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Spill Technology Newsletter

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Report EPS 3-EC-82-6

Environmental Impact Control Directorate
December 1982

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Environmental Impact Control Directorate
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Ottawa, Ontario

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REVIEW NOTICE

This report has been reviewed by the Environmental Impact Control Directorate, Environmental Protection Service, and approved for publication. Approval does not necessarily infer that the contents reflect the views and policies of the Environmental Protection Service. Mention of trade names or commercial products does not constitute endorsement for use.

TABLE OF CONTENTS

TABLE OF CONTENTS

SPILL TECHNOLOGY NEWSLETTER

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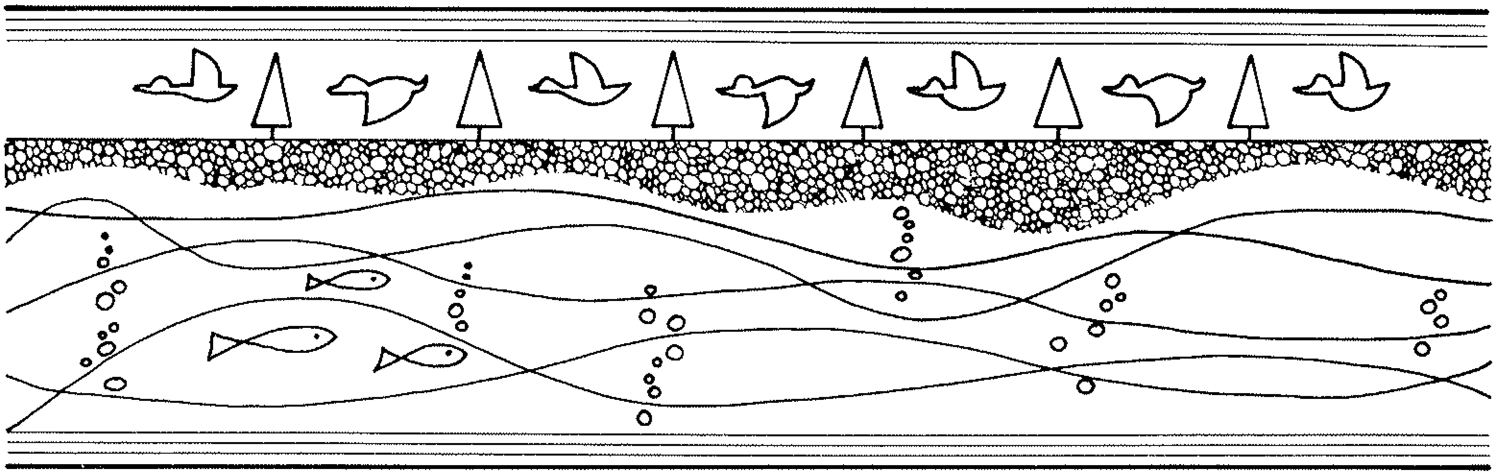

Table of Contents

Spill Technology Newsletter

EDITORS

Mr. M.F. Fingas and Dr. D.E. Thornton

Research and Development Division
Environmental Emergency Branch
Environmental Impact Control Directorate
Environmental Protection Service
Department of the Environment
Ottawa, Ontario
K1A 1C8

Phone: (819) 997-3921

The Spill Technology Newsletter was started with modest intentions in 1976 to provide a forum in Canada for the exchange of information on oil spill countermeasures and other related matters. The interest in it was such that we now have over 2,500 subscribers in Canada and around the world.

To broaden the scope of this newsletter, and to provide more information on industry and foreign activities in the field of oil spill control and prevention, readers are encouraged to submit articles on their work and views in this area.

INTRODUCTION

The first article in this issue is by Ken Meikle and Bill Wallace who review the development and testing of a beach cleaning device. This device, a caltrop belt (bed-of-nails belt), has been shown to recover oil from the surface of beaches consistent with its design objectives. The second article by Dave Scarratt of the Department of Fisheries and Oceans reviews the impacts of offshore oil production on fish and fishing operations. The third article is by Peter Blackall and Dave Thornton and provides a review of the activities of the 1980 Baffin Island Oil Spill Program. The initial results of the tests conducted in 1980 are also summarized.

REPORTS AND PUBLICATIONS

- The Finnish Department of Environmental Protection has released the report, "The 1979 Baltic Oil Spill; Environmental Studies". The report is available from the Ministry of the Interior, Department for Environmental Protection, Hakaniemenk. 2, SF-00530, Helsinki, Finland.

- The report, "An Evaluation of the Accumulated Environmental Impacts to be potentially experienced by the Yukon Territory with Construction of the Foothills Oil and Gas Pipelines", is now available from the Lands Directorate, Pacific and Yukon Region, Environment Canada, Room 904, 1001 West Pender Street, Vancouver, B.C. V6E 2M7.

- The Environmental Emergency Branch has recently released two contractor's reports, the titles of which appear below. These reports are unedited and have not undergone rigorous technical review but will be distributed on a limited basis to transfer the results to people working in related fields. For copies of these reports contact: Publications Coordinator, Environmental Impact Control Directorate, Environmental Protection Service, Ottawa, Ontario, K1A 1C8.

  "Evaluation and Prevention of Corrosion Leaks on Buried Storage Tanks".

  "An Oilspill in Pack Ice".

- Offshore Environment in the 80's, a workshop on the environmental considerations of east coast offshore hydrocarbon development, was held in St. John's, Newfoundland, in December 1980. The proceedings are now available, at a cost of $25, from

  Offshore Environment in the 80's,
  P.O. Box 5037,
  St. John's, Nfld.
  A1C 5V3

  The workshop was sponsored by the East Coast Petroleum Operators Association, Institute for Resource and Environmental Studies (Dalhousie University), Newfoundland Institute for Cold Ocean Science (Memorial University), Newfoundland Department of Consumer Affairs & Environment, Nova Scotia Department of Environment, Environment Canada, and the Canadian Petroleum Association.

- The following reports are available from the U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia, 22161, Telephone (703) 487-4650. Most reports are also available on Microfiche at $3.35 each (U.S.A. Price). Canadian buyers add $2.50 to each paper copy and $1.50 for each microfiche report. Prices are quoted in U.S. dollars.

  "Oil Pollution Abstracts. Volume 7, Number 1 (January 1980 - June 1980)." H.W. Offen, H. Ehrenspeck, C. Matuck, D. Hannan, and R. Stefani. California University, Santa Barbara. January, 1981. 355 p. PB81-140493 $26.00.

"Petroleum in the Deep Sea Environment: Potential for Damage to Biota." J.F. Karinen. National Marine Fisheries Service, Auke Bay, Alaska. 1980. 11 p. PB81-141095 $5.00.

"Future Configuration of Tank Vehicles Hauling Flammable Liquids in Michigan. Volume I. Final Technical Report." R.D. Ervin, C. Mallikarjunapao, and T.D. Gillespie. Michigan Department of State Highways and Transportation, Lansing. December, 1980. 245 p. PB81-143281 $18.50.

"Future Configuration of Tank Vehicles Hauling Flammable Liquids in Michigan. Volume II. Apppendices." R.D. Ervin, C. Mallikarjunapao, and T.D. Gillespie. Michigan Department of State Highways and Transportation, Lansing. December, 1980. 108 p. PB81-143299 $15.50.

"Assessment of the Risk of Transporting Propane by Truck and Train." C.A. Geffen. Battelle Pacific Northwest Laboratories, Richland, Washington. March, 1980. PNL-3308.

"Chemical Bulk Handling. January, 1976 - September, 1980 (Citations from the Energy Data Base)." W. Van Put. National Technical Information Service, Springfield, Virginia. September, 1980. 148 p. PB81-850521 $30.00.

UPCOMING CONFERENCES

- The 1982 Hazardous Material Spills Conference has been scheduled for April 19-22, 1982, at the Milwaukee Exposition & Convention Centre. For further details on this conference contact; Harzardous Material Spills Conference, Suite 700, 1629K Street, N.W., Washington, D.C., 20006.

- The International Society of Petroleum Industry Biologists will be presenting a Symposium on "Land and Water Issues Related to Energy Development" in conjunction with the Fourth Annual Meeting. This event is scheduled for 22-25 September, 1981, at the Denver Hilton, Denver, Colorado. For further information contact: Dr. P.J. Rand, Environmental Sciences, Atlantic Richfield Company, 515 South Flower Street, Los Angeles, California, 90071.

- The 4th International Conference on Used Oil Recovery and Reuse will be held September 28-October 1 at the Caesars Palace Hotel in Las Vegas. For further information contact; Association of Petroleum Re-refiners, 2025 Pennsylvania Avenue, N.W., Suite 913, Washington, D.C., 20006.

- The Sixth Annual Inland Spills Conference will feature emergency procedures to contain and clean up hazardous materials spills. The conference is scheduled for October 13-15 at the Layfayette Motor Hotel in Maietta, Ohio. For more information contact; OHIO EPA, Office of Training and Safety, 361E. Broad Street, Columbus, Ohio, 43215.

- "Ocean Pollution - 1981: The North Atlantic." will be held October 19-23, 1981, at the Lord Nelson Hotel, Halifax, Nova Scotia. For further information contact; Dr. J.H. Vandermeulen, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, B2Y 4A2, Phone (902) 426-2479.

- The Second International Environment and Safety Exhibition and Conference will be held 2-4 September, 1981 at the Wembley Conference Centre, London, England. For further information contact: IEeS Exhibitions and Conferences, Newgate, Sandpit Lane, St. Albons, Herts. AL4 0B5. Telephone (0727) 31337.

THE DEVELOPMENT AND TESTING OF BEACH CLEANING DEVICE: THE CALTROP MARK II

Submitted by: K.M. Meikle
Environmental Emergency Branch
Environmental Protection Service
Ottawa, Ontario

From a report by: W.G. Wallace
C. Banks
Eastern Marine Services Ltd.
Musquodoboit Harbour, Nova Scotia

Introduction

A device for clearing oil from beaches was designed and constructed by Neill and Gunter Ltd. and the Nova Scotia Technical College under contract to the Environmental Emergency Branch (EEB). Called the Caltrop, it uses a spined belt (essentially a belt with nails driven through it) to pick up oil and accompanying sand from recreational beaches. A prototype, in which a spined belt revolved around a drum, was tested in laboratory situations and also on a recreational beach. The oiled sand adhered between the nails on the belt and was conveyed to a bin, into which it was stripped by the action of a rotating brush. Motive and operating power was derived from a small garden tractor which towed the unit and provided power via a hydraulic system. Motive power was applied to the drum driving the belt and, since the belt provided a large area of contact with the ground, sufficient traction was available to move the unit over various types of sandy beaches.

Field tests conducted using this prototype unit revealed several deficiencies that would have to be corrected before it could be considered field operable. These included under-powering, lack of a recovered materials handling system, and poor maneuverability. To overcome these problems a Mark II version was designed and built by eastern Marine Services Ltd. under contract to EEB. It employs the basic operating principle of the prototype unit, but incorporates a large number of modifications.

Design of the Modified Unit

To correct the several deficiencies the following basic modifications were made:

1) The pick-up belt and drive system was split into two independently-driven treads. A roller chain fastened to the edge of each belt is sprocket-driven by a hydraulic motor at a 3:1 reduction ratio. They are served by separate pumps because of the inherent problems with flow control when hydraulic motors are operated in series from a common pump. The drive system provides independent forward, neutral and reverse for each tread to allow both large and small radius turns to be made.

2) The pattern of nail spacing in the treads was altered to a square pattern, to allow removal of oiled sand by stationary wire brushes set to fit between the nails. This reduced the power needed to clean the belt and the power available is now sufficient to remove the oily sand, drive the machine at a reasonable forward speed, and operate the disposal conveyor.

3) A small conveyor was installed to receive the oiled sand mixture brushed off the treads and carry it to one or the other side of the machine, as selected by the operator. A spring loaded scraper blade at each end of the conveyor removes the oiled sand mixture into a plastic bag which is then tied off and dropped for later pick-up. Weight changes to the machine during use are minimized, and the collected oiled sand is conveniently packaged for subsequent handling.

A simple test apparatus was constructed to determine the forces necessary to clean the oiled sand mixture off the treads. Three rows of nails were driven into a 10 mm thick piece of plywood to simulate a section of the belt. A pair of rotary wire brushes was mounted onto a slider bar which could be hand-pushed down the rows of nails. A straight-edged wire hand brush was also rigged for comparative testing. A typical oiled sand mixture was prepared and applied to the test board.

Tests were conducted with the rotating wire brushes operating at various RPM from 0 to 450 and at various forward velocities. From these tests it was determined that the rotary brushes provided no increase in clearing efficiency but markedly increased the power required compared to a straight, non-rotating brush. The straight wire brush was then pulled through the board while speed and pulling force were measured. A curve was drawn from the test data and extrapolated to give force requirements for speeds to 4.8 km/hr. A design speed of 4.0 km/hr. was chosen (reasonable walking speed) and a tread width of 375 mm was selected. From these parameters, a hydraulic motor-pump system was designed, and the necessary input horsepower was calculated.

The prime mover is a small 4-cylinder used auto engine with manual transmission. This allows a variation of pump speed with change of transmission and throttle setting.

The transverse conveyor is 20 cm in width. It is powered by a separate pump and hydraulic motor and is controlled by a simple 4-way, 3-position valve to allow delivery to either side of the machine, depending on which side is away from the oil-contaminated area.

Evaluation Method and Results

Mechanical durability testing was done in the Eastern Marine Services shop area and determined that the components were suitable for operational testing. The two-tread design of the machine with independent hydraulic motors and pumps resulted in a highly maneuverable unit. With spring loaded differential hydraulic controls capable of reverse mode, the unit can turn within its own length. Initially, problems were encountered in aligning the tread belts and in keeping them from jumping the drive sprocket or running off the edge of the lower drum. These problems were solved by tensioning the belts and aligning them with extreme care.

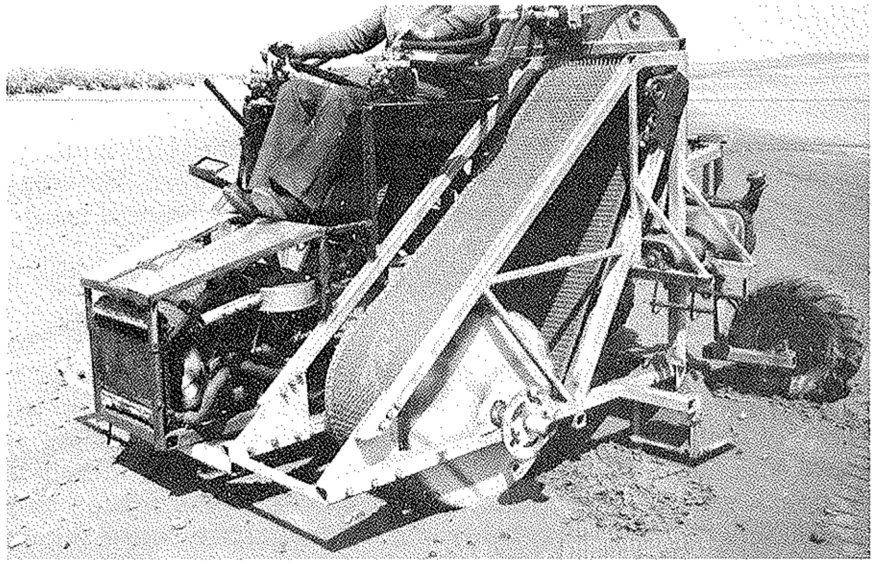

FIGURE 1. Side View of the Prototype Caltrop II Maneuvering on the Beach

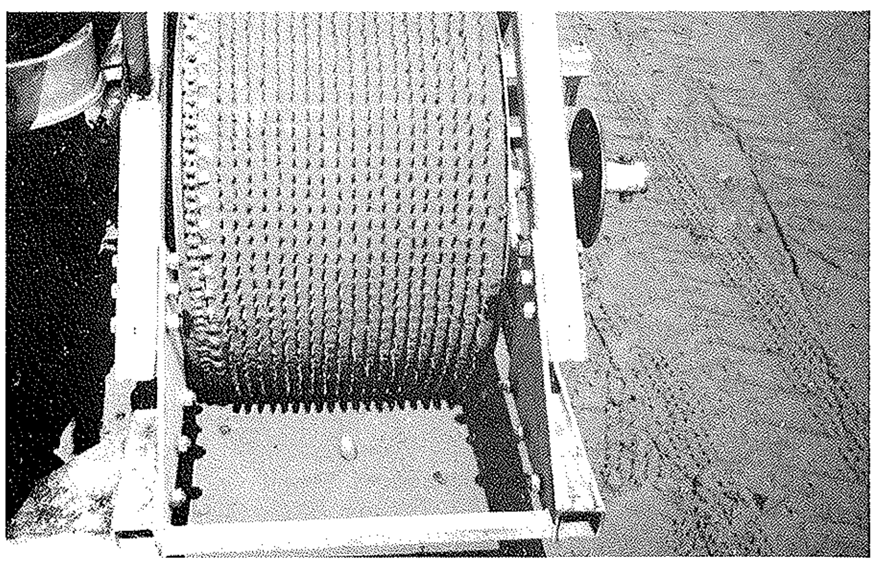

FIGURE 2. Close-up view of a Caltrop belt. Note that on dry and un-oiled sand the belt does not pick up beach material

The power train component built into the Mark II unit was designed to permit some variation of power output within the limits of the hydraulic pumps and motors. In mechanical testing, the power level was sufficient to provide traction at the design speed on a 10% grade while still operating the conveyor system and brush cleaning the belts.

The machine was operated at Martinique Beach to determine the handling characteristics on wet, semi-dry, and dry loose sand.

It bogged down in the dry loose sand; the bearing pressure was higher than this type of sand would support, even with the auxiliary pneumatic tires in place on the tread drum axle. The tread drum sank into the sand until sufficient bearing area was in contact, but then it was necessary for the drums to climb up out of the depressions they had made and the traction area was insufficient. The machine was moved to semi-dry and wet sand where the mobility, maneuverability and controllability were excellent.

Oil barrel outrigger supports were fabricated and attached to the machine so that torque was transmitted through the lower drum axle to the oil barrels as well as the spined treads. Even with this extra bearing area, the machine bogged down continuously when driven onto dry loose sand.

Oil recovery tests were carried out in a private gravel pit, where a test bed 26 m x 8 m was leveled and covered with 50 mm of sand. Bunker C oil was spread on areas 400 mm x 6.1 m to simulate one tread length. The depth of sand was limited so that the machine could maneuver without bogging down.

Under the test conditions, the oiled sand mixture was picked up, brushed onto the conveyor belt and deposited in the disposal bags with a minimum of spill-over. Some oiled sand was lost immediately after pick-up because the sheet metal behind the tread belt did not extend close enough to the pick-up point. The bagging system worked well, although the bag holder platforms were set too close to ground level and some terrain interference resulted.

Recovery was evaluated using the following factors:

Oil Content Factor: - the percentage, by weight, of oil recovered per weight of oiled sand mixture recovered.

Oil Recovery Factor: - the ratio of oil or oiled sand recovered to oil or oiled sand encountered.

Although all of the tests conducted by EMS used a nominal oil thickness of 10 mm., it was found that the oil would percolate 50 mm down through the sand layer after extended oil residence times. The tests were carried out in temperatures of 24° to 27°C., and the Bunker C was quite fluid.

An average Oil Content Factor of 25% was calculated from 5 measured tests.

The Oil Recovery Factor ranged from 82-100% down to as low as 15-20%. These were not measured values and were obtained by estimating the amount of oil left behind on the encounter track. The higher values were obtained with fresh oil that had been on the beach less than 30 minutes. The lower values were for runs made using ashphaltic mixtures of oil and sand collected during previous tests, and for runs made following longer residence times that allowed some of the oil to percolate into the sand beyond the reach of the spines.

Conclusions and Recommendations

The concept of a spined belt as applied in the tested configuration will only pick up heavy visous oil efficiently from recreational beaches under limited conditions of fresh oil deposit, low residence time, and high oil to sand ratio.

The Mark II Caltrop device demonstrated:

- good maneuverability on hard-packed sand;
- adequate power levels;
- the feasibility of continuous operation with a spined-belt machine;
- smooth, continuous handling of the recovered product;
- too high a sand bearing pressure for soft sand; and
- the inadequacy of a single chain affixed to a flat belt when used as a propulsion mechanism.

Neither problem is serious since both can easily be overcome by a rearrangement of the mechanical components of the machine.

However, the wide range in the value of the Oil Recovery Factor suggests that a more optimum combination of spine length, shape and spacing might be obtainable from a more detailed theoretical analysis and further testing to better define the requirements of the shearing stresses, adhesion qualities, traction loads and bearing pressures involved.

Future Plans

The Mark II machine has been turned over to the Canadian Coast Guard (CCG). EEB does not plan any further development work in view of the current lack of potential customer interest. CCG plans are not firm, but further testing at their Mulgrave, N.S. base is being considered.

CONSEQUENCES OF OFFSHORE OIL PRODUCTION ON FISH STOCKS AND FISHING OPERATIONS

D.J. Scarratt
Department of Fisheries and Oceans
Biological Station
St. Andrews, New Brunswick E0G 2X0

The article by Dr. Scarratt on the consequences of Offshore Oil Production on fish stocks and fishing operations was presented at the "Offshore Environment in the 80's" Conference, in St. John's, Newfoundland, in December, 1980, and is essentially an executive summary of the work of the Marine Environment and Ecosystem Subcommittee of the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC). The article has also been published as a CAFSAC Research Document No. 81/8. The report summarizes the results of a very commendable initiative to relate current knowledge and research to a practical and important issue.

Responding to requests from several quarters both within DFO and from other Departments, the Marine Environment and Ecosystem Subcommittee of CAFSAC (Canadian Atlantic Fisheries Scientific Advisory Committee) undertook an internal consultation on this topic at the Bedford Institute of Oceanography on October 27-28, 1980.

The objective of this consultation was to draft a statement of the opinion of the scientists, who are members of or associated with MEES, as to the probable consequences of the additional oil contamination to be anticipated as a result of future offshore hydrocarbon production at Sable Island and in the Grand Banks. The purpose of this paper is to summarize the presentations, discussions and conclusions which were reached. These will be published as a CAFSAC research document and will be available shortly.

Three points must be made about the consultation to avoid subsequent misunderstanding:

1. The views expressed were the personal opinions and interpretations of the individuals concerned, and not the considered position of any organization or department.

2. The output from the consultation does not represent, and cannot substitute for, a detailed written review of the same set of problems done more formally and taking more time than two days to execute. However, it must be said that the general conclusions of such a study are unlikely to be very different from those expressed in this report.

3. No consideration was given to future program requirements to solve any of the uncertainties exposed, nor to countermeasure recommendations for any of the practical difficulties likely to be encountered.

However, before summarizing our discussions, some overview of the effects of oil on marine systems would be appropriate. In general, the environmental problems can be divided into five main categories, any oil spill may combine elements of any one, or all five of these. It will depend entirely on the nature and source of the oil, the location, time of year, weather, and a host of other factors.

1. Lethal toxicity. Oil may be poisonous and may kill plants or animals directly. Toxicity is closely related to solubility in water. Low boiling point hydrocarbons with small molecules are generally more soluble, and hence, more toxic than large molecule, higher boiling point compounds. Thus, gasoline, diesel, and light fuels are extremely toxic and, in some circumstances, storms for example, their high volatility doesn't prevent them from becoming mixed in with sea water. Thus, Baker (1976) reported large numbers of littoral (beach dwelling) organisms killed after a spill of gasoline in Milford Haven. It is well known that eggs and larvae may be more susceptible than adults.

Residual fuels, such as Bunker C, from which the lighter fractions have been removed, are generally considered less toxic than refined oils. However, this is only relative. Lindén et al. (1979) report reductions in littoral invertebrates following a spill of medium fuel oil south of Stockholm in 1977.

Crude oils occupy intermediate positions in that they contain a range of fractions from light to heavy. They may initially be very toxic. This was observed during the AMOCO CADIZ crude oil spill in Brittany where hundreds of thousands of razor clams and sea urchins were killed during the initial 2 weeks of the spill despite the ample opportunity for mixing of oil throughout the water column.

Initial toxicity of crudes and products may be reduced as lighter fractions volatilize or are diluted. However, this means there is a relative enhancement of the heavier fractions, many of which are carcinogenic or mutagenic and are resistant to degradation or weathering. It has also been suggested (Malins, pers. comm.) that weathering itself may generate such compounds, and the suggestion that weathering will eliminate toxicity is an overly simplistic assumption.

2. Physiological disruptions. Sublethal physiological or behavioral disruption can occur at concentrations considerably lower than those causing outright mortality. Examples are changes in respiration, metabolism, sexual maturation, larval development (even to the extent of malformations in herring or lobster larvae with subsequently reduced survival). There may be alterations in chemoreception with subsequent behavior changes. The classic example is the baiting of lobsters with a kerosene-soaked brick. That the lobster may later be found to be inedible is one of the reasons that the method has not really caught on. Other examples are more serious. It has been suggested that migratory routes of certain fish can be interrupted, and lately there have been comments from New England fishermen that lobsters can no longer be found in the immediated vicinity of the site of the wreck of the ARGO MERCHANT off Nantucket Shoals. It must be stressed though, that if this is true, it has not been unequivocally established that oil is the cause, although

it is known that some species avoid contaminated areas. Among the plants, some phytoplankton species are in fact stimulated to grow in very low oil concentrations, but photosynthesis is inhibited at higher concentrations. Thomas (1973) showed that settlement of littoral macrophytes was inhibited after the ARROW spill in Nova Scotia.

