is the most hazardous operation to control.

We would require stocks of raw maerials and components to be on hand for about 7500 units as there is a minimum lead time of 2 months on most items. (Without holding stock we would be scheduling 1500 in month 3 after order receipt.) Therefore approximate cost of stock that would have to be on hand is $300,000.00.

Contd. --

3. Our production schedule, starting right upon receipt of order, would be :-

Month 1 - 1500
Month 2 - 3000
Month 3 - 3000
Month 4 - 3000
Month 5 - 3000

At the end of 5 months we would have produced 13,500 units of the 30,000 required. At the rate of 3000 per month we would complete the order in 10.5 months total time.

This time could possibly be shortened and monthly quantities increased if we could make the mixing process faster and more efficient.

4. The approximate cost per unit for quantity of 30,000 produced in one continuous production run, F.S.T. and transportation included is $107.39 each.

In conclusion of Section B, the DREV developed unit, we state that we are interested to manufacture such items. All delivery schedules given are predicated on the fact that preproduction items would have been produced by ourselves and were acceptable to the user. We would be paid for material bought in advance and stored; we would be paid for the equipment purchased; facilities must be set up to produce this item.

All details would have to be cleared re Royalties, Patent rights, etc., that may be involved in this technology transfer. There is no cost allowance in our pricing for any costs pertinent to Patent, Royalties etc. Most details could be cleared up at the preproduction stage for which there would be a separate cost.

For general information, from our analysis of the DREV design, we can see some areas that could be changed which could certainly have a bearing on the end product cost. One such item is the igniter. We have a cheaper, reliable igniter which we use on many items that could be used in lieu of the igniter specified. This would delete the need for $66,000 of tooling plus the cost of the plastic parts which could mean $1-$2.00 per unit. A small contract to prove this out would be all that is required.

We trust that this information will assist you in your analysis of this project.

Yours very truly,

R.F.LITTLE
Manager-Technology

RFL/ib

Thiokol Corporation, a Subsidiary of

MORTON THIOKOL, INC.

Elkton Division

In reply refer to: EP611-83

February 23, 1983

R. C. Belore
346 Frank Street
Ottawa, Ontario
K2P 0Y1

Subject: Oil Spill Igniters

Reference: Environmental Emergencies Branch, Environment Canada letter to Mr. Crawford, dated January 11, 1983

Gentlemen:

The Elkton Division of Morton Thiokol has a strong interest in manufacturing the oil spill igniters defined in the referenced letter. We routinely produce rocket motors and gas generators that use solid propellants very similar in formulation to that used in the DREV igniter. A brochure describing our facilities and capabilities is enclosed.

We can provide units per Scenario 1 or 2, that is, either 2500 igniters to be manufactured and delivered within 3 months of an incident (Scenario 1) or 30,000 igniters manufactured and stockpiled over a 5-year period (Scenario 2). We can accommodate either of these approaches with minimum difficulty. For Scenario 1, the purchasing agency would have to fund a tool-up and demonstration effort to establish the production capability approximately 9 to 12 months in advance of the full capability being established. Scenario 2 is a more cost effective approach from an igniter unit price standpoint.

Our rough order of magnitude estimate of the unit price is $45 to $60 for the DREV igniter and $35 to $55 for the Dome Petroleum igniter, depending on which scenario and propellant formulation are selected.

Our rough estimate of the maximum number of igniters that could be made at a reasonable cost in the 5-month period specified in Scenario 3 is 15,000 units.

P.O. Box 241, Elkton, Maryland 21921 (301) 398-3000

I hope that this preliminary response meets your immediate requirements. We look forward to providing a more in-depth response if the Canadian Government elects to proceed further with this program. Please direct your inquiries to W. F. Sanford, manager of new products.

Very truly yours,

John P. King

for U. E. Garrison
Vice President and General Manager

WFS/py
Enclosure: Elkton Division Facilities Brochure