3. Incorporation of oil in organisms. There are two principal concerns here. The first is the incorporation of carcinogenic or mutagenic compounds such as 3-4 benzopyrene or other polycyclic aromatic hydrocarbons. Such compounds stimulate plant growth and their carcinogenic and growth stimulating properties are directly related. They occur naturally and also in crude and residual oils. Some species, such as molluscs, do not have the capability of metabolizing these compounds and, as a result, they may accumulate. They are quite resistant to environmental degradation. Tumorigenesis has been documented for some fish taken from polluted waters, and clams exposed to oil have been shown to have high incidence of neoplasias.

Besides the potential problem for the clam. There may also be a problem for the would-be consumer. Concentrations of Bunker C as little as 50 ppm in clam flesh impart a distinct and not very pleasant flavor. Recent work by Vandermeulen and Penrose (1978) showed that clams exposed to ARROW Bunker C at the time of the wreck still contained oil after 6-7 years, and even 3 months in clean sea water were insufficient to remove it. Lobsters have also been shown to become tainted by Bunker C incorporated into their tissues. This has occurred both in the laboratory, and to a lesser extent, in the field, but lobsters, it seems, have a greater capacity for self cleansing. It is also known that among commercial fish, herring and mackerel may be tainted by oil. This will be discussed in greater detail below.

4. Physiological alteration of habitats. This can occur by the selective elimination or suppression of oil-sensitive species. For example, diesel oil spilled by the TAMPICO MARU selectively eliminated urchins and abalones which browse in kelp. Thus, kelp plants were allowed to grow unimpeded by browsing and produced a luxuriant canopy which persisted for 5 or more years. There were also major shifts in the animal populations as the eliminated species began to return. Similar events occurred after the TORREY CANYON spill in S.W. New England, although here most of the damage was caused by highly toxic dispersants used to clean recreational beaches and shores.

5. Incorporation into sediments. This can take two forms - one conspicuous, the other less so, but both represent a way in which oil can be bound into the sediments which acts as a reservoir slowly releasing oil to the environment for many years. The first type is the creation of impermeable pavements in both coarse and fine sediments. Even today, 10 years after the ARROW spill, extensive areas of pavement are still visible on gravel beaches in parts of Chedabucto Bay. In other parts, oil was incorporated into salt marsh sediments where it inhibited the development of marsh flora sediments and acts to suppress the fauna. It may remain virtually unchanged for 10 years or more.

In deeper water oil may become incorporated into sediments, either as a result of downward mixing due to wave action, or by being adsorbed onto particles and separating out, or in the feces of copepods and other zooplankton. It is now thought that as much as 10% of some oil spills may in fact reach the bottom of the sea. Lindén et al. (1979) show how oil reaching the bottom in 35 m of water becomes incorporated into the clam, Macoma balthica. The flounder, Pleuronectes flesus, which feeds on Macoma was subsequently shown to have elevated body burdens of oil. They believe the effects on the soft bottom will be longer lasting than those on the beaches.

Those are the basic environmental principles that we must contend with. All of them have implications for the wellbeing of the marine environment, and a number of them have direct implications for fisheries.

It was with this background that we began our discussions around six general questions. These are paraphrased below and each is followed by the relevant part of text of the executive summary of the CAFSAC report.

1. What are the likely scales and frequency of accidental release of hydrocarbons from foreseeable developments off the East Coast?

This subject was introduced by Tom Dexter of EMR.

Developments in the Sable Island area are likely to be for gas with minor amounts of light condensate. Product will be piped ashore except that condensate will be accumulated and shipped by tanker. Oil spill size is therefore not likely to exceed 10,000 tons of light gravity condensate.

On the Grand Banks, crude oil is light and sweet with high proportion of volatiles. Production is likely to be by caisson-protected seabed well heads feeding a single riser to a floating storage vessel. Maximum blow-out expected is 20,000 bbl/day but it is anticipated wells could bridge in 5-20 days. Maximum spill would be total loss of contents (M bbl) of storage vessel, or shuttle tanker loss. Offshore Labrador reserves are likely to prove to be exclusively gas, but development will probably be deferred 10-15 yr due to environmental and technical limitations.

World-wide statistics suggest a frequency of blowouts exceeding 100 bbl to be about one per thousand wells drilled and for spill exceeding 1 bbl to be about 1 per 250 wells. To date 172 wells have been drilled in East-Coast waters without mishap. Production wells have slightly higher spill rate and frequency than exploratory wells. An oil field the size of Hibernia might be expected to have a .25 probability of a blowout during the life of the field. Chronic oil spillage seems more likely to occur as a result of transhipment operations but no statistics were available. Shuttle tanker ballast water might be a source of chronic pollution.

2. What levels of oil contamination may be expected in water, sediments and what would be the physiological consequences for biota.

This subject was introduced by John Vandermeulen, MEL.

Concentrations of oil in water in the vicinity of or under a slick may be expected to be in the order of 10-200 ppb. Depending on mixing characteristics, these concentrations may exist throughout the water column (down to 100 m) and persist a few days or weeks. Hibernia oil being light, will volatise readily and up to 40% may be lost to the atmosphere within 24 h of release, however the proportion of oil dissolved or dispersed in the water will increase with sea state.

Fish egg and larval mortality and abnormal larval development of vertebrates and invertebrates would be observed at the expected oil concentrations. Based on experiences with AMOCO CADIZ, it would be expected that benthic species might suffer mortality or physiological disruption in shallow areas. Routes by which bottom sediments might become contaminated are not clearly defined, but in shallow areas, oil concentrations in sediments might reach 10-100 ppm which would have physiological implications for the benthos, however stratification on the Grand Banks might serve to keep oil in the upper water layer and thus inhibit sediment contamination.

Phytoplankton production might be enhanced at low concentrations of oil in water, and inhibited when oil concentrations are high. Zooplankton might be depressed but existing data are equivocal. Teleost eggs and larvae are expected to be impacted but current ignorance of the distribution in space and time makes prediction, and subsequent measurement of impact difficult. It was suggested that impact might be more readily measurable using physiological, or clinical criteria, rather than gross assessments of deformities, or population reductions.

3. What kind of observational programs would be required to detect the effects on biota?

This introductory paper was presented by Mike Sinclair of Marine Fish Division, BIO.

Effects fall into two categories: lethal and sublethal, each requiring different sampling and analytical techniques, but both would require adequate baseline data and distribution.

Assessment of mortality requires estimates of population abundance and distribution before the event, however existing ichthyoplankton programs on the Scotian Shelf do not generate information of sufficient precision to allow assessment of mortality due to an oil spill. Analysis of Bay of Fundy sampling programs suggests a station density of the order of 1 per 100 sq nm would be required for each of 3 or 4 surveys for each stock of interest. Covering all breeding stocks on the Scotian Shelf and Grand Banks would require a major escalation of existing effort. Diversion of existing programs in the event of an emergency would simply reduce the value of those programs without contributing meaningful data on the effect of the spill on the populations at risk.

Due to a wide annual variability in populations, existing juvenile and pre-recruit surveys have very large confidence limits and it is unlikely that mortalities less than an order of magnitude greater than normal would be detectable. Precision of adult stock estimates is much better and would probably allow an oil-induced mortality of 25% or less to be detected.

Monitoring for sub-lethal effects appears to have greater probability for success and likelihood of cost-effectiveness. Specific pre-event monitoring of selected effects for representative samples of the population would be required. These could include physical parameters such as deformations and fish larval tail flexures as well as pathalogical or clinical measurements such as identification of histological changes, or enzyme activity. These should be additional to simple measurements of hydrocarbon body burdens.

A caveat was that impact of episodic contamination might be difficult to distinguish from the cumulative effects of chronic discharges. None of the methodologies currently available seem likely to give estimates of loss which could be used for compensation purposes.

4. What is the likelihood that such effects would impair recruitment, and that such impaired recruitment would be separable from natural variation?

This subject was introduced by Dan Ware of MEL.

Hydrocarbons appear to be most toxic to early life-history stages of commercial species.

Each stock has a more or less discrete time and area for spawning and while most spawn during summer, no time of the year is without one or more vulnerable species. The timing and location of spawning and subsequent distribution of larvae is imperfectly known for most stocks, nevertheless the area impacted by a spill is likely to be only a small fraction of the total area occupied by larvae. Annual variation is such that with some species even a 50-100% loss of a weak year-class is unlikely to have a detectable effect of recruitment. A similar loss of an excellent year-class would be detectable, but except for stocks spawning in discrete shallow areas, such a detectable effect seems not likely to occur.

The distinction must be clearly made between no detectable effect and no material effect on the population. It is quite conceivable that a post-spill survey would yield numbers of dead, moribund or deformed larvae, statistically convincing manner and be shown to have a subsequent effect upon recruitment a number of years later, or upon the fishery over the normal lifetime of that year-class.

The one area of concern not resolved was that the concentration of developments close to the break of the shelf might result in concentration of spilled oil on biologically dynamic areas and thus impact core areas of larval distribution. It is not known whether larvae from all parts of the patch have equal chance of recruitment.

The impact of supression of primary production upon subsequent fish stock biomass will be undetectably small or negligible.

5. What consequences for offshore fishing operations may be expected?

I introduced this topic.

It seems unlikely that adult or commercial sized fish will be killed by oil development activities.

Because of lack of information it is difficult to predict exactly what might happen when a year-class of larvae is impacted by a spill: the effect might be similar to that of a weak year-class entering a multi year-class fishery, thus except in inshore waters or restricted stocks spawning in shallow water, it's unlikely that offshore oil discharges will have measurable impact on fish stocks or year-class success.

Except in restricted or shallow waters, it seems unlikely that fish will be tainted by oil. It is possible that catches may be contaminated and possibly tainted, if caught or held in oiled nets. Apart from the visible presence of oil, there are no established standards for rejecting contaminated catches.

There is high probability that spills in the Grand Banks may cause fouling of fishing gear which may in turn cause catch contamination. High volatility of oil may be offset by the high paraffin content which might cause the oil to become waxy at low temperatures.

The degree of interference to fishing operations by pre-emption of space cannot be predicted. Careful engineering should minimise or eliminate damage to, and loss of, fishing gear caused by under-water obstructions.

It is unlikely there will be any need to modify Canadian or Foreign harvesting strategies except in the event of major spills causing extensive slicks which might require long-term exclusion measures in order to protect gear from oiling.

Except for costs incurred by oiling of gear or provable damage, determining costs to the fishery of an oil spill will prove extremely difficult. Given that recruitment may be as much as 8-10 yr post spill, and density-dependent factors may play a significant role. The statute of limitations may prove troublesome. Two stocks are considered to be particularly vulnerable: Georges Bank herring - because of small stock size and shallow restricted spawning areas; Grand Banks capelin, because they spawn in a single location and only 1 or 2 year-classes contribute to the fishery.

6. What will be the effects, if any, of counter-measures?

This topic was introduced by R.H. Cook, Director of the St. Andrews Station.

The most effective counter-measures against episodic and chronic pollution are prevention and organisation. Notwithstanding recent developments booming seems likely to have only minimal effects at containing oil offshore prior to recovery. Burning, likewise may be of minimal practicability. Aerial application of dispersants might have some usefulness in dispersing slicks which would otherwise hazard fishing gear, but no clear opinion exists as to the subsequent biological impact. Dispersant spraying might minimise physical impact on shorelines. Decision to use dispersants should be made on case-by-case basis.

Slick modelling and prediction should enable forecasting of likely trajectories and identification of threatened fishing areas.

Research and development should continue into counter-measures technology.

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THE BIOS PROJECT - 1980 REVIEW

Submitted by:

Peter J. Blackall
BIOS Project Manager
Environmental Protection Service
No. 804, 9942 - 108th Street
Edmonton, Alberta
T5K 2J5

Gary A. Sergy
BIOS Project Coordinator
Environmental Protection Service
No. 804, 9942 - 108th Street
Edmonton, Alberta
T5K 2J5

David E. Thornton
Chairman
BIOS Project Management
Committee
15th Floor, Place Vincent Massey
Hull, Québec
K1A 1C8

Introduction

In the November-December 1979 issue of this Newsletter, Volume 4(6), an article entitled "EXPERIMENTAL OIL SPILL: OIL IN ARCTIC COASTAL ENVIRONMENTS" outlined the objectives and general design of what has become known as the Baffin Island Oil Spill (BIOS) Project. Since that article was written the first year of the projected four-year program has been completed successfully.

This article provides a brief review of the major, primarily baseline studies carried out during the first year of the project and summarizes some of the preliminary findings.

Project Objectives and Rationale

The primary objectives are to determine if the use of dispersants in the Arctic nearshore will reduce or increase the environmental effects of spilled oil and to assess the fate of spilled oil (the "nearshore" study), and to compare the relative effectiveness of other shoreline cleanup techniques (the "shoreline" study).

Only three primary strategies are feasible operationally for responding to oil slicks threatening the Arctic nearshore, namely: the nearshore use of dispersants (probably from aircraft), the use of shoreline cleanup techniques, and the "No-Response" option. Simply stated, the BIOS Project is designed to determine some of the advantages and disadvantages of these options.

1980 Program Review

Because of the broad spectrum of studies encompassed by the BIOS Project, it was necessary, for management purposes, to combine related studies into project components under the direction of small technical committees. This system resulted in five committees dealing with the following components: Oil Discharge, Physical, Biological, Chemical, and Shoreline. The following review follows the same breakdown.

Oil Discharge Component

The 1980 objectives of the Oil Discharge Component were: to design the distribution systems for the two nearshore study test spills; to select the most favourable atmospheric and oceanographic conditions under which to make the two oil releases; and to decide which of the three test bays to use for each of the spills and the experimental control.

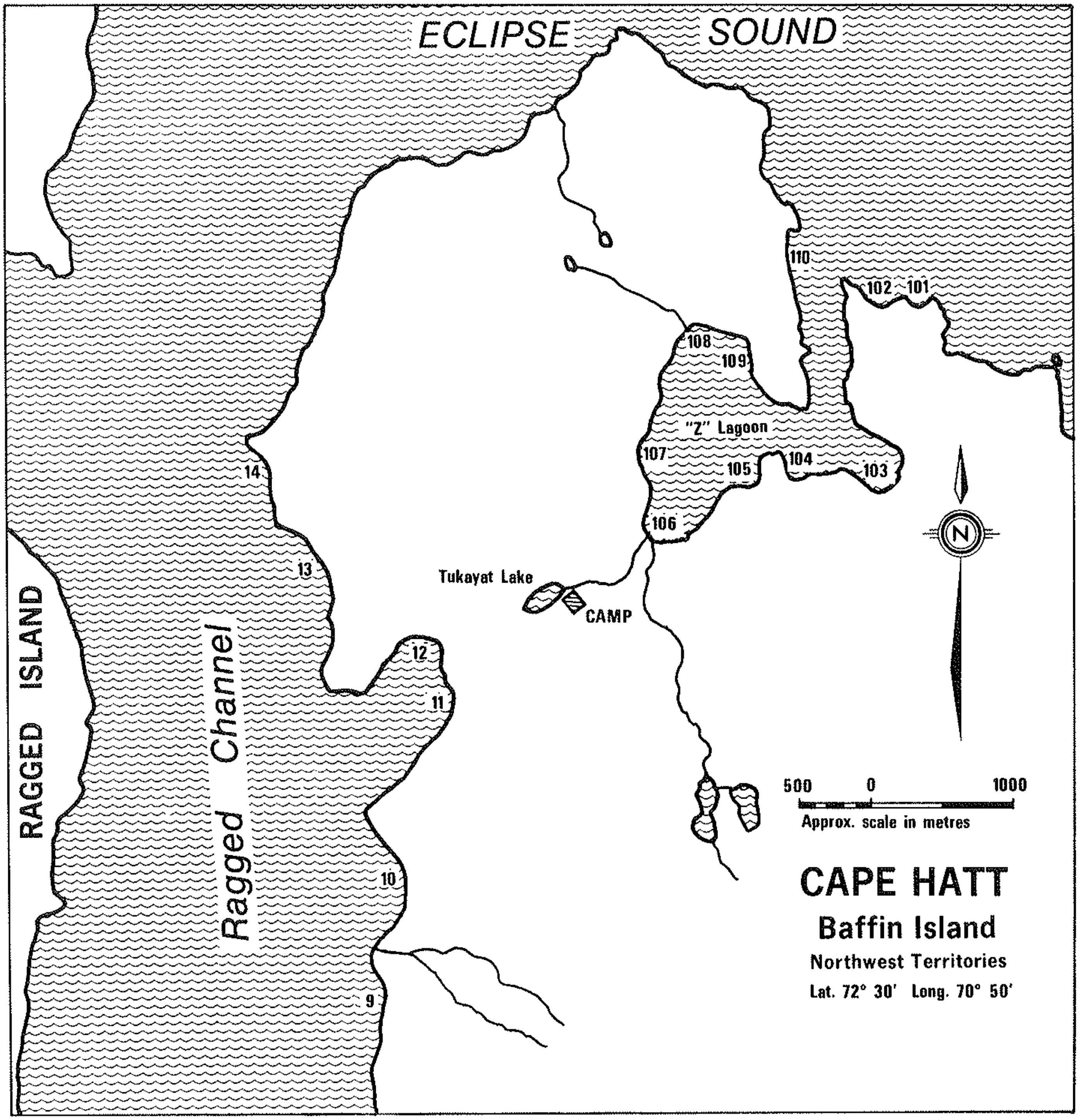
A preliminary selection of the test bays was made after an analysis of the results of the 1980 field program. It was decided that Bay No. 11 should receive the untreated oil slick, Bay No. 9 should receive the dispersed oil, and Bay No. 10 should be used as the control (see Figure 1). This choice maximizes the chance of completing the major discharges during the short summer "window" under current and wind conditions which will minimize the chances of short- and long-term cross contamination between bays.

Additional oceanographic measurements will be made in 1981 prior to the test spills in order to verify this selection. In addition, dye will be discharged through the oil/dispersant discharge system, and the movement of the dye will be monitored to locate within the bay the optimum discharge location for the oil and dispersant mixture.

During the conceptual design of the nearshore study it was decided to use equal volumes of oil for both spills. Given the shoreline lengths and intertidal widths in the test zones, and water volumes and average currents in the bays, the volume of oil was selected as 15 m^3/bay based on a target shoreline contamination of untreated oil of about 1 cm thick and a chemically dispersed oil concentration of about 10 ppm.

The oil selected was "Lagomedio", a medium-gravity (API 32) crude oil from Venezuela. The Lagomedio crude was chosen because of its medium gravity, its ready availability in bulk on the east coast of Canada, and because data on its properties and dispersability existed.

As the BIOS project was not designed to evaluate dispersant effectiveness, an early decision was made to discharge premixed oil and dispersant through a diffuser system to ensure an even dispersant-oil-water mixture in the test bay. This should also minimize the risk of only partial dispersion of the oil which might occur if the dispersant was sprayed onto a surface slick.


ECLIPSE
SOUND
110
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108
109
"Z" Lagoon
107
105
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103
106
14
13
Tukayat Lake
CAMP
12
11
N
500
0
1000
Approx. scale in metres
RAGGED ISLAND
Ragged Channel
10
9
CAPE HATT
Baffin Island
Northwest Territories
Lat. 72° 30' Long. 70° 50'

The oil and dispersant will be pre-mixed at a 10 to 1 ratio in a tank and then mixed in the discharge line with seawater in a ratio of 1 to 5. The resulting oil-in-water dispersion will be pumped through a perforated discharge pipe positioned such that the currents in the bay will carry the resulting cloud of dispersed oil across the test area. A theoretical analysis and laboratory tests confirmed that the system should provide an oil-particle size distribution with median droplet diameters in the 4-8 u range.

Based on the oceanographic measurements, which have identified longshore currents in Bay No. 9, the discharge pipe will be placed perpendicular to the shore and should extend to approximately the 15 m bathymetric contour. This will require a discharge pipe approximately 100 m in length. The discharge pipe will be anchored approximately 1 m above the sea floor in order to ensure the dispersed oil particles contact the sea bottom.

The spacing and final diameter of the orifices will be selected to ensure that a fairly even concentration distribution is attained throughout the water column at all depths.

The untreated oil will be released from the centre of a circular discharge plate. The plate will be towable and moved parallel to the shore about 10 m from the water's edge. This procedure will permit the oil to be distributed evenly along the 200 m length of shoreline test zone.

Both oil releases will occur during a six-hour period to allow equal opportunity for impact on the environment. Following the discharges, surface slicks in the bays will be recovered using skimmers and sorbents, and the recovered volumes measured.

The six-hour spill period was chosen for practical reasons. This period is equal to one half of a tidal cycle and is the longest period during which current patterns remain relatively constant. Once the second half of the tidal cycle begins, current reversals present an increased threat of cross-contamination between bays.

Physical Component

The major objectives of the first-year physical studies were to gather, assess and correlate data for the various parameters describing the physical environment at Cape Hatt. Included were Meteorologic, Geomorphologic, Oceanographic, Bathymetric, and Ice-Mechanics studies.

Meteorologic Study:

The 1980 Meteorologic Study began in late May with the establishment of a full weather station at the base camp (see Figure 1) and six outlying anemometer stations strategically located to determine localized wind velocity and direction patterns around Cape Hatt. The more remote anemometer stations utilized fourteen-day automatic recorders, while the more accessible stations had one-day charts and required routine servicing. The meteorologic data collection continued from late May through to the end of September with a three-week gap in early July when the camp was closed.

The Meteorologic Study revealed that the prevailing winds were from the north-northeast and the west-southwest. Further, it was confirmed that the local topographic features channel the wind along or perpendicularly to the SW coast of the Cape, increasing the chance of acceptable wind conditions for the oil discharges during the brief summer period.

Geomorphologic Study:

The Geomorphologic Studies were initiated in mid-May when subtidal sediment samples were collected along three transects in each of test Bay Nos. 9, 10 and 13, along single transects in Bays 101 and 102, and in Z-Lagoon. Samples were obtained by drilling holes through the sea ice and lowering the sampling equipment to the bottom. Both 11.5 cm diameter cores and surface grab samples were collected; the particular method being determined by the study requirements and the bottom sediment type. At each sampling station, duplicate samples were collected for use in the Chemistry Component of the Project.

Each Geomorphologic Study core was transported to the camp laboratory where it was separated into two halves, photographed, logged and subsampled for grain-size analysis and biological examination. A small sample of sediment from the surface of each core was retained and preserved in formaldehyde for foraminiferal examination. The duplicate cores for the Chemistry Component were collected in chemically cleaned, plexiglass, core-barrel liners, protected from contamination by placing teflon sheeting over the ends, and immediately frozen prior to shipment south for analysis.

The grab samples were obtained using a "Forest Peterson" grab lowered sideways through a 30 cm diameter hole in the ice. The samples were placed in large plastic bags and transported to the laboratory where they were photographed, logged, and subsampled for grain-size analysis, foraminiferal examination and biological examination. The duplicate grab samples collected for the Chemistry Component were stored in chemically cleaned glass jars and immediately frozen.

Upon completion of the preliminary biological surveys in early August, it was decided to abandon Bay No. 13 and substitute Bay No. 11 as the third study bay. This necessitated the collection of subtidal sediment samples in Bay No. 11, using scuba divers. The divers collected surface samples along three transects. Core samples were not collected as the previous cores revealed very little stratification.

During the August sampling period scuba diver observations were made of the sea floor to a water depth of 20 m in order to gain a firmer understanding of the sedimentology of the area. In Bay No. 9 photographs of the bottom were also taken.

Beach profiles were surveyed in all bays along the same transects used for the subtidal sampling. Additional profiles were also surveyed at supplementary beach sites. The elevations along each profile were measured approximately every 1.5 m and at intervening topographic inflections or facies changes. The top 15 to 20 cm of sediment in each facies encountered was sampled for grain-size analysis.

In addition to the sediment sampling, the thermocouple temperature-measuring probes were inserted in one of the beach faces to allow determination of changes in the permafrost level throughout the open-water period.

The results of the Geomorphologic Study revealed a commonality in sediment grain-size distributions between the three test bays on Ragged Channel. The beach sediments were found to be gravelly sand and sandy gravel, consisting primarily of poorly sorted coarse sand and gravel. The subtidal sediments beyond the three to five metres water depth were found to be typically silty sand and muddy sand, consisting primarily of poorly sorted fine and very fine sand and coarse silt. Cobbles and boulders were scattered over the nearshore shelf and generally formed a veneer in the deeper water offshore. Ice-scour features were common and were observed at least to the 20 m bathymetric contour. The study also revealed that a small variation in marine energy regimes existed between the bays; with Bay No. 11 having the lowest energy level, Bay No. 10 having the highest, and Bay No. 9 being intermediate. Further, it was determined that, in the intertidal zone, a selective sorting process was occuring involving the removal of fines to deeper water.

Oceanographic Study:

The first field session of the Oceanographic Study ran from June 10 to June 23.

Five current meters, on three strings, and two tide gauges were installed through holes cut in the sea ice. A total of 41 CTD (conductivity/temperature/depth) casts were made as well as 21 depth soundings. Two of the current meter strings, each incorporating two meters, were placed in Ragged Channel; one offshore from Bay No. 13 in about 75 m of water and the other offshore between Bays No. 9 and No. 10 in the same water depth. The meters at these two stations were placed at the bottom and at mid-depth. The third current meter string, with one instrument, was located at the southern end of the entrance channel to Z-Lagoon, at the bottom, in about 13 m of water. One tide gauge was moored in Bay No. 10, and the other one in the centre of Z-Lagoon.

The second field session of the Oceanographic Study began on August 14 and ran through to September 15.

A total of 65 CTD profiles were taken at various locations around Cape Hatt every two or three days in order to obtain an appreciation of water stratification under various atmospheric and oceanographic conditions. Two wave recorders were installed, one offshore from Bay No. 102 and one in Bay No. 10. These instruments were positioned in order to provide a means of correlating wave-energy levels with wind measurements.

During late August and early September a radar set was positioned, initially on Bays No. 11 and 12 and later between Bays No. 9 and 10, for tracking current-monitoring drogues. Numerous drogues were released in both areas on several occasions with keels at various depth, and under varying wind and wave conditions, in order to determine micro circulations in the area.

Complementing the drogue study, a number of tape moorings were established in Bays No. 9, 10 and 11 with tapes at various depths. The inclination of the tapes to the horizontal and their orientation provided simultaneous multi-depth estimates of current speed and direction.

Prior to departing the Cape Hatt site, most of the moored equipment was recovered. One current meter string, offshore from Bay No. 13, and the tide gauge in Z-Lagoon were not retrieved.

The season's oceanographic date indicated that water circulation in Bay No. 11 is minimal with a clockwise eddy present under anticipated spill conditions. A clockwise eddy was also identified in Bay No. 10. In Bay No. 9 the currents were parallel to the shore and averaged 5-10 cm/s. It was also noted that a prominent pycnocline usually existed between the 1 to 5 m water depth in Ragged Channel, depending on wave conditions, due to the inflow of freshwater from local snow melt and melting of the permafrost active layer.

Bathymetric Study:

Bathymetric measurements were made in the test bays in Ragged Channel, the test bays on the east coast of Cape Hatt, and in Z-Lagoon. A sufficient number of measurements were taken to allow construction of 5 m bathymetric contours.

The bathymetry revealed a slightly shallower slope in the intertidal zone offshore from Bay No. 11 in comparison with Bay Nos. 9 and 10. Further, a sill is present across the mouth of Bays No. 11 and 12.

Ice-Mechanics Study:

The Ice-Mechanics Study began in the field in late July, just prior to break-up. By July 25, nine time-lapse camera systems were installed around Cape Hatt. They were positioned to provide film coverage of break-up and freeze-up in the various test bays and the waters surrounding Cape Hatt. Nearly continuous footage was taken at all sites until after freeze-up.

In addition to information from the time-lapse systems, observations of the ice break-up and freeze-up patterns around Cape Hatt were made using the project helicopter. Interesting features were recorded on 35 mm slide film and notes were taken. Also, ice features along the shoreline in the various test bays were observed and recorded.

The Ice-Mechanics Study revealed that break-up was complete in the Cape Hatt area by the end of the first week in August and freeze-up was well advanced by October 6.

In addition, an ice-mound feature was found to be common on most of the study beaches. The mounds were stratified with beach sediment and in some cases were up to 1 m high. The exact mechanism which formed these mounds is not known, although wave action and/or ground water flows are suspected.

Chemical Component

The objectives of the first-year chemical studies were: to determine the pre-spill environmental chemistry of the water and sediments in the various test bays at Cape Hatt; to determine the baseline hydrocarbon chemistry of the water, sediments, and tissue of selected organisms; and to provide chemical support to the Shoreline Component test spills.

Environmental Chemistry Study:

The bulk of the analyses was carried out in support of the micro-biological study in Ragged Channel.

Sampling for Environmental Chemistry began in early June and the initial field session was complete by June 23. Both water and surface sediment samples were collected through the ice during this period in conjunction with the micro-biological work. Problems were encountered with the surface sediment grab sampler due to the presence of cobbles on the sea floor, which often prevented closure of the sampler jaws. As a result, the suite of samples was augmented by samples collected by divers entering the water through holes in the ice.

The second sampling session began in early August and continued through to the end of the third week in September. During this period all the samples were again collected in conjunction with the micro-biological work and divers collected all of the sediment samples.

In total, 141 water samples and 30 sub-tidal sediment samples were collected for the Environmental Chemistry.

The averages of the water sample analyses are summarized in Table 1.

It is presumed that a phytoplankton bloom occurred in July during and just after break-up and that the sampling period did not coincide with the peak chlorophyll levels. The nutrient levels dropped drastically during August and September. The nitrate levels fell to near zero and this was probably the limiting nutrient.

The results for the sediment Environmental Chemistry are summarized in Table 2.

Baseline Hydrocarbon Study:

Four analytical methods were used to determine hydrocarbon levels in the water and sediment samples: infrared spectrometry (IR), ultraviolet fluorescence (UV/F), gas chromatography (GC), and combined GC and mass spectrometry (GC/MS). The latter two methods (GC and GC/MS) were also employed for tissue analysis.

The first water samples for baseline hydrocarbon analysis were collected in June. The samples were extracted in the field laboratory with Freon 113. One set of samples was

TABLE 1: ENVIRONMENTAL CHEMISTRY WATER ANALYSIS - AVERAGES OF RESULTS

PARAMETER	Month (Date)	June (1-23)			August (1-31)		September (1-21)
Temperature	°C	-1.7 all depths			4.5 - 1.8 1 m - 10 m depth		<0
Salinity	0/00	32.7 except thin freshwater layer under the ice			15 - 32.7 1 m - 10 m depth		30.0 all depths
Dissolved Oxygen	mg/L	saturation varied between 85% and 120%			11.7	± 0.7	
pH		7.76	±	0.14	7.74	± 0.15	
Reactive Nitrate	μg.at/L	7.9	±	0.4	0.28	± 0.41	
Reactive Phosphate	μg.at/L	1.31	±	0.08	0.56	± 0.14	
Suspended Solids - organic	mg/L	0.48	±	0.21	0.58	± 0.09	
- inorganic	mg/L				0.93	± 0.32	
Dissolved Organic Carbon	mg/L	1.27	±	0.29	2.35	± 0.74	
Particulate Organic Carbon	μg/L	28 57.5	± ±	21 (5-10 m) 41 (1 m)	162	± 41 (all depths)	
Chlorophyll a	μg/L	0.05	±	0.04	0.48	± 0.31	

TABLE 2: ENVIRONMENTAL CHEMISTRY SEDIMENT ANALYSIS - AVERAGES OF RESULTS

PARAMETER		Month (Date) June (1-23)	August (1-31)	September (1-21)
Sub-Tidal				
Total Organic Carbon	%	0.67 ± 0.20	0.55 ± 0.34 0.24 ± 0.10	(10 m depth) (2-3 m depth)
Total Nitrogen	%		0.15 ± 0.04	by weight
Beach				
Total Organic Carbon	%		0.60	by weight

Notes:
1. Values were obtained for the levels of interstitial nitrate and phosphate in sub-tidal sediments but the value exhibited a great deal of variation.
2. Uniform lead 210 levels in subtidal sediments indicated that the sedimentation rates in the area are very low, and/or biological activity and/or ice scouring are mixing the sediments.

collected and sent south before being extracted in order to provide a check on field methods.

In August and September some large-volume water samples were collected from Ragged Channel for GC/MS analyses. A flow-through system utilizing a polyurethane plug was used, but difficulties were encountered due to the cold conditions. In total 39 water samples were collected for baseline hydrocarbon analysis.

The first sub-tidal sediment samples were collected by the geomorphologists in late May and early June. In total 23 cores and 16 grab samples were collected and sent south for baseline hydrocarbon analysis.

In September, another set of sub-tidal sediment samples was collected by divers. Six samples were collected in each of the test bays in Ragged Channel. These latter samples were collected from the bottom in the immediate area of the benthic biology sample plots. In total 57 sub-tidal sediment samples were collected.

On August 22 a suite of beach samples were collected from the shores of the Ragged Channel test Bays No. 9, 10 and 11. They were taken in triplicate from both the high- and low-tide lines at each of the three transects in each bay. In total 54 samples were collected.

In September, 72 tissue samples were collected for baseline hydro-carbon analysis from Bays No. 9, 10 and 11 and from Z-Lagoon. Three species of benthic algae (Fucus sp., Agarum sp., and Laminaria sp.), six species of benthic fauna (Leptasterias polaris, Psolus fabricii, Strongylocentrotus droebachiesis, serripes groenlandica, Mya truncata, and Astarte borealis) and one species of fish (Myoxocephalus scorpius) were sampled. All samples were analyzed by GC and 20 percent of the samples were also analyzed by MS. For the smaller organisms (e.g. Mya), each sample consisted of at least 10 individuals. For the larger organisms, each sample consisted of at least 100 grams of tissue.

The data from the water analysis indicated that petroleum hydrocarbon levels were very low. No UV/F signal was noted, indicating that no detectable levels of aromatic hydrocarbons were present. The GC/MS analyses of large-volume samples indicated hydrocarbon concentrations of less than 1 part per trillion.

The sub-tidal sediments were found to be clean with respect to recent additions of petroleum hydrocarbons. However, low levels of polycyclic aromatic hydrocarbons, at the one part per billion level, were found. The source of this contamination is believed to be global atmospheric fallout of products from fossil fuel combustion.

The tissue analysis revealed varying but low levels, in the part per billion range, or aromatic hydrocarbons in all species.

Chemistry Support of Shoreline Component:

The shoreline test plot sediments were sampled prior to and during the 16-day period after each discharge. Samples for total hydrocarbon determination using IR were collected before each spill, immediately following and at 2, 4, and 8 days thereafter. A single composite surface sample for GC/MS analysis was taken from each plot on days 2, 3, 4, 8 and 16, following each oil application. In addition, a suite of water samples was taken for IR and UV/F analysis in conjunction with each oil discharge.

Biological Component

The primary objectives of the 1980 Biological Component were to characterize the baseline populations and biotic parameters of the Cape Hatt test bays such that the effects of oil and chemically dispersed oil could be determined accurately following the test oilspills. The biological component was broken into two primary study areas, namely microbiology and benthic biology.

Benthic Biology:

The objectives of the benthic study were to quantify the sub-tidal benthos in terms of species composition, overall community structure, principal associations, and biomass; to describe the probable major pathways of energy transfer, and trophic interrelationships; and to select species and biotic associations to be used as potential indictors of oil-related effects.

The benthic infauna received the highest priority in the benthic study. They were collected in August and September by divers using an airlift sampler from three shallow (3 m) and three deeper (7 m) plots in each of Bays No. 9, 10, and 11. Eight replicate samples were collected from each plot with each sample comprising a 0.062 m^2 area to a sediment depth of 10-15 cm. Analysis included identification and enumeration of species and total biomass, which was used to determine the nature and extent of variability between plots at different depths within each bay and between the three bays. Major components of community structure were assessed, including length/weight relationships and median lengths of dominant species. The trophic position and habitat of major species were also documented and the numbers and sizes of dead bivalve shells of selected dominant species were compared.

Benthic epifauna were recorded quantitatively using photographic techniques along a shallow and deeper water belt parallel to the shore and near the infaunal plots. Marine algae were collected for identification and estimations were made of abundance and aerial coverage along the same belt transects.

Specimens of infauna, epifauna and algae were collected from each bay and analyzed to estabish background hydrocarbon levels as summarized in the Chemical Component section.

The infauna of the study area at Cape Hatt were typical of that in nearshore regions of Eclipse Sound and Lancaster Sound. Benthic biomass was higher than those recorded in other Arctic areas. This is attributed to the effectiveness of the airlift sampler.

Bivalves accounted for 93% of the biomass. Bivalves and polychaetes, in approximately equal proportions, accounted for 86% of the animals collected. Four species were dominant in both biomass and density: Mya truncata, Astarte borealis, Astarte montagui, and Macoma calcarea.

The density and biomass of bivalves and biomass of polychaetes was higher at the 7 m stations than at the 3 m deep stations, which were more influenced by ice, wave action and freshwater runoff. Over all stations the average biomass and density of total infauna were 1171 g/m^2 and 2905 individuals per square metre (ind/m^2) respectively. One of the dominant organisms, Mya truncata was present at mean densities of 178 ind/m^2 and mean biomass of 596 g/m^2.

Filter feeding was the dominant feeding mode of the infauna.

The most evident benthic epifauna were sea urchins (Strongylocentrotus droebachiensis), starfish (Leptasterias polaris), brittle stars and crustaceans such as ostracods, amphipods and cumaceans. Epibenthos were more abundant at the 7 m depth than the 3 m depth with an overal average density of approximately 1160 ind/m^2.

The macrophytic algal community was dominated by filamentous and dendritic forms. A total of 29 species were identified. A canopy of foliose algae (including Fucus sp.) was unevenly distributed at the 3 m depth (average biomass 739 g/m^2). At 7 m depth, sparsely distributed kelps, Laminaria spp and Agarum cribrosum, were the only conspicuous canopy macroalgae (average biomass 301 g/m^2).

Microbiology:

The microbiological program consisted of two elements, each with slightly different but complementary objectives. One set of studies was "effect" oriented and designed to characterize the numbers and heterotrophic activities of bacteria in the water and sub-tidal sediments. The intent was to relate these measurements to other biological and chemical cycles, so that following the test spills a measurement of the effects of petroleum and petroleum dispersant mixtures on the numbers and heterotrophic activities of bacteria over time can be made.

The other set of microbiological studies was designed to assess the baseline levels of activity for oil microbial degradation. The baseline will allow a measurement of the changes in this activity and oil-degrading microbial populations after exposure to the spilled oil.

The first phase of the microbiological program ran from June 3 to 16 during the spring field session, and the second phase started on August 13 and ended on September 16. Water samples were collected using a Niskin water sampler, and sediment samples were collected using a Peterson grab sampler, a coring device, or divers, depending on the field conditions and the availability of divers.

The results of the microbiological work revealed total counts of bacteria in the water of approximately 10^9 cells per litre through August and September-about tenfold higher than during June. Further, the total viable heterotrophs were 10^6 to 10^7 cells per litre during August and September, with maximum values measured during the last week of August. In comparison, the values were 10^4 to 10^5 cells per litre in June. Heterotrophic potentials (maximum rate of glutamic acid uptake) peaked in late August about 6 ug/L/day.

Bacterial activity in the sediment was very concentrated in relation to that in the water column, with larger fluctuations in values between stations in the same sampling cycles. Total counts of bacteria reached 6.1×10^8 cells per milliliter and total viable heterotrophs reached 10^6 cells per milliliter of wet sediment and heterotrophic potentials reached 25 ug/mL/day during August and September, about double the June average. 14C - hexadecane mineralization was at the lowest rate detectable and signified a very low level of activity. The most probable number (MPN) of oil-degrading cells as determined by acid production from the test crude oil were in the range of 10^3-10^5 cells/litre in the water column and cells/mL in the sediments. These results were confirmed by oxidation of tritiated test crude oil.

In addition to the benthic and microbiological studies, preliminary studies on the under-ice fauna were carried out. Diver observations on the community were made and two species of amphipods (Gammarus setosus and Onisimum littoralis) were collected for laboratory experimentation. These organisms were subjected to the test oil and oil plus dispersant in various concentrations with observations being made on survival, blood and medium chloride levels, and heart rate. G. Setosus do not appear to be adversely affected in the laboratory by low levels of the water soluble fractions of oil and oil plus dispersant although preliminary findings indicate increased hydrocarbon concentrations in the blood of O. littoralis when exposed to oil.

Shoreline Component

The objective of the 1980 Shoreline Component was to establish sets of intertidal oil plots in both relatively high- and low-energy environments, for the long-term study of the natural recovery rates of oiled coastlines in the Arctic. The design included both backshore and intertidal plots to compare the natural recovery rates of oiled beaches acted on by relatively low- and high-energy Arctic marine forces, such as waves and ice movement, and other Arctic weathering processes. The establishment of the shoreline test plots was also to serve as a learning experience that would help in the design of both the future shoreline experiments and the nearshore test spills.

The field work began in early August, immediately after the sea ice left Z-Lagoon. Prior to spilling the oil, the oil-discharge apparatus was assembled and tested. The apparatus involved a spreader bar slung on the back of an all-terrain vehicle carrying a drum of oil. Also, a 50 percent water-in-oil emulsion was prepared as each set of test plots involved one aged-oil plot and one plot of emulsified, aged oil.

Four pairs of plots were established: the first pair in the backshore of Bay No. 102, the second in the intertidal zone of Bay No. 102, the third in the backshore of the point east of Bay No. 109, and the fourth in the intertidal zone of Bay No. 103. Each test plot was 4 meters wide and 10 meters in length alongshore. An oiling rate of 0.01 m^3/m^2 was used on all plots. For the emulsion plots this required placing 0.02 m^3/m^2 of emulsion on the plots.

In comparison with the aged oil, the emulsion did not adhere as well to the sediments in the low-energy plots and the bulk of it was washed away within several days.

The plots in the high-energy intertidal zone experienced a number of dramatic erosional and depositional cycles. Within 12 hours of the spills, portions of the plots were buried by up to 30 cm of sand and gravel, while other areas were eroded clean of oil-contaminated sediment. In subsequent storms the plots were further eroded and buried, with the result being the gradual removal of the oil.

The backshore plots provided information on the rate of evaporation of the oil. It was found that the major portion of the weathering took place in the first two days, with little measurable change detectable by GC analysis between 2 and 8 days after the spills. The various plots will be sampled for long-term changes during the next three years.

As a possible countermeasure for oiled beaches, the effect of added nitrogen and/or phosphate fertilizer on the biodegradation of oil will be tested. Two backshore plots were established in August 1980 as part of this experiment and the analyses of the microbial developments were started.

As hoped, the shoreline test spills provided a valuable learning experience for the Project personnel. Perhaps most importantly, a knowledge of the variability of oil penetration into the local beach materials was obtained. This information will be of great value in the statistical design of the sediment sampling programs for the future spills.

Conclusion

1980 served as a unique learning experience for all the personnel involved in the BIOS Project. With few exceptions, all of the Project aims and objectives were attained. This success was due primarily to the many hours of hard work and tremendous ingenuity demonstrated by the personnel involved in the field programs. We hope this coming field season, which entails the major experimental oilspills, is just as successful.

The 1980 technical reports, in working document form, will be available to interested parties in the near future. Formal publication of the BIOS Project reports will not take place until the four-year study is complete in 1984.

ACKNOWLEDGEMENTS

Funding Agencies/Programs

Department of the Environment, Environmental Protection Service
Department of Indian Affairs and Northern Development
Canadian Offshore Oil Spill Research Association
US National Oceanic and Atmospheric Administration
US Coast Guard
The Norwegian State Pollution Control Authority
British Petroleum/UK
Offshore Labrador Biological Study

Supporting Agencies

Department of Fisheries and Oceans
Canadian Coast Guard
Atmospheric Environment Service
Department of National Defence
Geological Survey of Canada
Centre for Cold Ocean Resources Engineering
Petro Canada
Dome Petroleum
Texaco Canada
Exxon Corporation
Chevron Oilfield Research Co.
Imperial Oil Ltd/Esso Resources Canada
American Petroleum Institute

SPILL TECHNOLOGY NEWSLETTER

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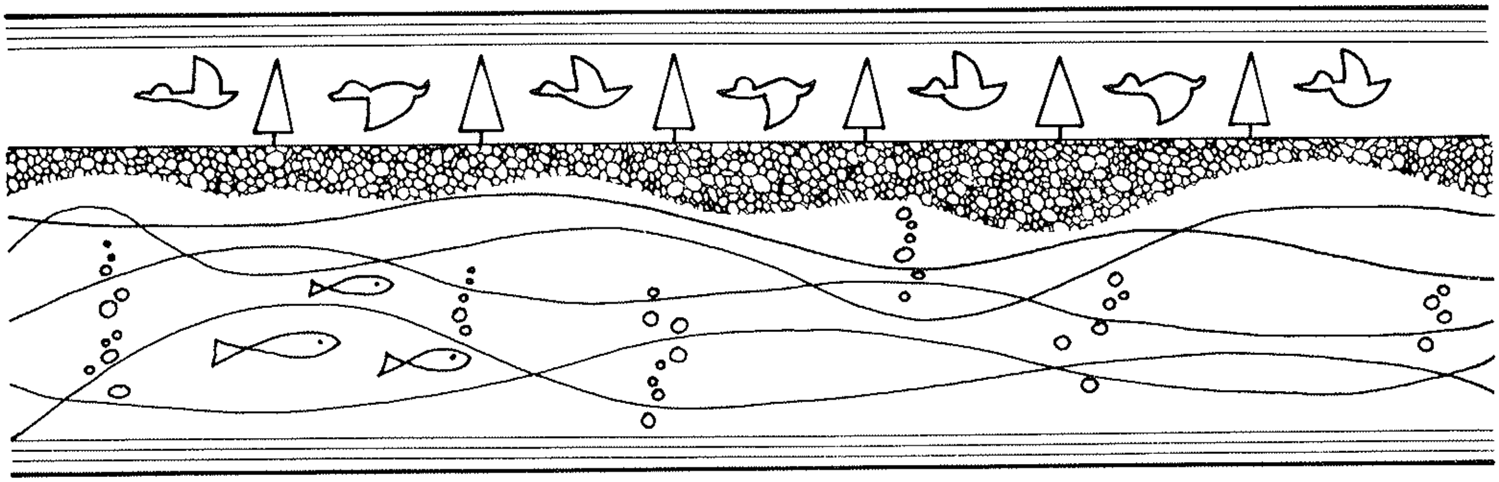

Table of Contents

Spill Technology Newsletter

EDITORS

Mr. M.F. Fingas and Dr. D.E. Thornton

Research and Development Division
Environmental Emergency Branch
Environmental Impact Control Directorate
Environmental Protection Service
Department of the Environment
Ottawa, Ontario
K1A 1C8

Phone: (819) 997-3921

The Spill Technology Newsletter was started with modest intentions in 1976 to provide a forum in Canada for the exchange of information on oil spill countermeasures and other related matters. The interest in it was such that we now have over 2,500 subscribers in Canada and around the world.

To broaden the scope of this newsletter, and to provide more information on industry and foreign activities in the field of oil spill control and prevention, readers are encouraged to submit articles on their work and views in this area.

INTRODUCTION

The first article of this issue provides an ecologist's point of view on experimental spills. This article is a reply to that of Don MacKay, which was published in the September-October issue of the Spill Technology Newsletter. The second article is by Ken Meikle, the head of our technology development unit, who provides a summary of the development and testing of incendiary devices for igniting oil. This form of countermeasure is very applicable in Arctic situations. The third article by Christian Bocard and associates detail the Protecmar experiments conducted near France to assess the aerial application of dispersants in actual field conditions. Their results indicate that chemical dispersants were not particularly effective in dispersing experimental oil slicks in the Mediteranean in sea states of Beaufort 1-3 using a variety of application and mixing techniques. The fourth article is again by Ken Meikle and is a summary of the development and testing of the AMOP boom.

REPORTS AND PUBLICATIONS

- The Booklet "Against Oil Pollution: A Guide to the Main Intergovernmental and Industry Organizations Concerned with Oil Pollution in the Marine Environment" is available for 1.25 pounds from; Witherby and Company, 32-36 Aylesbury Street, London, ECIR OET, United Kingdom.

- Anyone interested in receiving general information publications from Environment Canada, such as bulletins, brochures, fact sheets, leaflets, etc... send your name and address to: Michel Gagnon, Information Kiosk, Environment Canada, Main floor, Terrasses de la Chaudière, 10 Wellington Street, Hull, Quebec, K1A 0H3.

- The Environmental Emergency Branch has released a new publication; the title and abstract of which appears below. This publication may be obtained upon request from:

  Publications Coordinator
  Environmental Impact Control Directorate
  Environmental Protection Service
  Ottawa, Ontario
  K1A 1C8

Preliminary Assessment of Certain Beach Cleanup Techniques EPS 4-EC-81-1

A study was performed to evaluate, in a controlled environment, the effectiveness of in-situ burning, sorbent techniques, a coating agent, a burning promoter and combinations thereof for protecting beaches or cleaning oil off contaminated beaches. The test program was carried out in British Columbia in the Vancouver area during January and February 1979. The location and time of year were selected to simulate the colder ambient temperatures that could be expected in the arctic and sub-arctic regions in the non-winter months.

Fine gravel, sand and mud flat type beach soils were used in combination with two crude oils - one light-to-medium density and the other medium-to-heavy - as the primary parameters in the study. Thickness of the oil coating, position of the water table, and application of a burning promoter and a surface coating agent were the other main parameters in the program.

The effectiveness of the burns was evaluated in terms of type of burn achieved (i.e., good, fair or no burn), type of residue left, additional depth of penetration of the oil in the soil due to the burn, and efficiency of the burn as determined by comparing the amount of oil present before and after the burn.

- The following reports are available from the U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia, 22161, Telephone (703) 487-4650. Most reports are also available on Microfiche at $3.35 each (U.S.A. Price). Canadian buyers add $2.50 to each paper copy and $1.50 for each microfiche report. Prices are quoted in U.S. dollars.

Oil and Petroleum

"Biodeterioration of Oil Spills. 1964-February, 1981 (Citations from the NTIS Data Base)". National Technical Information Service, Springfield, Virginia. February, 1981. 145p. PB81-803827 $30.00.

"Oil Water Separators. 1964-December, 1980 (Citations from the NTIS Data Base)". National Technical Information Service, Springfield, Virginia. February, 1981. 163p. PB81-802134 $30.00.

Other Hazardous Substances

"Fire Protection Systems for Rail Transportation of Class A Explosives: Interim Report." R.W. Bukowski. National Bureau of Standards, Washington, D.C. November, 1980. 35p. PB81-153975 $6.50.

"Handbook for Obtaining Chemical Use and Related Economic Information". M. Sittenfield. Roman Consultants, Inc., Philadelphia, Pennsylvania. December, 1980. 163p. PB81-159915 $14.00.

"Analytical Methodology for the Determination of Chlorophenols in Human and Environmental Samples." Health Effects Research Lab., Triangle Park, North Carolina. August, 1980. 11p. PB81-148587 $5.00.

"Biological Effects of Short, High-Level Exposure to Gases: Nitrogen Oxides". J.D. Morton. Enviro Control, Inc., Rockville, Maryland. July, 1980. 95p. AD-A094 502/2 $9.50.

"Biological Effects of Short, High-Level Exposure to Gases: Sulfur Dioxide". J.M. Normandy, P. Szlyk and B. Brienza. Enviro Control, Inc., Rockville, Maryland. May, 1980. 176p. AD-A094 504/8 $15.50.

"Frequency of Leak Occurence for Fittings in Synthetic Organic Chemical Plant Process Units." J.R. Blacksmith, G.E. Harris and G.L. Langley. Radian Corp., Austin, Texas. January, 1981. 169p. PB81-141566 $14.00.

"Biological Effects of Short, High-Level Exposure to Gases: Ammonia". L.J. Letgers. Enviro Control, Inc., Rockville, Maryland. May, 1980. 87p. AD-A094 501/4 $9.50.

"Biological Effects of Short, High-Level Exposure to Gases: Ammonia, Carbon Monoxide, Sulphur Dioxide, and Nitrogen Oxides". L. Letgers, T.E. Nightingale, J.M. Normandy and J.D. Morton. Enviro Control Ltd., Rockville, Maryland. June, 1980 31p. AD-A094 505/5 $6.50.

"State-of-the-Art Survey of Hardware Delivery and Damage Inspection Methods for Coast Guard Hazardous Chemical Spill Response". R.T. Walker. Coast Guard Research and Development Center, Groton, Connecticut. August, 1980. 130p. AD-A093 82616 $12.50.

"Principles of Toxicological Interactions Associated with Multiple Chemical Exposures". National Research Council, Washington, D.C. December, 1980. 204p. AD-A093 809/2 $17.00.

BRIEF NOTES

Researchers from the Graduate School of Oceanography and the Department of Ocean Engineering at the University of Rhode Island have joined forces with modelers from Applied Science Associates, Inc., an ocean engineering consulting firm in Wakefield, R. I., to apply an integrated modeling system to assess the impact of oil spills on commercial fisheries. The study is funded by the Department of Interior, Bureau of Land Management and is coordinated through its New York office.

The oil spill-fishery interaction model composed of an oil spill fates model, a shelf hydrodynamics/constituent transport model, and a fishery population model, originally developed by Reed and Spaulding, has been improved and applied to the Georges Bank Gulf of Maine region to assess the probable impact of oil spills on several key fisheries. The model addresses first order direct impacts of oil on the commercial fishery through hydrocarbon induced egg and larvae mortality.

Surface and subsurface oil concentrations are mapped in space and time and tested for intersection with similar mappings of fish eggs and larvae. The reduced cohort of young of the year is included as input to a Leslie matrix based population model. Hydrocarbon induced mortality is estimated by assuming a threshhold toxicity. Final output is measured in terms of differential catch, comparing the natural and hydrocarbon impacted fishery.

Simulations of four seasonal tanker (14 million gallons) and blowout (50 million gallons) spills at two separate locations in the OCS lease areas have been completed for Atlantic herring, haddock, Atlantic cod, and yellowtail flounder. Results to date suggest a complex interaction between spill location and timing, the spatial and temporal spawning distribution, and the hydrodynamics of the area. The largest impacts occur for spring and winter spills.

For additional information on the program contact:

Malcolm L. Spaulding
Department of Ocean Engineering, Lippitt Hall
University of Rhode Island, Kingston, R. I. 02881
401-792-2537

Saul B. Saila
Graduate School of Oceanography, University of Rhode Island
Narragansett Bay Campus, Narragansett, Rhode Island 02882
401-792-6239

ON EXPERIMENTAL OIL SPILLS - A REPLY

Submitted by: J.S. Gray
Institute for Marine Biology and Limnology
University of Oslo
Oslo, Norway

I read with interest Mackay's provocative article on experimental oil spills published in the September-October issue of this newsletter. Like Mackay I too am concerned about the time and money that is wasted on so-called biological base-line studies, but unlike Mackay I am an ecologist. I believe that Mackay has done an excellent job in asking biologists to justify themselves and I will attempt to do so.

Mackay argues that the approach he favours is determining how much oil will reach a given system then by laboratory toxicity tests determine whether or not this has an effect on organisms and then from a knowledge of species interactions deduce how the given concentration will affect the entire system. How wonderful it would be if things were so simple, particularly biological systems, but alas this is not the case. Mackay acknowledges that most toxicity tests are done at unrealistic concentrations. This is for two reasons, firstly concentrations are high in order to illicit a response and usually because the organism in question is a tough animal that one is able to maintain in laboratory cultures. The species that are sensitive and would indicate subtle changes often cannot be cultured. Yet the organisms that we should use in toxicity tests are those which are ecologically important, species which control the structure of communities such as the starfish Pisaster which on the west coast of the U.S. controls the dynamics of rocky shore communities. If this species is affected then consequences on the whole system can be predicted. However, in many communities we know of no such "key" species perhaps because the community has not been studied in detail or more likely in my opinion because there is no such fine control. I believe that in most marine communities there are no key structuring species and the typical pattern is local patches which vary in time and space by a process which has been described as "contemporaneous disequilibrium". Each patch is out of phase with a neighbouring patch but each goes through a successional sequence where different species dominate. The factors which steer the successional sequence are innumerable and cover differential recruitment, competetitive and predatory interactions localized mortality etc etc. So it will not be possible to identify Mackay's "principal components and interactions" with any degree of precision.

Furthermore, I am not at all convinced that species adapt to pollution by being tolerant of a given concentration of chemical. The species found in typically highly polluted areas, in laboratory toxicity tests, have been found to be relatively sensitive to chemicals. The reason the species are found in polluted areas is because they have a certain life-history type that allows them to continuously reinvade the area if some of the population are wiped out by chemicals. On this basis laboratory toxicity tests cannot hope to predict ecological consequences. The only way to tackle the problem is to do experiments in situ and find out what happens.

I do however, strongly agree with Mackay that many biological programmes are needlessly expensive. The trend is to obtain a massive amount of data from innumerable sites with long species lists and counts. Mackay suggests that this is necessary to obtain some statistical significance. Most marine communities are characterised by being patchily distributed. In order to get statistically reliable results very large sample sizes are needed. But why can't the aims of the investigation be more closely defined? If instead of the dynamics of the whole community being investigated one is interested in quantifying effects of oil on a rocky shore why not mark out individual sample sites? After the spill these are revisited and exact counts obtained of mortality, not statistical estimates.

We have here in Norway developed a programme based on such techniques. In response to notice of an oil spill occurring anywhere in Norway one or more teams of ecologists are alerted. (The whole coast covering 1500 km is divided among six teams). Each team has collecting, diving and other equipment already packed. Military helicopters can be used to fly the team to difficult localities. On the basis of predictions of where within 50 km the oil is likely to hit, series of fixed sites are marked out along the coast. These are recorded photographically where possible and sediment substrata samples taken for later sorting. After the spill hits, the shore sites are revisited and counts made of mortalities, etc. Each team has annual training excercises and is constantly ready for action and two spills have been covered in the past year. This we believe is a much more realistic programme that setting up costly permanent baseline sites which may never be affected by oil.

The biological part of experimental spills should have much more clearly defined goals than the "spill-and-lets-see-what-happens" approach. We know sufficient about effects to predict most ecological consequences. If the oil is thick most rocky shore species will be killed and recovery processes depend on degree of exposure and how long the slowest species takes to reestablish. Surely today we should be asking much more subtle questions such as raising hypotheses about whether after a spill bacteria compete with microflagellates for available nutrients, which will have consequences for the whole planktonic system. Similarly in sedimentary habitats in aerobic situations what is the role of microfauna in grazing bacteria involved on oil degradation and how does this balance affect the macrofauna? Such questions need interdisciplinary research and team work and I believe like Mackay that these are the important areas to investigate. Let us get away from the simplistic biological investigations which cost large sums of money but from their inadequate hypothetical framework cannot be expected to provide useful answers. Ecology is no longer a descriptive science but has a sound base in the traditional hypothetico-deductive approach that is so widely used in physics research. Formulation of proper hypotheses that can be tested should be an integral part of the biological programme of experimental oil spills.

INCENDIARY DEVICE FOR OIL SLICK IGNITION

Submitted by: K.M. Meikle
Environmental Protection Service
Ottawa, Ontario

INTRODUCTION

The design and development of two incendiary devices intended to be dropped from aircraft to ignite confined oil slicks on Arctic melt pools and other remote water surfaces have been described by Twardawa and Couture (1980).

The operational considerations and assumptions that formed the basis for the design criteria have also been reported (Meikle, 1981).

The purpose of this article is to:

1. summarize the results of the Arctic field testing of both designs;
2. explain the choice of design for commercial production;
3. describe a design change incorporated;
4. report the results of field tests of the production version; and
5. outline the further testing to be done to complete the project.

ARCTIC FIELD TEST

The ability of both the canister-shaped device and the sandwich configuration to ignite oil within the specified limiting conditions was established previously by laboratory tests that provided the required degree of control over the key factors. Physical aspects of the design (mechanical and structural) were satisfactorily demonstrated both by controlled drops from a fixed tower and by actual drops into water from a helicopter flying at the design altitudes and airspeeds.

Before a choice could be made between the two contending designs, it remained to establish their functional reliability and compare operational performance under field conditions. While that could probably have been adequately accomplished elsewhere under conditions approximating those expected to prevail in the area for which the devices were primarily intended (Arctic melt pools), an element of uncertainty would undoubtedly have remained. It was, therefore, decided to take advantage of the opportunity afforded to test the devices under actual Arctic conditions in conjunction with the Oil and Gas Under Sea Ice experiment sponsored by Dome Petroleum Limited (Dickens and Buist, 1980).

A total of thirty prototypes (twenty canisters and ten of the sandwich design as shown in Figures 1 and 2), were manufactured by the Defence Research Establishment Valcartier (DREV) and shipped to the test site off McKinley Bay, NWT. By the time the devices could be assembled, the over-ice sections of the Mackenzie highway were no longer in use. Therefore, to effect delivery in time for the expected appearance of the spring melt pools and comply with the regulations pertaining to the transportation of such devices, it was necessary to send them by road to Whitehorse in the Yukon and charter an aircraft for the remaining distance.

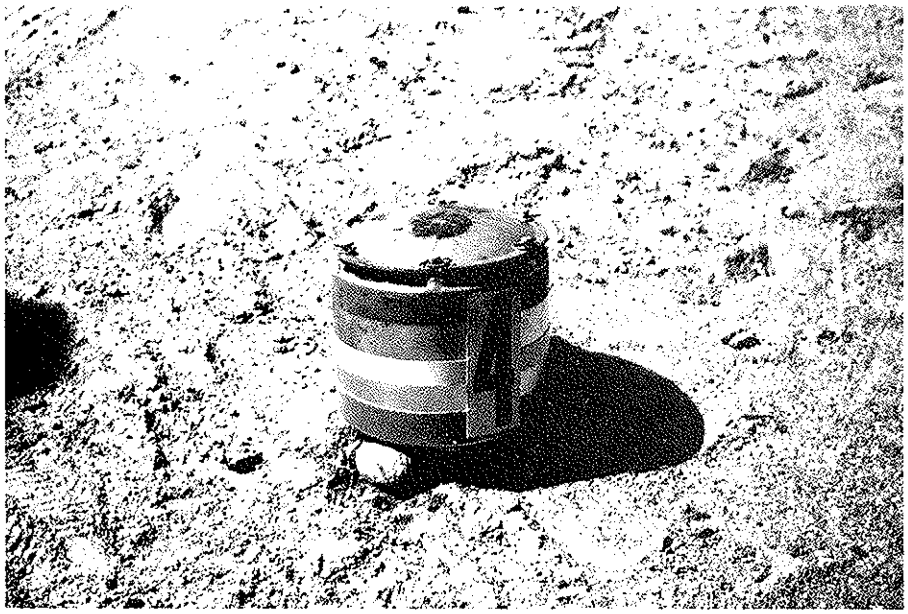

FIGURE 1 PROTOTYPE CANISTER DEVICE

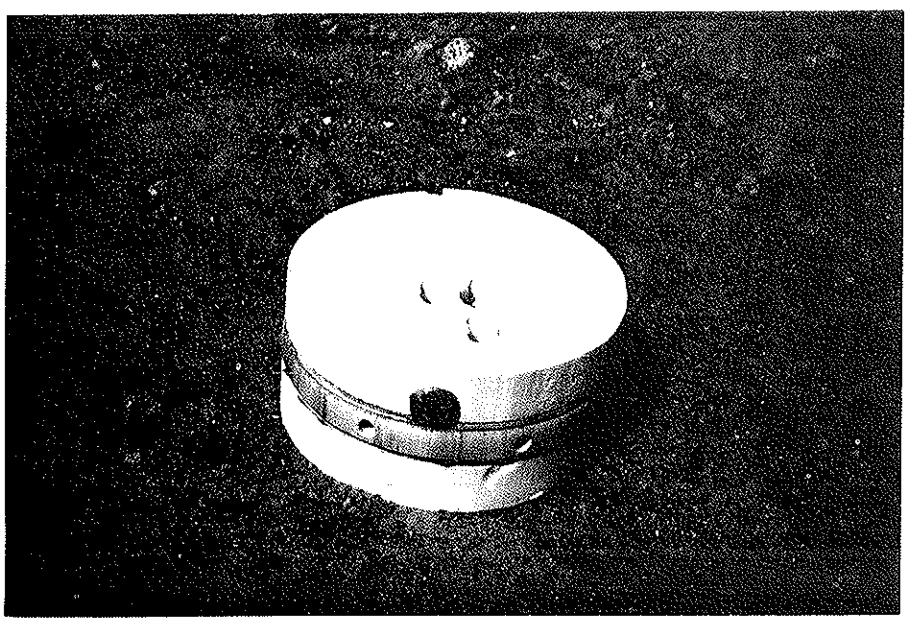

FIGURE 2 PROTOTYPE SANDWICH DEVICE

FUNCTIONAL RELIABILITY

For the purposes of this assessment "functional reliability" concerns only the functioning of the ignition train and the generation of the intended flame; it does not take into account the accuracy of delivery or the ignitability of the target material.

a) Canister Model

Fourteen devices were dropped from altitudes ranging from 5 to 10 metres at forward airspeeds of 2 to 5 knots. Two of them misfired completely (no flame generated) and a third fired but failed structurally and only burned for about 45 seconds (the dome separated shortly after ignition occurred). The remaining six were placed in slicks by hand instead of being dropped from the air and, of these, one misfired. The overall functional reliability for the prototypes was, therefore, 80% (slightly under 79% if only those that were air-dropped are considered). Delay time averaged 20 seconds, easily satisfying the minimum 15 seconds sought. The average burn time for those that activated properly was only 93 seconds or 77.5% of the 2 minute minimum specified. Disregarding the shorter-than-desired burn time (which was sufficient for the type of oil encountered in this case), the overall functional reliability of the canister prototype easily exceeded the minimum 75% that was specified.

b) Sandwich Configuration

All of the 20 prototype devices ignited and generated the expected heat pattern. Delay times and burn times were not recorded for any of them, but those that encountered oil achieved slick ignition. Functional reliability of this design was, therefore, superior to that of the canister design and also exceeded the specified requirements.

OPERATIONAL PERFORMANCE

"Operational performance", in the context of the Arctic trials, included adequacy of handling arrangements, delivery accuracy, and ignition of oil slicks on melt pools.

Both designs satisfied the handling requirements in that they were transported, stored, embarked, activated and launched without disclosing any design deficiencies.

The trials confirmed that incendiary devices such as those developed by DREV can be dropped from a helicopter with sufficient accuracy without launching and sighting aids. Targets with an estimated area of only 4 m^2 were hit from an altitude of 5 m while transiting at speeds of 2 to 5 knots. Inert drops at 30 knots from 15 m confirmed that structural requirements had been satisfied.

The canister, despite its cylindrical shape, did not roll after impact, but it was never able to free-float in the intended upright attitude because the depth of water was always less than the 10 cm specified by the designer. Despite the attendant adverse affect on performance, the device still readily achieved self-sustained burning of the oil providing its position in the pool was suitable for the prevailing wind conditions.

One fact determined from the series of burns done during the experiment was that the flame would only propagate upwind if the wind-speed did not exceed 10 km/h. For higher windspeeds, the incendiary device must, therefore, be placed in the upwind part of the pool.

The sandwich configuration was able to float freely in the prevalent depths of water and also confirmed its ability to produce self-sustained burning of the oil. However, a major problem was disclosed in that the disc-shaped sandwich tended to roll excessively after impact, degrading deployment accuracy to the extent that only 3 "hits" were obtained; that is, only 3 came to rest in their intended target pools of oil.

PRODUCTION CHOICE

The sandwich configuration was chosen as the one to be brought to the stage of being approved for commercial production in Canada. Although the canister arrangement with its heat deflecting dome would probably be able to ignite slightly more-weathered oil than the sandwich, a major re-design would have had to be undertaken to make it able to float in the shallower-than-expected melt pools found to prevail. On the other hand, only a minor change was expected to cure the post-impact rolling problem experienced with the sandwich, and the required modification could be made without delaying the availability of the finished product.

It was, therefore, decided that the small increase in capability that might be possible with the canister model did not justify the additional cost and the further delay that would be involved.

MODIFIED SANDWICH DESCRIPTION

The basic design was retained intact and all that was changed was the shape of the plywood and styrofoam layers. These were simply squared-off, leaving the layer of incendiary composition unchanged as a circular disc that produces a uniform peripheral flame.

A production order for 200 of the modified igniters was placed through the Department of Supply and Services with the successful bidder, ABA Chemical Limited of Guelph, Ontario. The change of shape and the styrofoam filler that now surrounds the incendiary composition are shown by Figure 3, which is a photograph of one of the first ones produced.

MODIFICATION PROOF TEST

Ten of the first batch of 20 were selected for drop-testing from a helicopter to confirm that the change to the square shape had in fact cured the roll-after-impact problem.

The area chosen for the test was on the surface of a still-frozen lake at DREV and took place on 12 April, 1981. The ice was still firm enough to walk on with care and, except that there were no melt pools, the surface was very similar in contour, texture and firmness to that observed at McKinley Bay on 11 June, 1980. It was, therefore, ideal for determining the post-impact behaviour of the device when dropped from an aircraft onto a waterfree surface, the situation that had disclosed the problem initially.

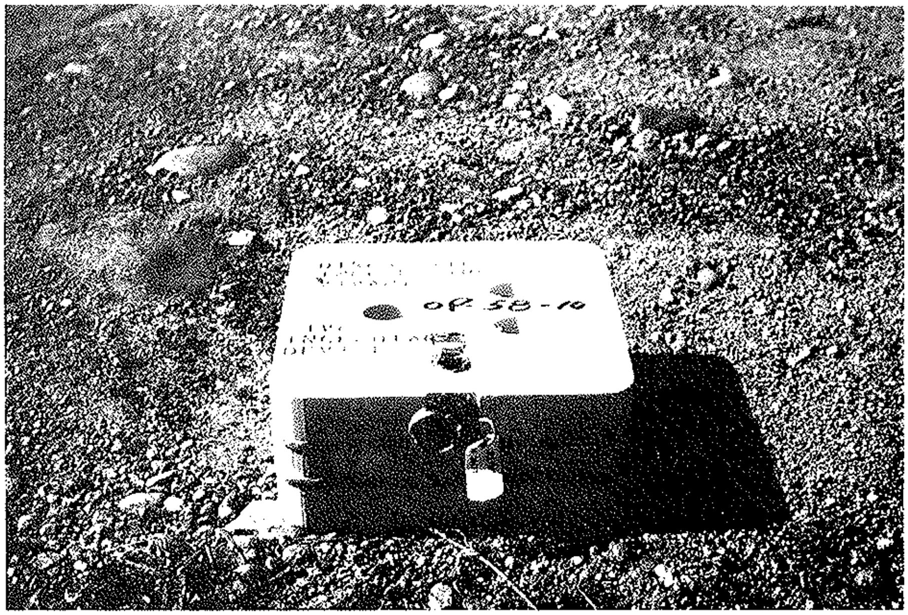

FIGURE 3 SANDWICH DEVICE - FINAL CONFIGURATION

A small triangular marker with a base approximately 60 cm a side was used to indicate the centre of the target area. As for previous air-drop trials, a Bell 206 helicopter with the door removed was used for this set. All 10 devices were dropped, 8 of them at the design altitude and airspeed of 15 m and 15 knots. The remaining 2 were dropped from about 30 m at an airspeed of 60 knots to simulate drops from a slow-flying fixed-wing aircraft.

Although the primary purpose of the test was to confirm that the rolling problem had been eliminated, the secondary purpose was to check the functional reliability of the production version. Accordingly, both still and motion picture photography was used to record results and the ignition sequence was timed.

The final report of the trial is still being prepared but it was confirmed that the rolling problem had been eliminated. There was some bouncing and skipping following the initial impact, but it was no more than is to be expected for any non-penetrating object similarly launched, and the modified shape was approved for the remainder of the production order.

Both of the devices dropped from the higher speed and greater height functioned correctly, exceeding the specified minimums for delay time and burn time. One came to rest initially balanced on one edge, but it toppled soon after burning commenced and provided the required minimum 2-minute burn thereafter. However, two of the eight devices released at the lower speed and altitude failed to ignite, and a third ignited but only burned along part of its periphery.

The two misfires were subsequently opened for examination and, in each case, the reason for failure was found. One of the complete misfires was caused by the use of an alternate cement that failed and allowed the firing mechanism to dislodge and interrupt the ignition train. A permissable alternate cement had been used and it has since been deleted from the specification; only the bonding material that proved satisfactory in the prototypes will be used for the remainder of the order.

The other misfire was also caused by a disruption in the ignition train, and the partial burn was attributed to a similar discontinuity. A minor design change has been incorporated that will not only preclude a recurrence of both types of failure, but it will also simplify production and reduce cost.

With these changes it is confidently expected that the 70% functional reliability demonstrated by this small initial sample will be substantially improved and the 75% goal will be surpassed.

PRODUCT APPROVAL TESTING

The incendiary devices developed by DREV for igniting pools of oil contain compositions that burn energetically and contain all the oxygen necessary for combustion. As such, they are classed as fireworks and their manufacture, purchase, use and possession are controlled by the Explosives Regulations of the Canada Explosives Act. Those regulations require that all firework compositions contained in legally manufactured or imported fireworks be tested by the Chief Inspector of Explosives and must comply with specific criteria. The finished firework in its casing or contrivance must also withstand tests for safety and reliability, and periodic run-of-work samples are tested to ensure that the required quality is maintained.

The transportation of such devices is also controlled in accordance with Department of Transport regulations for the applicable material category as determined by test and/or physical examination.

Providing devices for the tests associated with these regulatory requirements was one of the reasons for the previously mentioned order for 200 commercially manufactured devices of the selected design. The other reasons were to:

a) effectively transfer the technology from the military research establishment to Canadian industry;

b) obtain a quantity for evaluation of other possible applications; and

c) provide DREV with the number required for a series of environmental tests.

Those tests subject the product to extremes of temperature, high humidity, vibration, shock and rough handling in keeping with the design objectives, and serve both to prove the design and to confirm that the production version conforms to specification. To the extent that they satisfy requirements, the results of these tests will also be used by the regulatory authorities to avoid unnecessary duplication of effort.

A total of 120 devices will be expended for the environmental tests at DREV. The several tests will be performed in the sequence shown by Table 1, with new devices being added after each test. In this way, the ability of the device to withstand various combinations of tests will also be ascertained.

TABLE 1 ENVIRONMENTAL TEST PLAN

Test	No. of Items Sequentially Tested	No. of New Items Added to Test Lot	No. of Items Functioned
High temperature	60		12
Low temperature	48	12	12 12
Vibration	36	12	12 12
Temperature and Humidity Cycling	24	12	12 12
Rough Usage	12	12	12 12
12-metre Drop		12	

Briefly, the tests are as follows, and all devices subjected to only one test should function normally when activated; for those subjected to more than one test there should be no more than one failure after each stage:

a) High/Low Temperature - Items are to be conditioned for 24 hours at 50°C/ -40°C as applicable, and are then to be functioned at their soak temperature.

b) Vibration - Items are to be subjected to a sequence comprising four separate periods of 7 hours each at a frequency of 50 hertz and an amplitude of 0.25 mm. The items shall then be inspected for damage and functioned at ambient temperature.

c) Temperature and Humidity Cycling - Items shall be subjected to one 14-day cycle with temperature extremes of -50°C and 70°C, the relative humidity at the upper temperature limit being 90%. The items shall then be examined and functioned at ambient conditions.

d) Rough Usage - Items shall be placed loosely in a tumbling machine and tumbled for 15 minutes at the rate of approximately 12 revolutions per minute. No item shall function during the test and all items shall be safe to handle after testing. Items shall then be inspected for damage and functioned at ambient conditions.

e) 12-metre Drop - Items shall be subjected to a free-fall drop from a 12 m height onto a hard surface. Items must not function during the test and must be safe to handle afterwards.

EVALUATION FOR OTHER APPLICATIONS

Ten of the initial batch of 20 have been allocated to the Baffin Island Oil Spill (BIOS) experiment for evaluation at Cape Hatt as igniters of stranded oil on Arctic shorelines.

The remainder, less the few that may be required by the regulatory departments for examination and test, will be delivered to the Canadian Coast Guard for evaluation by operational personnel and to familiarize them with the capabilities of the device.

CONCLUSION

Subject to satisfactory results from the environmental test program at DREV, the multi-year project initiated in 1978 to develop an air-droppable incendiary device for igniting confined oil slicks on Arctic melt pools will be successfully completed by late 1981 or early 1982. The goal of making a safe, reliable and effective device commercially available for use in the event of an Arctic oil spill will have been achieved, and no further development is planned beyond that point.

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OPERATION PROTECMAR

Submitted by: Christian Bocard, Claude Gatellier
Institut Français du Pétrole
1-4, avenue de Bois-Préau - 92506 Rueil Malmaison (France)

Jean Croquette, François Merlin
C.E.D.R.E.
B.P. N° 308 - 29274 Brest Cedex (France)

INTRODUCTION

To measure the effectiveness of chemical dispersion at sea, small experimental oil slicks were treated with chemicals off the Mediterranean coast of France in 1979 and 1980. Dispersants were sprayed from boats using spray booms or hoses, from Canadair aircraft and from helicopters - a Lama with spray booms and an Alouette with a bucket device. Thermographic and colored photographs were obtained at different stages after treatment of the slicks. Special dynamic sampling devices were designed to recover representative samples of sea water from the surface and the water column. More than a thousand analyses were performed to determine the distribution of the dispersed oil.

When an accident at sea causes oil pollution, the first action should be to remove as much of the oil as possible by mechanical and physical means. Unfortunately, existing capabilities for confining and cleaning up an oil spill are often limited to protected harbors and estuaries since the performance of oil booms is generally limited to sea condition with waves less than 1.5 m high and currents less than 1.5 knots. Treatment of a spill with a chemical dispersant enhances the rate of natural dispersion and possibly prevents the formation of tar balls or mousse, and increases the rate of degradation.

When floating oil is treated with a suitable surface-active chemical and agitated, the oil is broken up into small droplets which will remain entrained in the upper zone of the water column if the drop size is below a certain minimum. The distribution of the oil through a large volume of sea reduces the chance for particles to recombine and again form a coherent film. A rapid dispersion could lead to hydrocarbon levels low enough to be acceptable. For the highest effectiveness, the bulk of the active ingredients of commercial dispersant formulations must be located at the water/oil interface. Therefore the application method is as important as the choice of surfactants.

The task is composed of two operations, firstly to apply the dispersant formulation to the floating oil, and secondly to mix the treated oil with the upper layer of the water either by natural waves or by mechanical agitation.

Dispersants may employ either a hydrocarbon base solvent or a water-miscible solvent. With the former, the undiluted material may be sprayed on to the oil layer and the function of the solvent is to facilitate the distribution of the surfactant throughout the oil phase. With the latter so-called concentrates, a mixing device on the workboat is usually used to dilute the dispersant with sea water before discharging the mixture under high pressure. The Warren Spring Laboratory of the British Department of Trade and Industry developed, 10 years ago, a method for applying dispersants (1).

In France, the Navy is in charge of fighting oil pollution at sea and has been using spray booms and surface breaker boards or chain-nets towed through the water. More recently the Navy has studied the jet application of concentrated dispersants and also their use without predilution by sea water. According to experimental work regarding soluble wastes, dilution by a factor of about 100 over a period of 10 hours may be expected under mild oceanic conditions.

Before the Protecmar tests little information was available about the actual fate of chemically dispersed oil from measurement of hydrocarbon levels on the water surface and in the water column (2) (3). A more recent paper describes a successful trial (4) with results about an enhanced gradient of dispersed oil in the water column.

Commercial dispersant formulations must meet requirements with regard to their toxicity and the French Environmental Office has been preparing a certification based on the following factors : toxicity and biodegradability of the dispersant itself and, after determination of the dispersant/oil ratio sufficient to obtain a specific emulsion under laboratory conditions, the toxicity and oil degradation of the specific emulsion (5).

Laboratory methods do not exactly simulate natural conditions and it is very difficult to use laboratory data to determine the most appropriate dispersant/hydrocarbon ratio necessary to break up oil and to produce relatively stable dispersions. Only experiments involving large treated oil spills will give information on the realistic fate of dispersed petroleum fractions.

The Protecmar program was conducted under the care of Centre de Documentation de Recherches et d'Experimentations sur les Pollutions Accidentelles des Eaux (C.E.D.R.E.) and the technical management of Institut Français du Pétrole (I.F.P.) assisted by a working group composed of IFP, CEDRE, French Navy, Civil Defense, Laboratoire National d'Essais and the oil companies, Compagnie Française des Pétroles and Société Nationale Elf Aquitaine representing Union des Chambres Syndicales de l'Industrie du Pétrole (U.C.S.I.P.).

The first series of trials were conducted on May 8-12, 1979 with ships and aerial support from the French Navy, Merchant Marine, Civil Defense and Société Nationale Aerospatiale. The second series of trials were conducted on September 16-19, 1980 with ships and aerial support from the French Navy, Merchant Marine, Civil Defense, Customs Department and private rented aircraft. Both trials were conducted off Toulon on the Mediterranean coast of France, under the operational responsibility of the French Navy.

EXPERIMENTAL TECHNIQUES

Oil Slick Generation

In both series of trials the discharged oil was a light fuel oil (specific gravity 0.89, viscosity 50 cS at 20°C) approximately equivalent to a partially evaporated crude oil, for example Arabian Light without its light components up to a boiling point of 150°C. Such an oil does not spread in the same manner as a fresh crude oil but it was thought that light fuel oil slicks are representative of many real weathered slicks. One slick consisted of 65 % water - 35 % Arabian Light oil emulsion representative of a freshly formed emulsion.

Protecmar 1. Thirteen slicks, approximately 3 m^3 each in volume were discharged from a tank truck aboard a landing ship through a 2 m diameter and 4 m high metal sleeve which was suspended in a half-immersed position and raised by a crane (Figure 1). Such a technique resulted in relatively compact slicks including thick areas down-wind. The 3 m^3 emulsion slick was generated by directly discharging oil from drums.

Protecmar 2. Seven slicks (five of approximately 5.5 m^3, one of 3 m^3 and one of 1 m^3) were discharged though a 9 m width boom, fixed at the bow of a tanker ship making stern-away at about 1 knot while pumping out oil (Figure 2). As planned, these slicks were more elongated and more homogeneous in thickness.

Patches of coloured dye (Rhodamine) were discharged at 1 m under the sea surface at both ends of the slicks in order to mark the drift of oil dispersed in the water column relative to the surface oil.

Dispersant application

1. Sea surface application. Warren Spring Laboratory (WSL) type booms and fire-hose nozzles were used to apply the dispersant. For Protecmar 1, booms were mounted on a high-sea tug-boat, approximately at two thirds of its length forward from the stern. For Protecmar 2, the booms were mounted at the prow of a supply-type boat with lengthening pieces in order to hold the nozzles about 1.5 m above the sea surface (Figure 3.) Concentrated dispersants were sprayed and diluted with sea water by using a Dubois mixing system. The total flow-rate was 6 to 8 m^3/h with a dispersant content from 8 to 12 % according to the viscosity of the products. It can be approximated that, at a working speed of 4 knots, the dispersant dosage was between 80 and 120 l/hectare. Second-generation (non-concentrate) dispersants were sprayed without dilution.

During Protecmar 2, one slick was treated by using two flat jet fire-hose nozzles (Hug Jet) which sprayed dispersant over approximately the same width as booms (Figure 4). In several cases, mixing systems were towed behind the booms : WSL-type breaker boards for Protecmar 1, and a recently developed system for Protecmar 2, which consisted of plastic chain nets (figures 3 and 5).

2. Aerial application. Pure concentrated dispersants were sprayed by a Canadair CL 215 aircraft and two light helicopters, a Lama and an Alouette III. For Protecmar 1, the whole length (28 m) of the booms fixed under the wings of the CL 215 was used (Figure 6). However it was observed that the external parts of the dispersant cloud fell more slowly than the part under the flaps. For Protecmar 2 it was decided to use only the internal 2/3 part of the booms (18 m) (Figure 7). Assuming, as indicated by observations, that for an aircraft altitude between 8 and 15 m the swath width is approximately 40 % larger than the boom span, it was estimated that at a working speed of 100 knots the dispersant dosage was between 90 and 110 l/hectare in both cases. The Lama helicopter was equipped with two 4.5 m booms attached to each side of the aircraft (Figure 8). The Alouette helicopter was equipped with a suspended bucket (Spray King System), with a spray boom 11 m wide (Figure 9). Both helicopters worked at about 50 knots. The dispersant dosage was between 80 and 100 l/hectare.

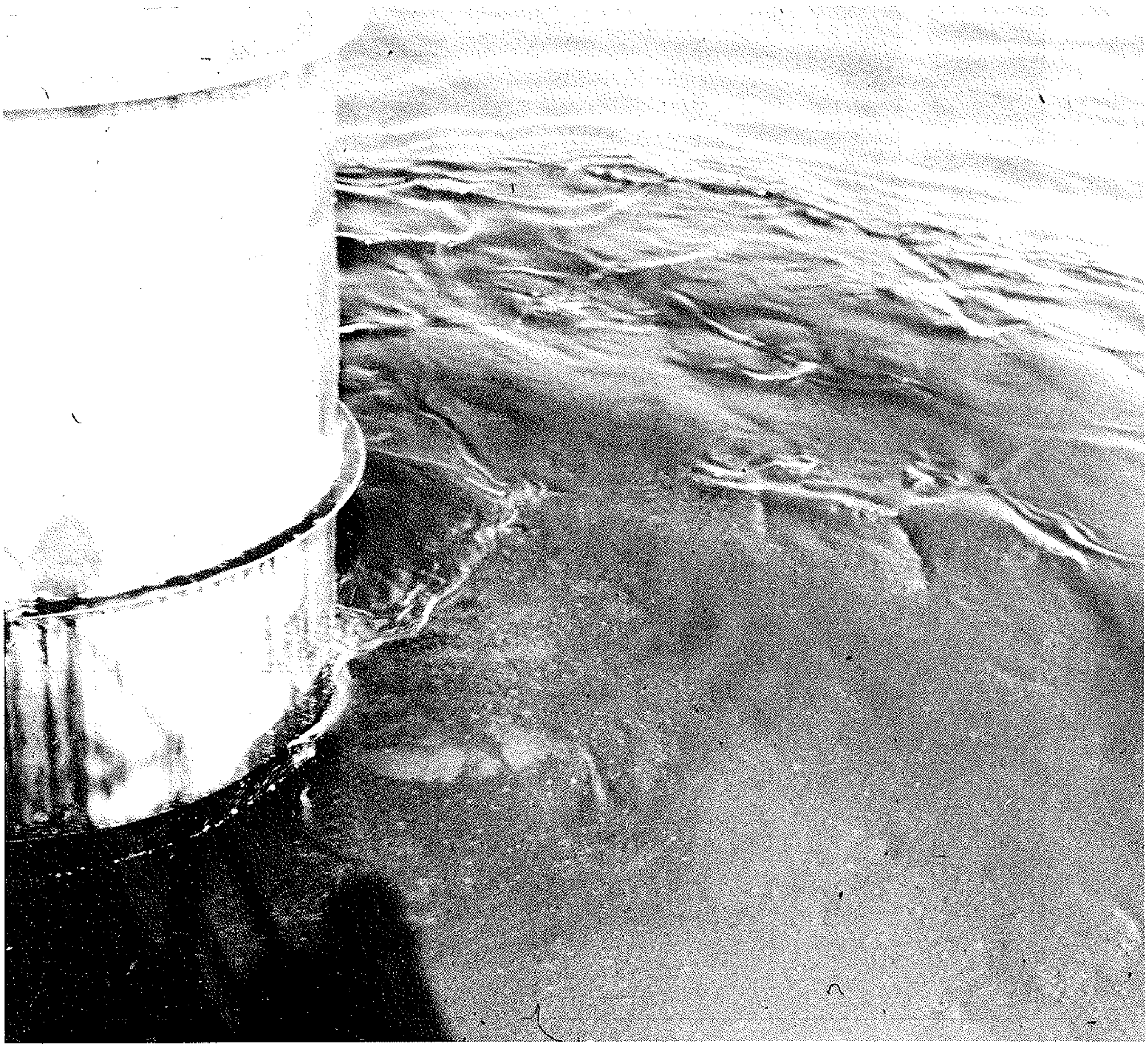


FIGURE 1 STATIC OIL DISCHARGE SYSTEM USED AT PROTECMAR 1

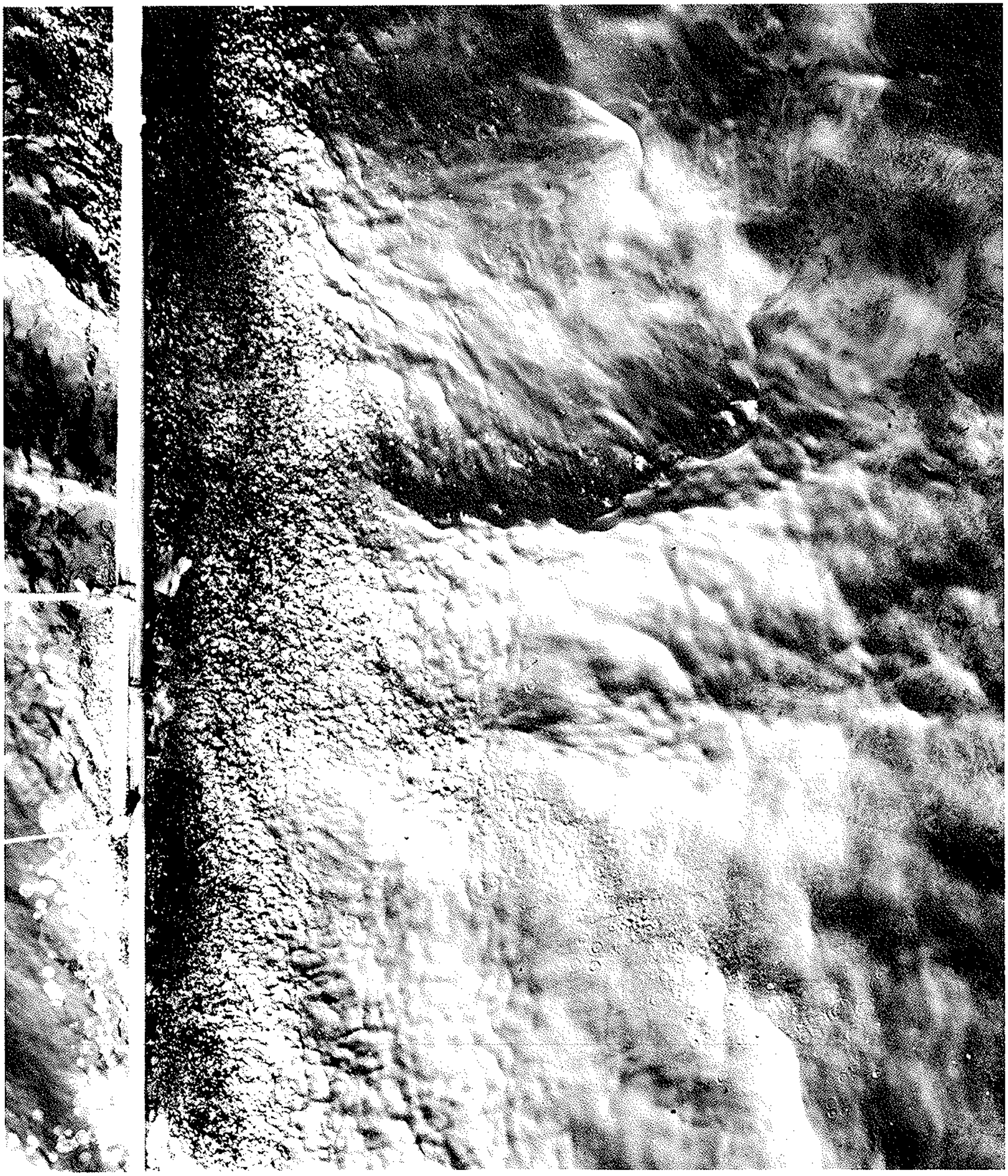


FIGURE 2 DYNAMIC OIL DISCHARGE SYSTEM USED AT PROTECMAR 2

FIGURE 3 DISPERSANT APPLICATION FROM VESSEL EQUIPPED WITH SPRAY BOOMS (PROTECMAR 2)

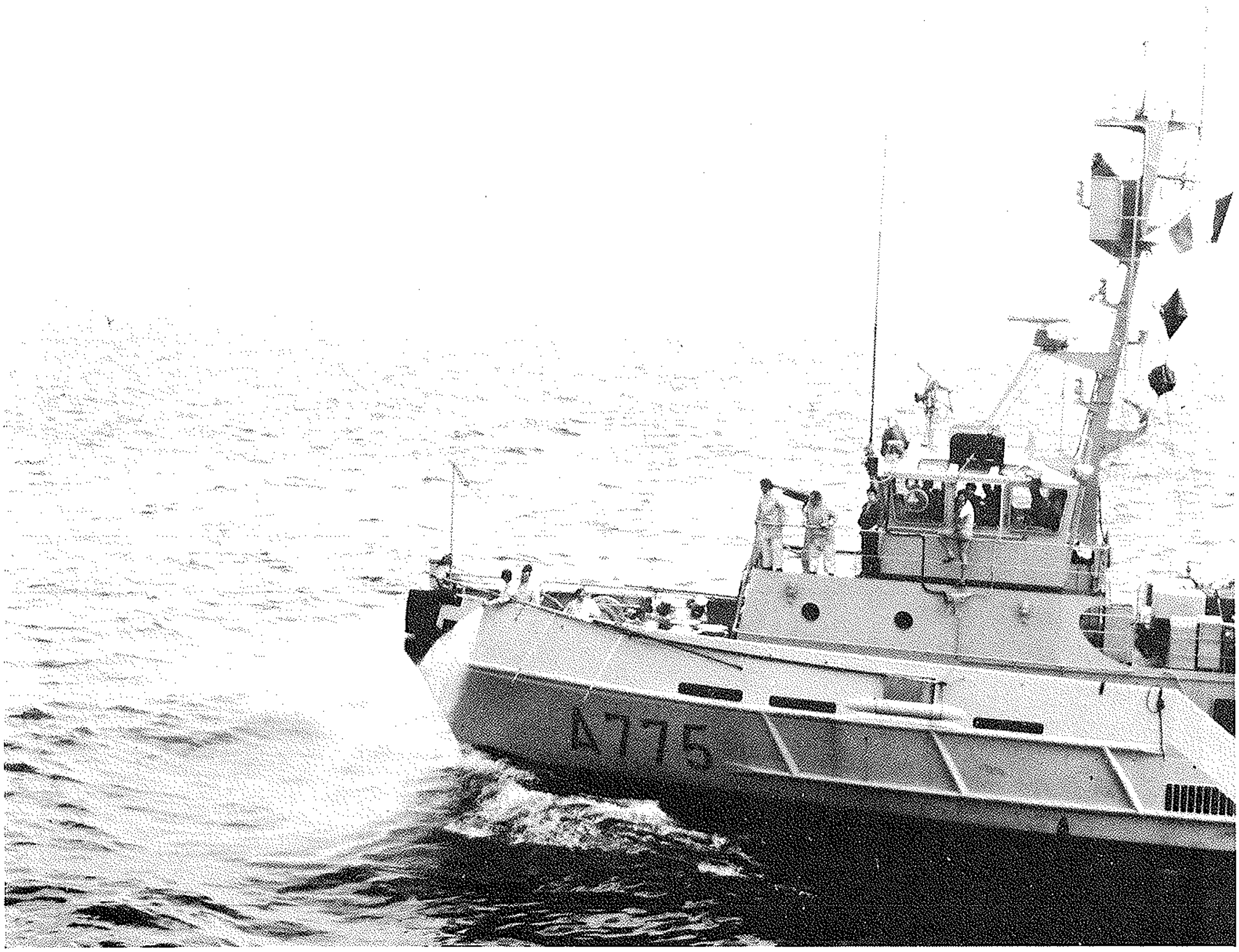


FIGURE 4 DISPERSANT APPLICATION FROM VESSEL WITH FIRE-HOSE JETS (PROTECMAR 2)

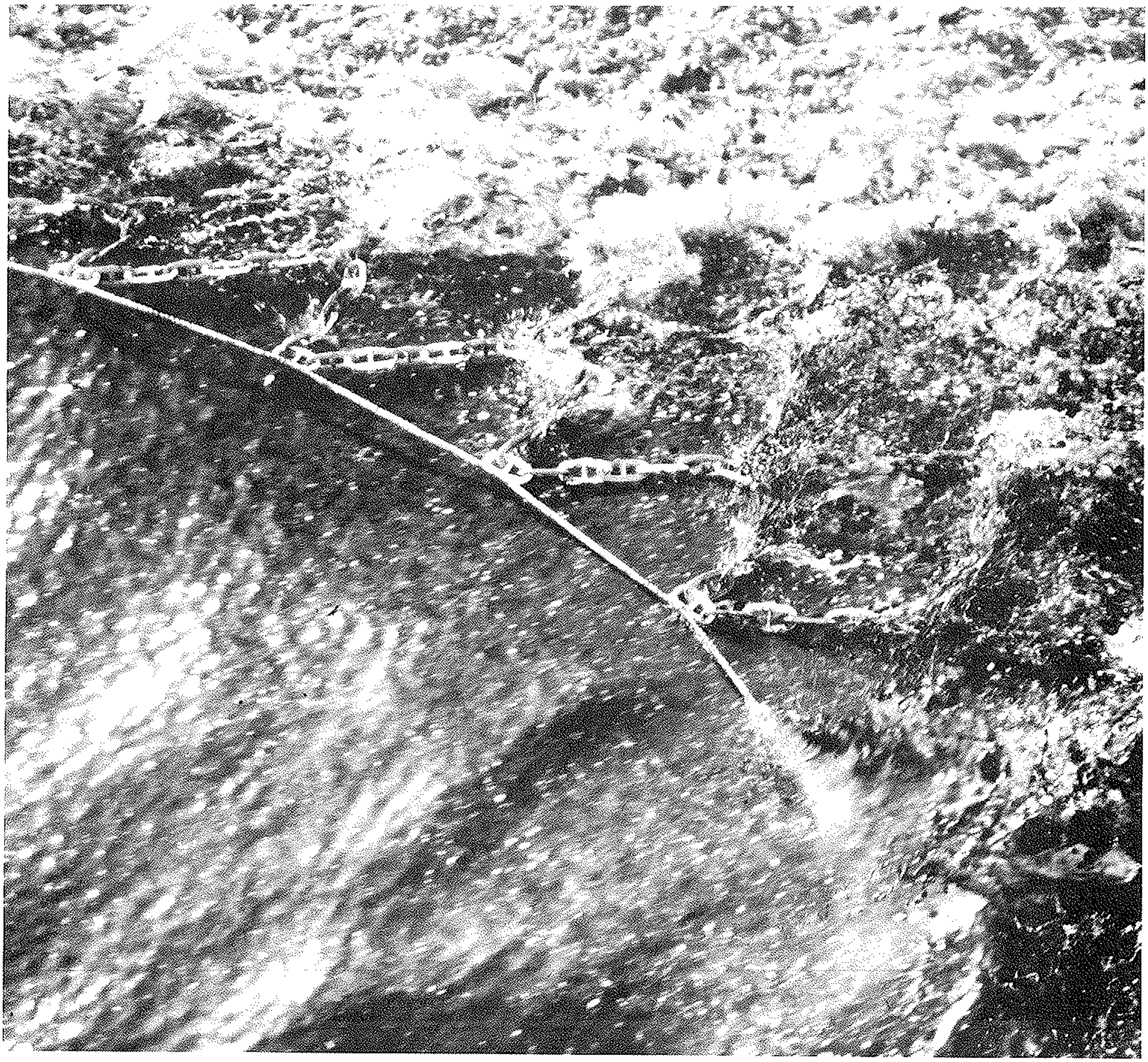


FIGURE 5 PLASTIC CHAIN NETS USED AS A MIXING SYSTEM

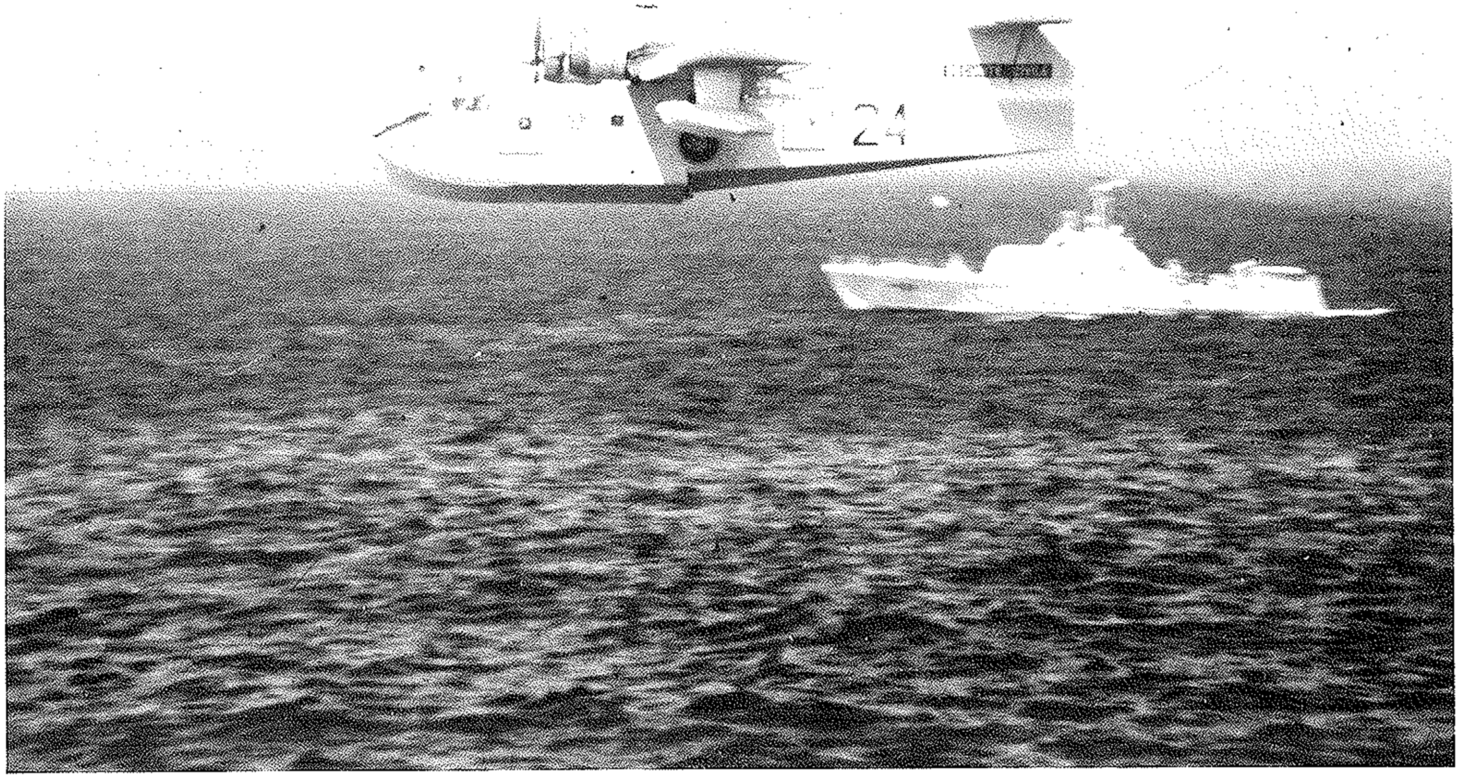


FIGURE 6 CANADAIR CL-215 AIRCRAFT APPLYING DISPERSANT

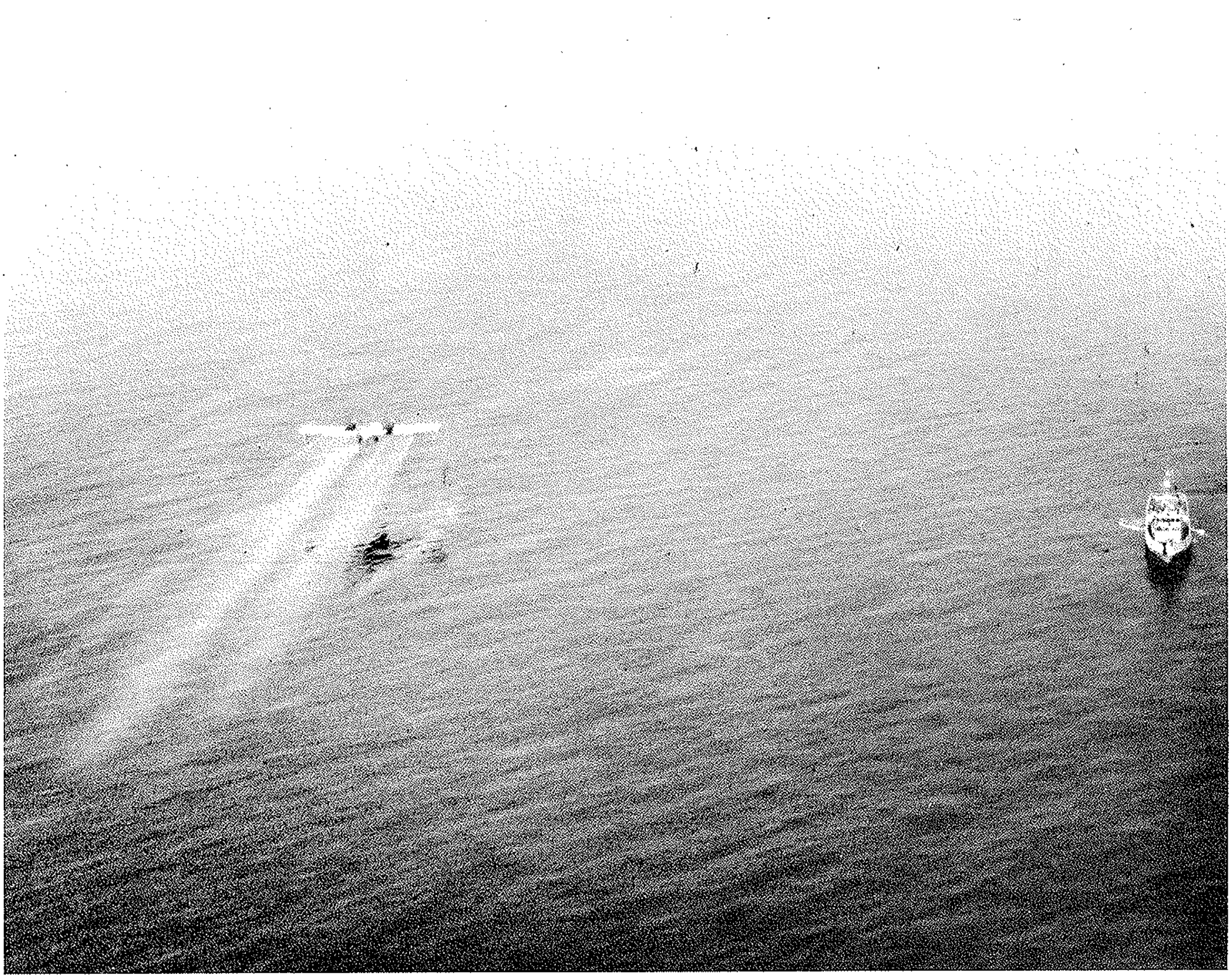


FIGURE 7 SPRAY PATTERN CREATED BY CL-215 WITHOUT THE EXTERNAL PARTS OF THE BOOMS

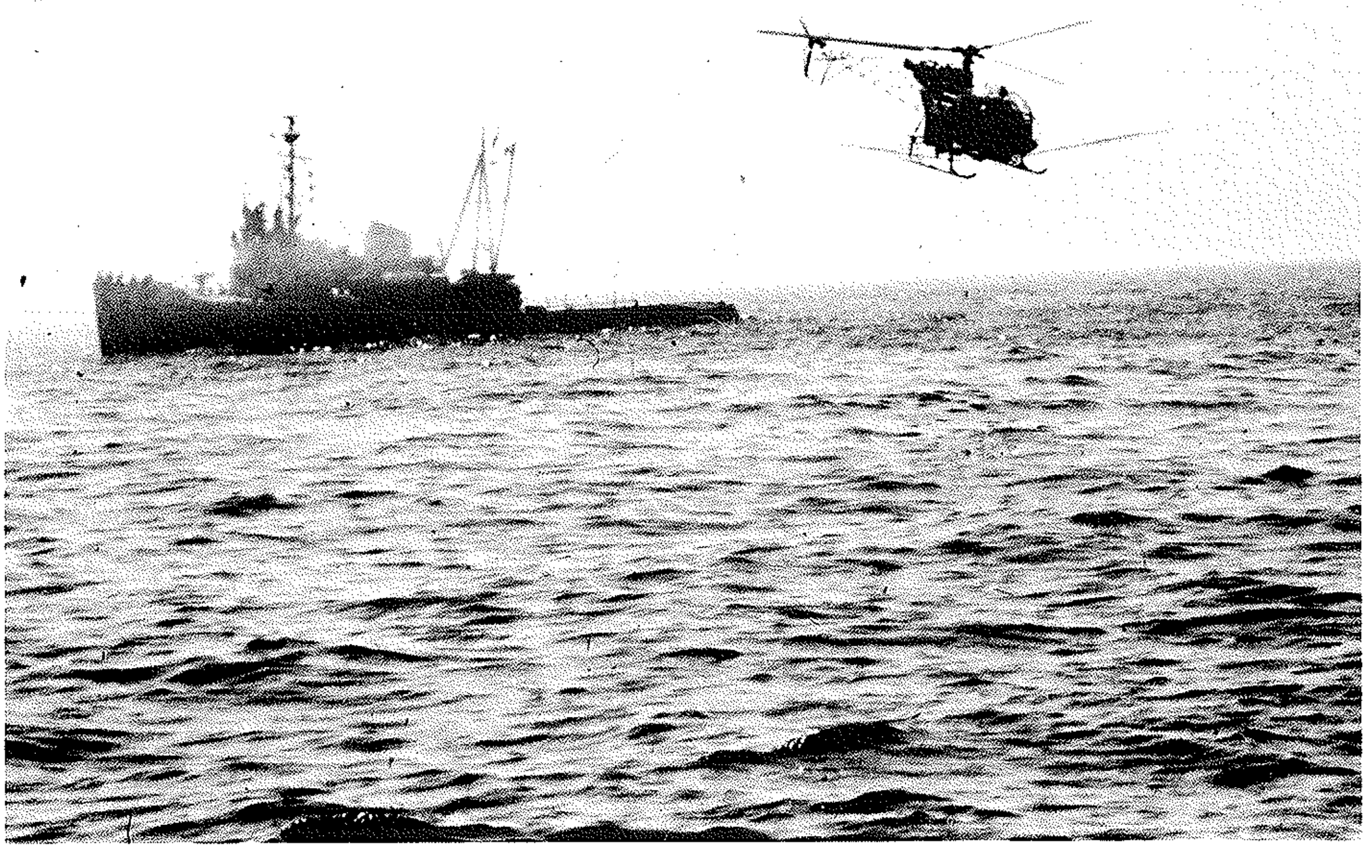


FIGURE 8 THE LAMA HELICOPTER EQUIPPED WITH SPRAY BOOMS

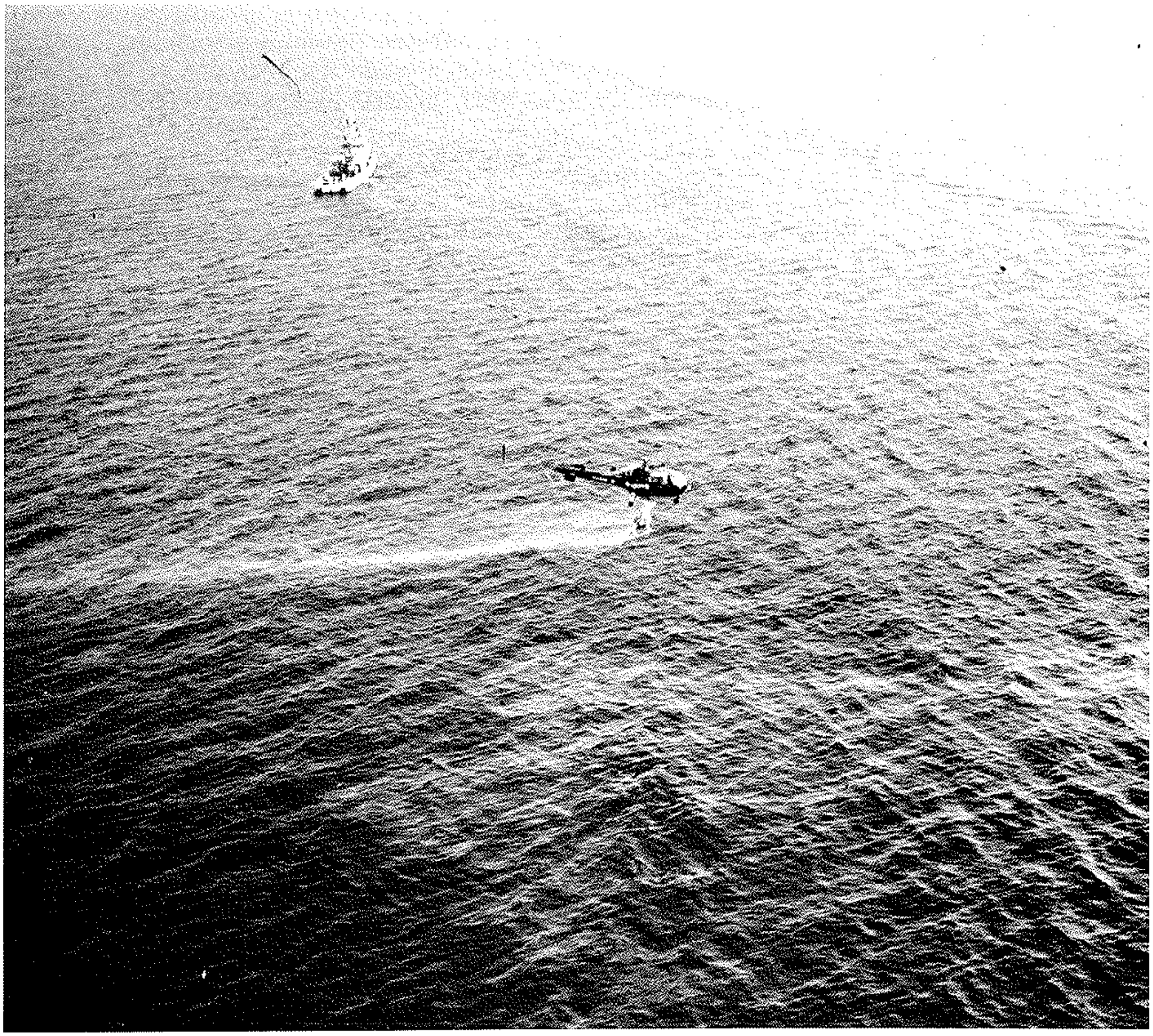


FIGURE 9 THE ALOUETTE HELICOPTER APPLYING DISPERSANT WITH A SUSPENDED BUCKET

Aerial control and photography

A dedicated helicopter was used to guide the spraying vessels and aircraft, sampling boats, and to take low-altitude photographs and films. A Cessna 330 aircraft equipped with supercyclope system was used to register infrared thermography and color photographs. For Protecmar 2 a second aircraft (Pilatus) equipped with a vertical camera was also used. A B17 aircraft equipped with a thermo-infrared Daedalus system and a color camera was used for one day. All this documentation enabled the evolution of the slicks to be recorded after treatment as well the position of the boats during sampling.

Sampling systems and analysis

In order to sample surface water without too much interference with water below, IFP designed a special dynamic sampler called Echantillonneur dynamique de l'Institut du Pétrole (EDIP). In a first version the water was collected in an open tube semi-immersed and drawn along the side of a picket-boat. By mechanical stirring and the addition of concentrate dispersant, the oil-water mixture was homogenised and some pumped on board to give a sample representing the hydrocarbon content of the 10-15 cm deep near-surface water. Better use was made of the laws of hydrodynamics by building another EDIP in the form of a catamaran, so that the inside walls of the floats would create a venturi effect (Figure 10). A baffle provided the additional turbulance required to homogenize the flow. Samples were recovered by pumping, as before, and are denoted by the symbol S hereafter. Another catamaran (Figure 11) equipped with a submerged venturi cylinder towed on the other side of the sampling vessel was used to obtain seawater samples (referenced P) from a depth of one meter.

During Protecmar 1, a vertical pipe was merely submerged along the side of the vessel. This technique was repeated using a pipe mounted at the bow to obtain samples during Protecmar 2 (referenced PP) at a depth of 2.5 meters.

The objective of dynamic sampling was to obtain samples during the movement of the launch. The systems collected samples at varying rates (0.25 to 0.50 l/s) during specified periods (10 to 20 s), to provide, in essence, a continuous composite sample which represented an average concentration over the path length of the sampling tube.

The tanker initially used to discharge the slicks was also used as a platform to obtain static samples (referenced T) by submerging a ballasted, flexible tube to depths of 3, 6 and 9 meters, (Protecmar 1) or to depths of 2.5, 5.0 and 7.5 meters (Protecmar 2).

For each kind of sampling, blanks were obtained to confirm the absence of any contamination in the pumps or tubes. EDIP tubes were cleaned between each sampling pass by injecting a special surfactant, and pumping water from clean sea. In order to measure low concentrations of oil in sea water by an IR spectrophotometric method, the hydrocarbons must be extracted from large volumes of water by carbon tetrachloride (CCl_4). Therefore 5-liter (2-liter for surface sample) new cans were obtained and cleaned with CCl_4. Before the operation each can was filled with 100 ml of CCl_4 and closed by a clean metal cap. After sampling, the cans were agitated manually and onshore the following day most of water was decanted and the remaining liquid, mainly CCl_4, was transferred into a glass bottle with an aluminum-wrapped stopper. The hydrocarbons were separated by chromatography and analysed using IR spectrometry.

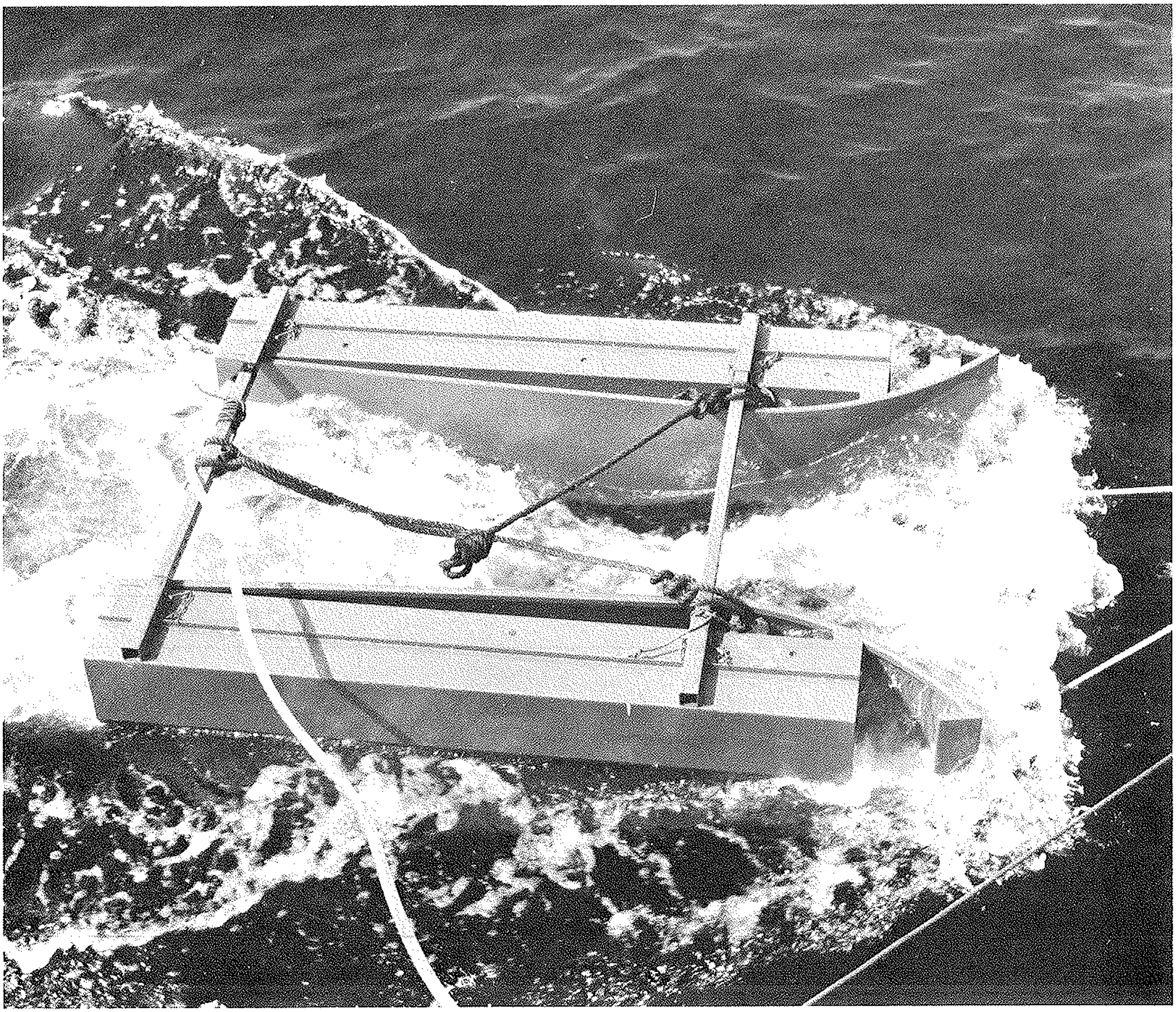


FIGURE 10 SURFACE DYNAMIC SAMPLING SYSTEM

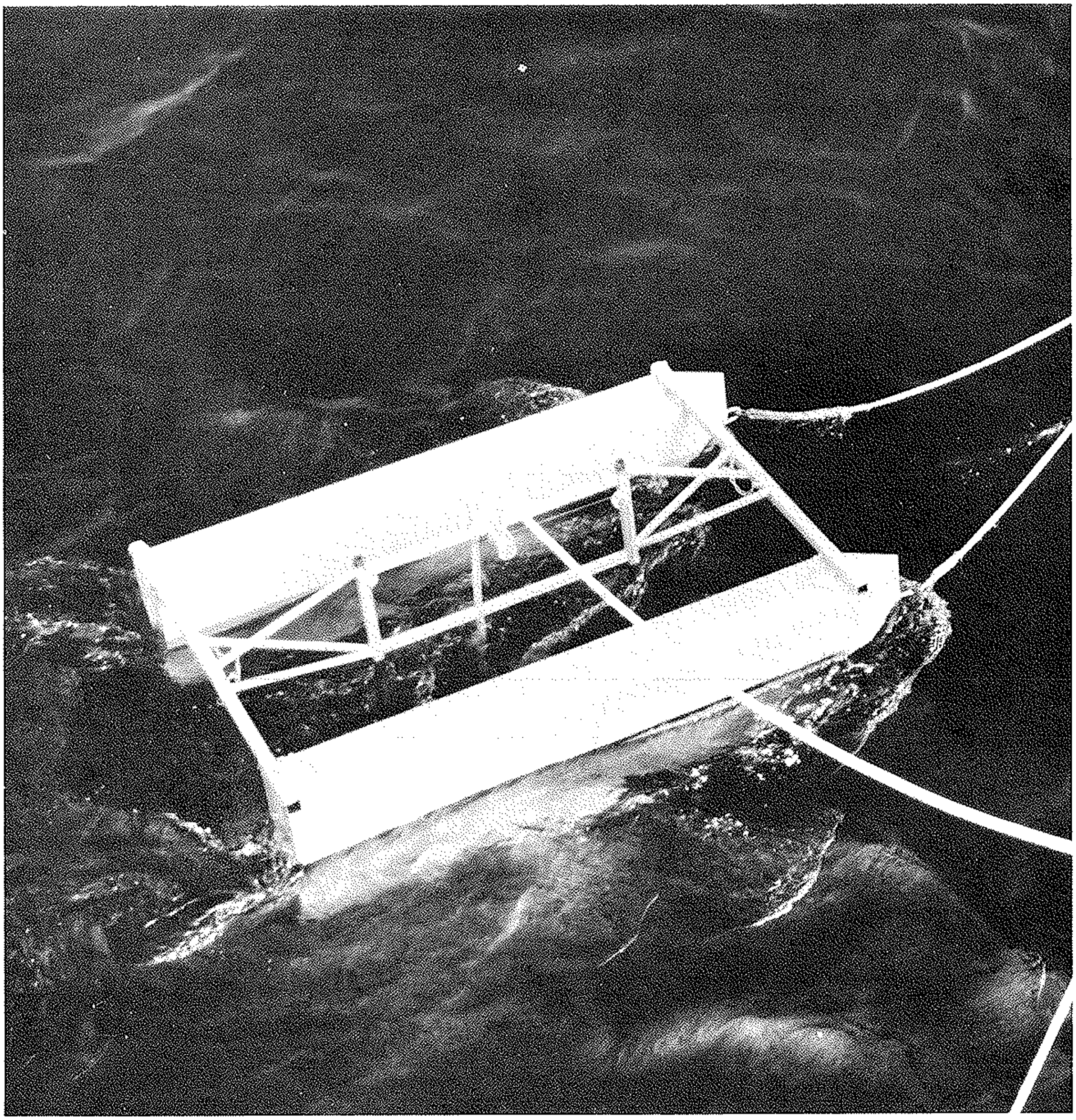


FIGURE 11 ONE-METER DEPTH DYNAMIC SAMPLING SYSTEM

PROGRAM IMPLEMENTATION

Both series of trials were conducted off Toulon, in an area centered 8 nautical miles south of Cap Sicié (42°55' N, 5°50' E). Except for the last day in both cases, the wind and sea state were quite calm (Table 1). A cloud cover or mist during three days of Protecmar 2 caused some photographic difficulties.

TABLE 1

	Sea state		Wind force (Beaufort scale)	
	8 h	15 h	8 h	15 h
May 8, 1979	1	1	NE 1	W 1
May 9,	1	2	NE 1	W 4
May 10,	2	1	NNW 2	W 2
May 11,	1	2	NE 1	W 2
May 12,	3	2	NW 3	SE 2
Sept 16, 1980	1	1	SE 2	SE 2
Sept 17,	1	2	0	W 3
Sept 18,	1	2	E 3	SE 3
Sept 19,	2	3	ESE 3	ESE 5

Protecmar 1

Table 2 summarizes the general program of Protecmar 1.

The doses of dispersants sprayed were preselected as follows: 1000 liters of BP 1100 X, 200 liters of the concentrate dispersants BP 1100 WD, Corexit 9527 and Finasol OSR 5. However, in some cases (especially involving treatments by vessel), the slicks could not be entirely covered with these doses. For example, slicks B1 and B3 received 300 l of dispersant, and the emulsion slick E1 was treated with 1600 l of Finasol OSR 2. Due to the relatively small dimensions of the slicks (300 to 500 m), the working time spent by the vessel in spraying on the slick was only 30 to 45 % of the total time.

Protecmar 2

The general treatment program is summarized in Table 3.

Before the trial it was decided to apply a maximum dispersant dose of 1200 l for a 6 m^3 slick (dispersant/oil ratio = 0.2). However, the treatment of slicks A2 and C2 was stopped before this ratio was reached.

The working time spent by the vessel in spraying varied between 40 and 60 % of the total time.

Table 2

Slick	Volume m^3	Discharge time	TREATMENT			SAMPLING			
			Time	Method	Dispersant used	Landing ship (S + PP + T) 1st Series	2nd Series	Vedette-boat (S + PP) 1st Series	2nd Series
A 1	3.5	9h38	10h24-10h50	Vessel only	none	11h16	16h13-16h28	11h53-11h56	14h34-14h42
A 2	3.5	10h28	11h16-11h56	Vessel booms	BP 1100 X 1000 l	12h14-12h45	14h17-14h20	12h50-12h59	16h40-16h42
A 3	3.5	13h35	14h09-14h47	Vessel booms + Breaker boards	BP 1100 X 1000 l	15h08-15h35	18h23-18h38	15h40-15h44	16h58-16h59
B 1	3.5	9h18	10h04-10h50	Vessel booms + Breaker boards	Finasol OSR5 300 l	11h05-11h12	15h32-15h48	11h26-11h33	13h56-13h59
B 2	3.5	10h08	11h40-12h25	Vessel Fire-hose	Finasol OSR5 200 l	12h33	14h05		14h03-14h08
B 3	3.5	13h43	14h04-14h48	Vessel booms	Finasol OSR5 300 l	15h06-15h13	-	15h18-15h20	
C 1	3.5	9h18	10h27-10h31	Canadair	BP 1100 WD 200 l	10h50-10h57	-	11h08-11h18	14h18-14h23 16h -16h03
C 2	3.5	9h54	11h16-11h20	Helicopter	Finasol OSR5 200 l	11h38-11h44	13h59-14h15	11h46-11h49	15h38-15h42
C 3	2.8 (including 30 % Diesel oil)	13h15	14h33-14h55	Helicopter	BP 1100 WD 200 l	15h01-15h13	-	15h14-15h26	-
D 1	3	9h17	10h35-10h47	Helicopter	Corexit 9527 200 l	11h03-11h11	15h52-16h	11h17-11h22	14h18-14h21
D 2	3	9h53	11h32-11h37	Canadair	Corexit 9527 200 l	11h48-11h58	14h07-14h15	12h -12h02	15h55-15h59
D 3	3	13h28	14h23-14h54	Canadair	Finasol OSR5 200 l	15h14-15h24	-	15h28-15h32	-
E 1 (emulsion)	3	9h28	9h58-10h55	Vessel booms	Finasol OSR2 1600 l	11h16-11h30	13h44-14h04	11h37-11h41	14h56-14h59
E 2	3	10h02	11h28-12h02	Vessel booms + fire-hose for agit.	Finasol OSR5 200 l	12h28-12h39	14h25-14h40	12h29-12h33	14h26-14h30

TABLE 3

Slick	Volume m^3	Discharge time	Treatment Time	Treatment method	Dispersant used
A 1	5.5	8h30	9h15-11h35	Vessel Booms	Finasol OSR7 1100 l
A 2	5.5	14h05	15h15-18h	Vessel Booms + chain nets	Finasol OSR7 800 l
B 1	5.5	8h45	9h30- 9h40	Canadair	Finasol OSR7 1200 l
B 2	5.5	13h05	13h55-14h15	Canadair + Stirring by vessel	Finasol OSR7 1300 l
C 1	1	8h45	9h50-10h05	Helicopter	Finasol OSR7 200 l
C 2	5.5	13h25	14h -16h15	Vessel Booms + chain nets	Hydrosol DN40 800 l
D 1	3	9h	10h -11h55	Vessel Fire-hose nozzles	Finasol OSR7 600 l

During Protecmar 2 the sampling program varied according to the kind of treatment:

1. When dispersant was applied from a ship:

   A first series of 6 P in the area between the slick and the sea water coloured by the dye.

   A second series of 10 S, 10 P, 10 PP and 9 T (three depths, three times) just at the end of treatment.

   A third series of 10 S, 10 P, 10 PP and 3 T (three depths) 45 minutes after the end of treatment.

   A fourth series of 5 S and 5 P, 150 minutes after the end of treatment (slicks A 1, and D 1).

2. When dispersant was applied by aircraft:

   A first series of 14 S, 14 P, 14 PP and 9 T just at the end of treatment.

   A second series, of 10 S, 10 P, 10 PP and 3T, 45 minutes after the end of treatment.

   A third series of 5 S and 5 P, 150 minutes after the end of treatment (slicks B 1 and C 1).

In tables 4 and 5, respectively, the sampling results for slick A 1, which was dispersed from a vessel, and for slick B 1, which was dispersed by Canadair aircraft, are included to illustrate the procedures selected. The figures also include the position and time of each sample.

DISCUSSION

Surface evolution of slicks

The immediate effects of dispersant treatments are illustrated in thermographs, figures 12a, 13a, 14a, and photographs, figure 17a. The visual effect of aerial spraying is particularly noticable. The visual effect of treatment by vessels is generally less marked due to the difficulty of covering the slicks uniformly in a series of parallel runs, especially with limited doses of dispersant during the Protecmar 1 trials.

It can be seen that the thickest parts of the slicks (several hundreds of mμ) appear to be almost unchanged, although observers aboard vessels noted some fragmentation into large drops. Even with higher dispersant doses for example by using several aircraft runs along the same path, the thick areas were not dispersed. Oil globules reappeared at the surface 15 to 30 minutes after aerial spraying during Protecmar 1 (Figure 13b), and after a little longer time during Protecmar 2 (Figure 17b). In Protecmar 1 it was conjectured that the persistent slick shown in figures 12c, 13c-d, and 14d several hours after treatment was caused by the combination of resurfacing globules and the spreading of the undispersed, thicker parts of the slick. In Figure 19, slick B 1 in Protecmar 2, is illustrated. The thermographs were used to measure the total area of Protecmar 1 slicks at different times after treatment and the values are summarized in table 6. These values were verified using colour photographs. Relative to the untreated slicks like A 1, the treated slicks spread to a much greater size, but in most cases this effect is enhanced by the vessels breaking the slick.

Oil dispersion in the water column

In the case of Protecmar 1, the oil concentration levels obtained from 2.5 m deep samples obtained from picket boats are generally higher than those of the samples obtained from landing vessels taken at comparable times and depths (see table 1). This implies that the dynamic sampling from the side of the boat using a tube fixed along the hull was affected by the water movements associated with each boat. It is considered that the lower values obtained in the Protecmar 2 trials (summarized in tables 4 and 5), with the sampling tube mounted at the bow, are probably more representative of the actual oil concentrations.

TIME	mg/l	mg/l	mg/l	mg/l
10h22mn30s		P 1 0.2		
23 00		P 2 0.2		
18		P 3 0.2		
47		P 4 0.2		
24 00		P 5 0.2		
11		P 6 0.2(5)		
11 43 26	S 1 0.6	P 7 0.2	PP 1 0.1(5)	
44 00	S 2 12.5	P 8 0.3	PP 2 0.2	
45 00	S 3 0.7(5)	P 9 0.3(5)	PP 3 0.2	
46 15	S 4 3.6	P10 0.2(5)	PP 4 0.3	
47 15	S 5 2.1	P11 0.5(5)	PP 5 0.4	
49 36	S 6 1.6	P12 0.6(5)	PP 6 0.5	
57 20			PP 7 0.2	
57 43	S 7 2.0	P13 0.1(5)	PP 8 0.3	
58 07	S 8 43	P14 0.8	PP 9 0.2	
30	S 9 1420	P15 0.7	PP10 0.2	
- - -	S10 4.0			
12 06 00				T7.5 0.1(5)
07 25				T5.0 0.1(5)
42				T2.5 0.4
10 00				T7.5 0.2
40				T5.0 0.1(5)
11 10				T2.5 0.3(5)
15 00				T7.5 0.1(5)
40				T5.0 0.2
16 18				T2.5 0.4
28 58	S11 1.0	P17 0.1(5)	PP11 0.1	
30 08	S12 36	P18 0.2	PP12 0.2	
31 35	S13 12	P19 0.2(5)	PP13 0.2	
32 48	S14 5.3	P20 0.4(5)	PP14 0.3	
33 36	S15 1.8	P21 0.4(5)	PP15 0.3(5)	
34 30	S16 6.0	P22 0.5	PP16 0.3	
45 25	S17 2.7	P23 0.1(5)	PP17 0.1(5)	
46 00	S18 33	P24 0.1(5)	PP18 0.1(5)	
37	S19 435	P25 0.2	PP19 0.2	
47 44	S20 1890	P26 0.1	PP20 0.2	
58 43				T7.5 0.1(5)
13 01 30				T5.0 0.2
02 00				T2.5 0.5
14 44 40	S21 1.1	P27 0.2		
45 20	S22 1.7	P28 0.1(5)		
46 15	S23 6.2	P29 0.1(5)		
49 10	S24 1.8	P30 0.1		
50 42	S25 8400	P31 0.1		

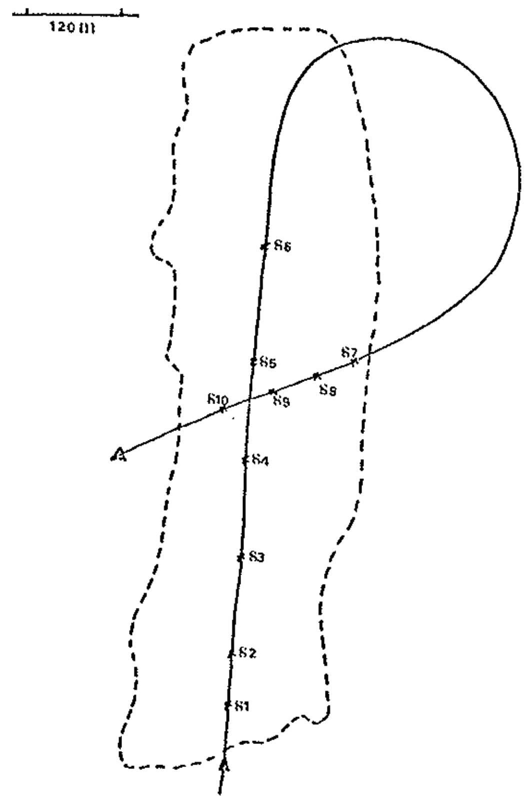


Table 4 Protecmar 2. Sampling of slick A1
(results are given in mg fuel per liter sea water)

TIME	mg/l	mg/l	mg/l	mg/l
9h57mn08s	S 1 3.2	P 1 0.1(5)	PP 1 0.1	
59	S 2 0.8	P 2 0.1(5)	PP 2 0.1	
58 48	S 3 44	P 3 0.2	PP 3 0.1	
.59 19	S 4 170	P 4 0.1(5)	PP 4 0.1	
10 00 00	S 5 560	P 5 0.2	PP 5 0.1	
24	S 6 1210	P 6 0.4	PP 6 0.1	
06 19	S 7 0.6	P 7 0.2	PP 7 0.1	
36	S 8 0.7	P 8 0.1(5)	PP 8 0.1	
58	S 9 0.7	P 9 0.1	PP 9 0.2(5)	
07 19	S10 1960	P10 2.5	PP10 0.1	
16 00	S11 0.7	P11 0.2	PP11 0.2(5)	
14	S12 5.2	P12 0.2(5)	PP12 0.1	
31	S13 10.(5)	P13 0.1	PP13 0.1	
47	.S14 3250	P14 0.1	PP14 0.1	
34 35				T7.5 0.1
35 26				T5.0 0.1
36 15				T2.5 0.4
39 26				T7.5 0.2
40 10				T5.0 0.2
41 00				T2.5 0.1(5)
45 27				T7.5 0.1
45 36	S15 480	P15 0.2	PP15 0.1	
46 02	S16 3.5	P16 0.2	PP16 0.1	
03				T5.0 0.6
37	S17 1020	P17 0.3	PP17 0.1	T2.5 1,0
47 36	S18 8.5	P18 0.6	PP18 0.8	
48 04	S19 5.5	P19 0.1(5)	PP19 0.1	
49 05	S20 3.1	P20 0.2	PP20 0.1	
58 37	S21 0.4	P21 0.2	PP21 0.1	
58 49	S22 1370	P22 0.2(5)	PP22 0.1	
59 01	S23 31	P23 0.1(5)	PP23 0.1	
59 15	S24 7.3	P24 0.3	PP24 0.1	
11 08 14				T7.5 0.1(5)
09 22				T5.0 0.1
10 34				T2.5 0.1
- - -	S25 0.9	P25 0.7	PP25 0.8	
13 30 36	S26 1.8	P26 0.4(5)	PP26 1.7	
45	S27 5.2	P27 0.5	PP27 0.9	
31 00	S28 1.4	P28 0.2(5)	PP28 0.7	
31 15	S29 0.8	P29 -	PP29 0.1	

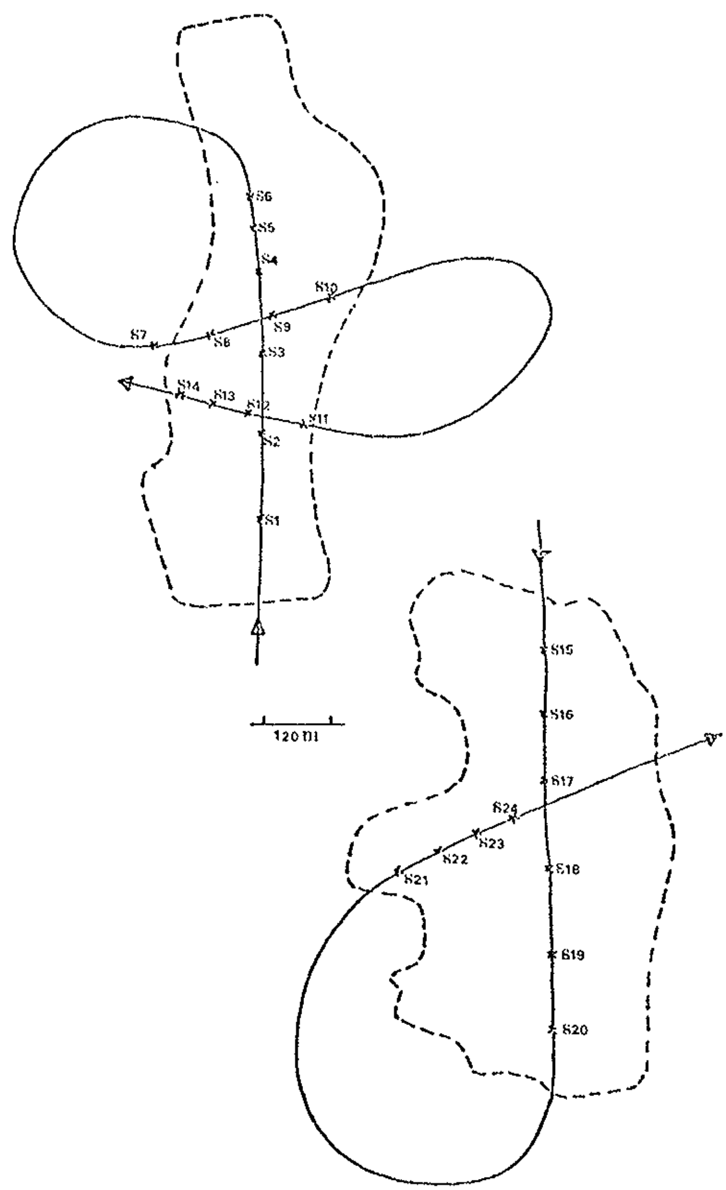
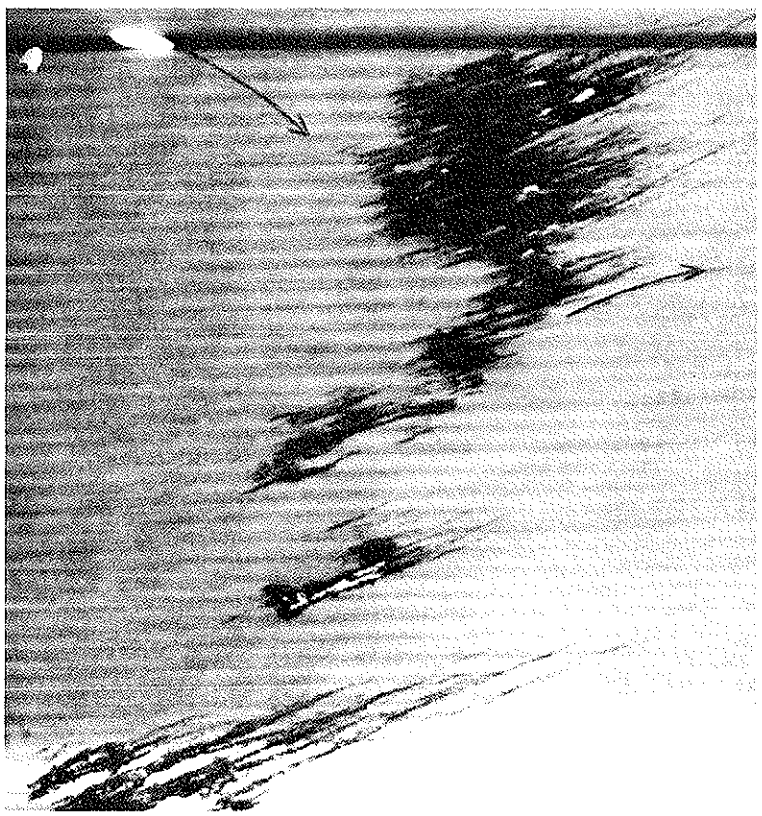


Table 5 Protecmar 2. Sampling of slick 81
(results are given in mg fuel per liter sea water)

(a)

(b)



(c)

FIGURE 12 PROTECMAR 1 - THERMOGRAPH OF SLICK B1
a - at the end of dispersant application
b - sampling 40 minutes after treatment
c - 4 hours after treatment

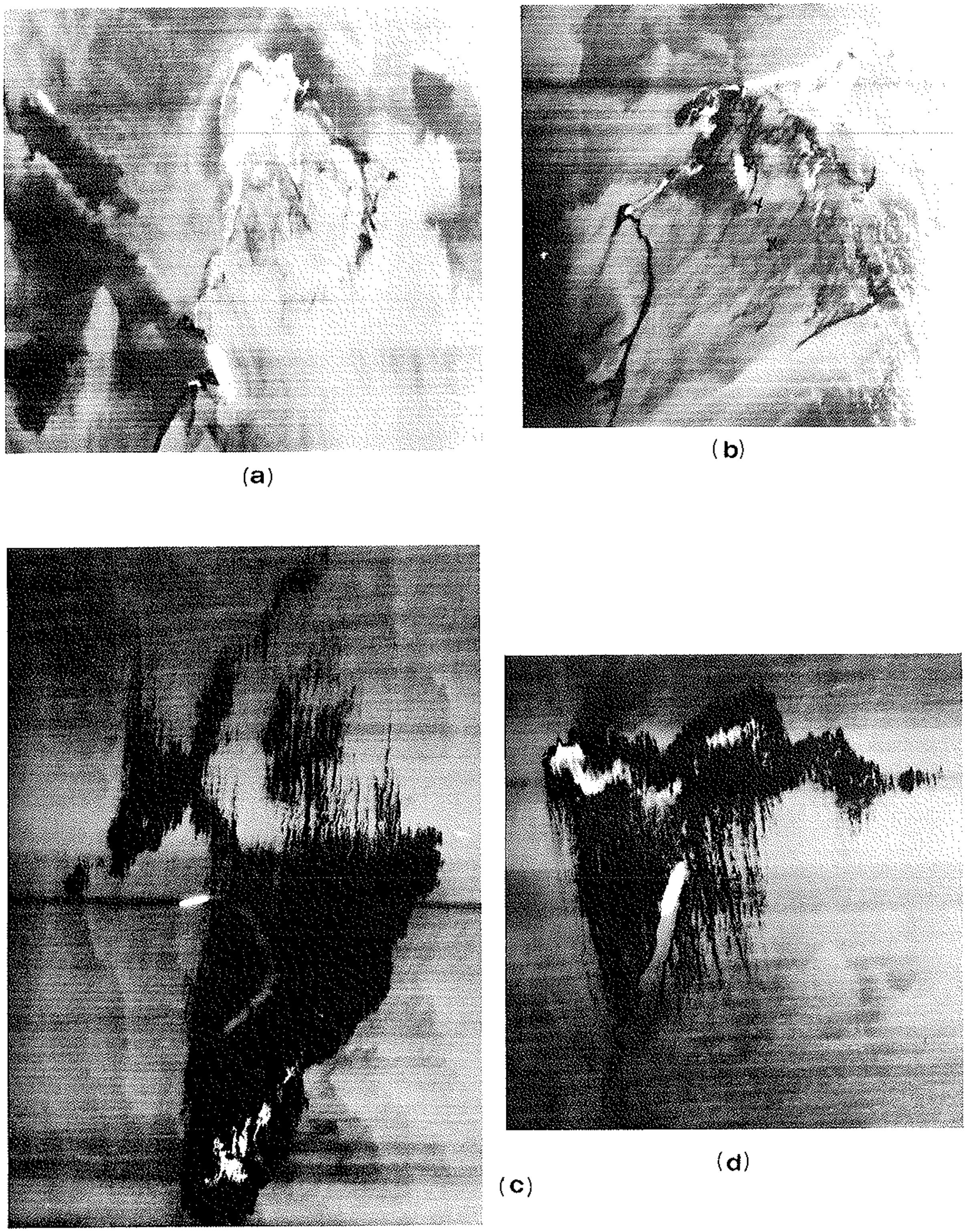
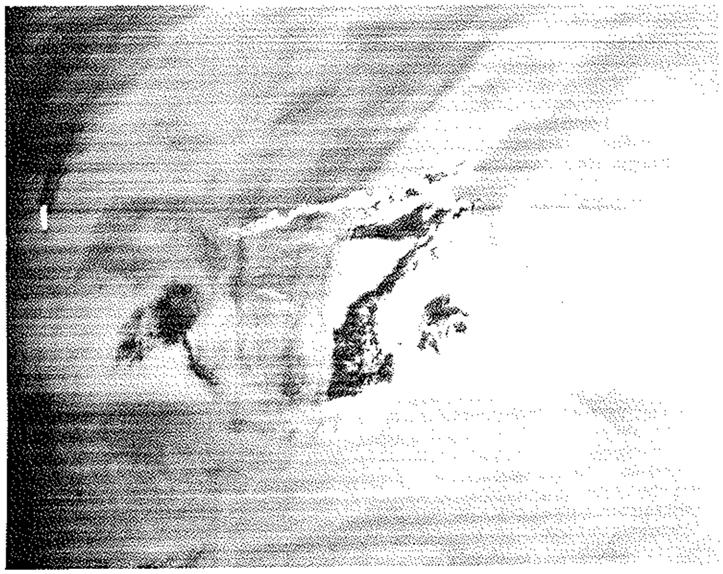
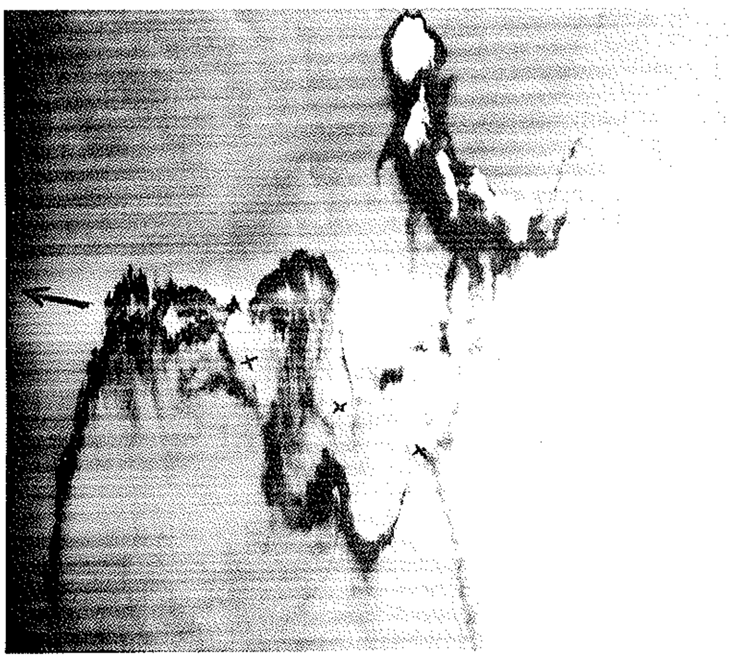


FIGURE 13 PROTECMAR 1 - THERMOGRAPHS OF SLICKS D1 AND D2
a - Slick D2 at the end of dispersant application
b - Slick D2 - sampling 25 minutes after treatment
c - Slick D2 - 5 hours after treatment
d - Slick D1 - 5 hours after treatment



(a)



(b)

FIGURE 14 PROTECMAR 1 - THERMOGRAPHS OF SLICK C1
a - During dispersant application
b - 5 1/2 hours after treatment

FIGURE 15 PROTECMAR 2 - PHOTOGRAPH OF SLICK A1, SAMPLING 15 MINUTES AFTER TREATMENT

(a)

(b)

FIGURE 16 PROTECMAR 2 - SLICK A1 3 1/2 HOURS AFTER DISPERSANT APPLICATION
a - Photograph
b - Thermograph

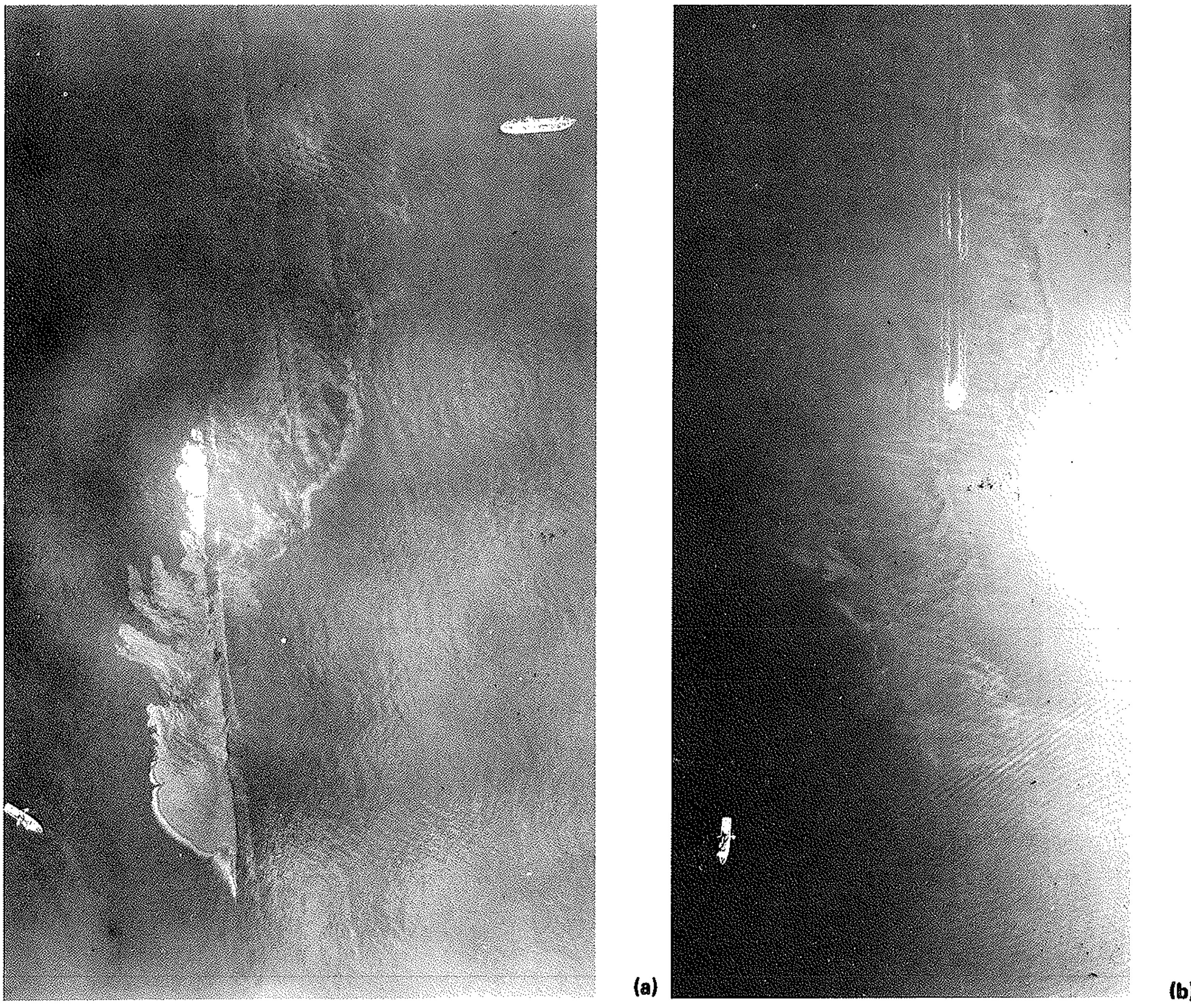
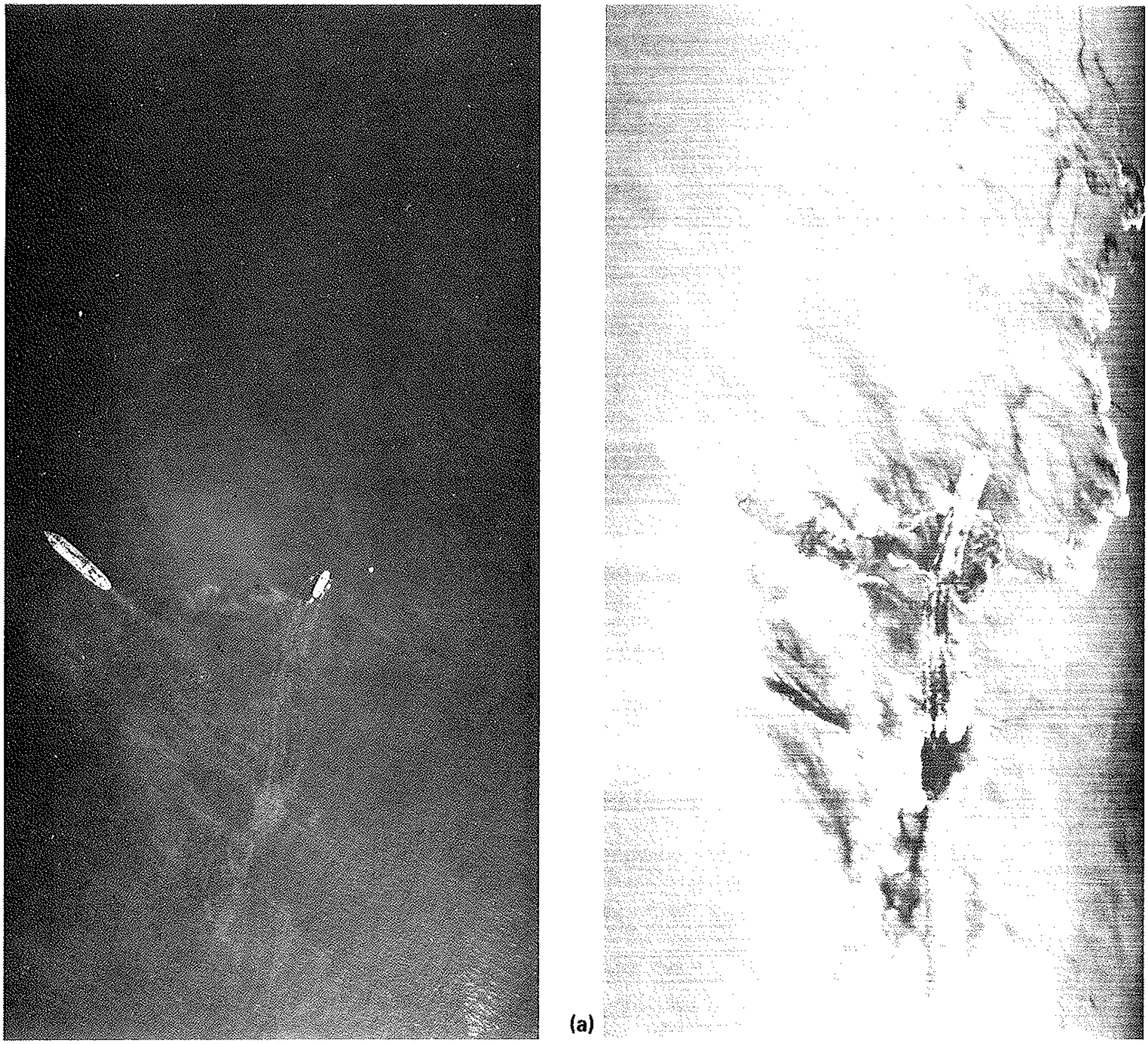


FIGURE 17 PROTECMAR 2 - PHOTOGRAPH OF SLICK B1
a - During dispersant application
b - Sampling 20 minutes after treatment



(a) (b)

FIGURE 18 PROTECMAR 2 - SAMPLING OF SLICK B1 1 HOUR 10 MINUTES AFTER TREATMENT
a - Photograph
b - Thermograph

(a)

(b)

FIGURE 19 PROTECMAR 2 - SAMPLING OF SLICK B1 3 HOURS 50 MINUTES AFTER TREATMENT

a - Photograph

b - Thermograph

TABLE 6 AREAS COVERED BY SLICKS BEFORE AND AFTER TREATMENT (km^2)

	At beginning of treatment	After treatment 25 mn	30 mn	35 mn	40 mn	2 h	4 h	5 h
A 1	1.4				2.9			
A 2	2.5						7.33	
A 3						20.7		
B 1	4.2				13			
B 2	1.15					11.6		
B 3	3.3 (half-treat.)		9.8					
C 1	4.8			5.45				
C 2	2.4		2.75			6.05		
D 1	4.4			7.05				7
D 2	3.75	10.1						12
D 3	2.85				8			
E 2	5					15		

The oil concentrations in Table 7 illustrate the effectiveness of the products, although the differences between the treated slicks and the untreated one (A 1) are not spectacular. Theoretically, if 1 m^3 of oil was spread over 2 hectares (giving a 50 mμ mean thickness approximately corresponding to the Protecmar slicks after treatment) and was then uniformly dispersed into the water column to the 1 m depth, the oil concentration would be 50 ppm and 5 ppm if the uniform dispersion extended to the 10 m depth. In the trials it must be concluded even in the cases of almost complete disappearance of oil from the surface (for example, slick B 1 in Protecmar 2) that most of the dispersed oil was rather close to the surface of the sea : less than the 1 m depth in Protecmar 2. The conclusions of Protecmar 1 cannot be so precise because samples were not taken higher than the 2.5 m depth. In Protecmar 2 trials it is considered that around 10 % of oil was usually dispersed at a depth greater that 1 m.

These results have to be compared with those obtained in USA, off the East Coast in November 1978 (3) by aerially treating crude oil slicks 2 hours after discharge ; these slicks were much more difficult to disperse (mean oil concentration at 1 m : 0.15 ppm) than immediatly treated slicks (mean oil concentration at 1 m : 0.7 ppm and 3 ppm according to the nature of crude oil). However a more effective dispersion was recorded in the Southern California trials in September 1979 (4) in the case of a 2 hours weathered crude oil slick treated by DC-4 aircraft : up to 5 ppm at 1 m, around 1 ppm at 6 m ; the 45 % dispersed oil ratio can therefore be discussed as this ratio takes into account, due to the analytical method, the relative amount of total applied dispersant. The authors explained the difference in efficiency between 1978 and 1979 trials in terms of different dispersant application doses : 360 l of dispersant in 1978 and 480 l in 1979 (calculated in the latter case from slick size and given application rate in liters per hectare) for around

TABLE 7 OIL CONCENTRATIONS IN THE WATER COLUMN AFTER DISPERSANT TREATMENT (ppm)

	1st series of sampling		2nd series of sampling	
	Picket Boat	Landing Vessel	Picket Boat	Landing Vessel
A 1	0.75 (1 h)	0.2 (30 mn)	0.35 (3 h 50)	0.15 (3 h 30)
A 2	0.95 (1 h)	0.65 (30 mn)	0.9 (4 h 40)	0.2 (2 h 20)
A 3	0.4 (1 h)	0.95 (35 mn)	1.1 (2 h 10)	0.35 (3 h 40)
B 1	1.24 (40 mn)	0.75 (20 mn)	0.85 (3 h 10)	0.45 (3 h 50)
B 2	1.05 (35 mn)	0.65 (15 mn)	1.15 (1 h 30)	0.45 (1 h 30)
B 3	2.35* (30 mn)	0.45 (20 mn)	-	-
C 1	0.95 (40 mn)	0.4 (20 mn)	0.65 (5 h 30)	-
C 2	0.75 (30 mn)	0.2 (20 mn)	0.2 (4 h 20)	0.55 (2 h 40)
C 3	2.9 (25 mn)	0.65 (10 mn)	-	-
D 1	0.5 (30 mn)	0.7 (20 mn)	0.55 (3 h 30)	0.95 (5 h)
D 2	2.4* (25 mn)	1.25* (15 mn)	0.85 (4 h 20)	0.45 (2 h 30)
D 3	1.4 (35 mn)	0.8 (25 mn)	-	-
E 1	0.7 (45 mn)	1.4 (30 mn)	0.45 (4 h)	0.75 (3 h)
E 2	0.6 (30 mn)	2.1* (30 mn)	0.7 (2 h 30)	0.35 (2 h 30)

* indicates 1 or 2 values > 3 ppm.

the same initial volume of oil (1,67 m^3 and 1,6 m^3 respectively). That the difference in observed dispersion efficiencies comes only from this fact is not clear.

SUMMARY AND CONCLUSION

Operation Protecmar consisted of two series of oil spill dispersant trials at sea and involved surface and aerial application methods.

No major differences were observed between the measured effectiveness of different spraying techniques with or without the use of surface agitation systems. Among the different implementation techniques that were tested, the Canadair CL215 aircraft appeared particularly attractive from a logistical standpoint.

In relatively calm sea conditions (up to sea-state 3) it is concluded that dispersant application on crude oil slicks affects mainly the sea surface : oil is dispersed very close to the surface and little oil is dispersed deep into the water column. It is possible that in more agitated sea conditions much more oil could be dispersed deeper into the water column and be subjected to vertical mixing-that was not apparently happening in these trials in the Mediterranean sea.

The trial results are considered to be relevant to the case of dispersant application to an oil slick several hours after an accidental spill has occured and even if a chocolate mousse, with a low content of water, has formed.

Further conclusions will be forthcoming when the complete results of Protecmar 2 are available.

ACKNOWLEDGEMENTS

We wish to thank all the people who cooperated in preparing and carrying out the trials. Special thanks must go to Capitaine de Frégate B. Fouchier, Security Officer of the Navy Port of Toulon for his unceasing efforts.

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DEVELOPMENT AND TESTING OF THE AMOP BOOM

Submitted by: K.M. Meikle
Environmental Protection Service
Ottawa, Ontario

INTRODUCTION

The primary purpose of this article is to summarize the results of the testing of the 18/18 Zooom boom at the U.S. Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT), Leonardo, New Jersey, in November 1980. This variant of the Zooom boom was chosen for the tests in preference to the AMOP boom because of its very close similarity and because it was commercially available from the manufacturer, Versatile Environmental Products Ltd. (VEP) of North Vancouver, B.C.

A secondary purpose is to briefly review the AMOP boom project from its origin to completion, indicating the sources of detailed information on the several stages involved.

BACKGROUND

No offshore boom research and development was undertaken during the first year of AMOP. The Arctic boom had been developed by Dome Petroleum specifically for the Beaufort Sea, several offshore booms were commercially available, the development of improved equipment for use in ice-free waters was underway in the United States, Norway and elsewhere, and it had been accepted for the time being that no further effort would be expended on development of Canadian offshore booms.

However, a review of the results of first-year AMOP work (Meikle, 1979) incidated that there was in fact a need to develop a lighter-weight offshore boom specifically designed for use in the Canadian Arctic and in other cold, remote areas off Canada's coast. In this context, an "offshore" boom is one that will function effectively in exposed, essentially ice-free waters beyond the confines of harbours, bays, and similar sheltered areas.

In the first place, impending oil exploration drilling in more northerly waters off the East Coast brought with it the possibility that an offshore boom could be needed on short notice to protect a remote area; too immediate a need for the equipment to be brought in by sea from the closest depot such as St. John's. However, suitable vessels could be available locally to deploy the boom if it could be brought to them in time. A northern transportation systems study (Anon., 1978) had clearly shown that air transportation is commonly the only alternative to marine, and is the only method of moving equipment quickly. Moreover, because airfields capable of handling large transports such as the Hercules are comparatively few and widely dispersed, delivery on board a deployment vessel could only be accomplished by helicopter in many situations.

The existing offshore booms were overly cumbersome for transportation by the smaller aircraft; for example, the Vikoma Seapack used by both the Canadian Coast Guard (CCG) and the petroleum industry's Eastcoast Spill Response Association (ESRA) weighs 4 536 kg (10 000 lbs). That is about 900 kg (2 000 lbs) over the maximum sling-load capability of the Sikorsky S-61, which is normally the largest commercially operated helicopter in the Arctic.

Secondly, the Vikoma Seapack is an imported product and its cost at that time had almost doubled in two years. For that reason the CCG had expressed strong interest in a comparable domestic boom, preferably one not so dependent upon mechanical support systems for effective operation. A possible candidate suggested was the larger version of the 305 mm (12 in) Bennett Zooom boom that had performed so effectively during recent deflection trials in the St. Lawrence River (Vanderkooy, 1979). However, the larger versions were not actually in production, and there were a few aspects of the design that were considered to be in need of improvement. More importantly, while the merits of the self-inflating concept were recognized, there was uncertainty as to the optimum size for an offshore version of that type of boom.

Previous experience had indicated that a 762 mm (30 in) diameter buoyancy chamber was considerably larger than necessary. The manufacturer of the Zooom boom was reasonably confident that a diameter of 457 mm (18 in) would suffice, but thought it possible that a 610 mm (24 in) diameter might be needed.

The utility of the Vikoma boom and trailerablehull container combination was well-known, and a comparable capability would be required for a replacement. In addition, for Arctic applications, the combination should also be helicopter-portable for a reasonable distance (80 km or more).

OBJECTIVES

Accordingly, it was decided to embark upon a phased AMOP project with the following objectives:

a. To determine the optimum size of self-inflating boom for offshore use to effectively contain or deflect oil under Beaufort Sea State 4 conditions.

b. To develop and prove a self-inflating Arctic offshore boom that does not require either a pressurized air supply or an internal spring mechanism for inflation.

c. To develop and prove a compatible multimodal storage and rapid deployment module.

METHOD

The project was divided into four phases as follows, with phases 1 and 2 being done currently:

Phase 1 - The design and manufacture of two 30 m long sections of each of two sizes of boom conforming to a general specification that the Zooom boom could meet, one having a buoyancy chamber diameter of about 460 mm and the other about 610 mm.

Phase 2 - The design, construction and testing of a compatible, multi-modal transportation and deployment container module to hold at least 305 m of boom.

Phase 3 - The comparative testing of the two 60 m lengths of boom at sea and determination of the maximum sea conditions at which each would effectively contain oil and deflect oil (these determinations were to be made using a simulant other than oil).

Phase 4 - The selection of the size considered most appropriate, and the procurement and comparative, qualitative testing of a comparable length of the boom against the Vikoma Seapack under operational conditions.

The work was contracted and, rather than limit the scope of the project to development of the Zooom boom to meet the requirements, it was decided to open the field to other possible contenders, at least for the initial phases.

SUMMARY OF RESULTS - PHASES 1 TO 4

The competition to perform the first three phases was won by McAllister Engineering Ltd., Vancouver, B.C., and the results have been reported elsewhere (McAllister, 1980). Briefly, at an estimated sea state of 4 on the Beaufort scale, the observed performance of the smaller boom was equal to that of the larger. Since oil is effectively dispersed naturally by the wave action at higher sea-states and both cost and weight favoured the smaller size, the 460 mm diameter buoyancy chamber with a 460 mm skirt was chosen for comparison to the Vikoma.

Concurrently, VEP had reworked the 18/18 model of the Bennett Zooom booms to conform to the specification for the offshore self-inflating boom and offered two commercially available alternatives to the boom designed for AMOP by McAllister Engineering. One was the standard version made with Shelterite 8128 vinyl - polyester fabric, and the second was identical except that the fabric was Cooley L-1023 KEP, a urethane- polyester material strongly recommended by VEP for Arctic use because of its superior resistance to abrasion.

To avoid the situation of knowing how the McAllister-designed boom performed in comparison to the Vikoma, and having to make assumptions regarding the commercially available alternatives that were essentially similar but nonetheless significantly different in important structural details affecting durability, it was decided to modify Phase 4. Instead of buying an additional 360 m of the AMOP boom to go with the 60 m used for size-selection to obtain a total length comparable to that of the Vikoma, only 120 m of additional AMOP boom was bought. The rest of the desired length was obtained by buying 180 m of the standard Zooom boom and 60 m of the recommended Arctic variant.

Open-sea trials were performed off St. John's, Newfoundland, in March 1980 and the results have been reported in detail (Purves et al., 1980). These trials, which included leaving the boom moored at sea for four days during which a moderately severe storm passed through the area, demonstrated that the key functional characteristics of all three examples of that type of self-inflating boom were identical and that their durability and handling qualities compared favourably to the Vikoma. However, contrary to expectations based on experience with the smaller Zooom boom in sheltered waters, it did not retain oil effectively even under the comparatively mild conditions prevailing for that test (4-8 cm waves on a gentle swell).

On the other hand, the Vikoma with its three-tube configuration giving it about 36 cm more freeboard but almost 8 cm less draft retained oil effectively under slightly more severe conditions (10-15 cm waves on a 2 m swell).

A further important finding from those trials was that the double-Z connector under consideration by the ASTM as the standard for oil booms was not suitable for offshore use. One connection failed during the trials and it was generally far too difficult to connect at sea even under the best of conditions.

The deployment module's performance during the trials off St. John's was not satisfactory. Although it had performed well in every respect during its acceptance and evaluation trials on the West Coast (McAllister, 1980), it threatened to capsize during the tow to the test area and the boom had to be deployed prematurely. It was subsequently discovered that the hull had accumulated a quantity of freshwater (rain?) within its double-bottom because of a minor construction defect, and the problem was not discovered during the pre-launch examination. On re-stowing the boom it was also found that deformation of the sidewalls hindered closing of the rear door and the internal compartmentization arrangements were awkward. Therefore, despite the previously demonstrated seaworthiness and helicopter portability of the module and its ability to deploy boom without having anyone embarked, the CCG does not consider it to be worth any further development.

OHMSETT TESTS

Precise determinations are very difficult if not impossible under normal offshore test conditions and the reason for the failure of the air-filled round buoyancy chamber and bottom-tensioned skirt to retain oil, was largely a matter of conjecture based on visual observations from above the surface of the water. It was, therefore, decided to investigate the behaviour of such booms in the presence of waves and oil in the controllable environment of the OHMSETT facility.

With the cooperation of the US Coast Guard under the shared funding arrangements in effect for the Baffin Island Oil Spill Project, a 30 m length of the standard 18/18 Zooom boom was removed from the module at St. John's and subjected to a week of intensive testing with oil at OHMSETT (Borst, 1981).

The boom was rigged in the tank in a catenary configuration with a gap opening of 17.6 m between the ends. The testing was comprised of two major segments, the first series was to determine whether shortening the tension member would improve oil retention, and the second segment, which comprised the major part of the work, was to quantify oil loss under various combinations of waves and current.

The Circo X heavy OHMSETT test oil was used for all runs; its viscosity at water temperatures of 6-7°C ranged from 2 600 to 4 200 centistokes and its specific gravity ranged from 0.930 to 0.938.

For the first series, an oil pre-load of 1.89 m^3 was used for each test and all runs were made under calm conditions. The speed at which failure occurred was recorded for the boom:

a. as received (i.e. per manufacturer's specification);
b. with the bottom tension member shortened by 3 links and rejoined with a shackle; and
c. with the same tension member shortened a further 3 links (total of 6 links shorter than "as received").

All runs in the second segment were made with the boom tension member 3-links shorter than specified by the manufacturer, and the nominal oil pre-load for each run was 3.89 m^3. This segment was divided into five groups of tests according to wave condition, and all runs with waves were made heading into the waves. One group of tests (seven runs) was done under calm conditions. The other four groups, with an average of four runs per group, were made with established regular waves in different combinations of two heights and three wave-lengths as follows:

Wave Height (m)	Wave Length (m)
0.41	19.22
0.19	19.22
0.19	8.31
0.19	2.77

Note: The combination of 0.19 m by 2.77 m waves is the induced condition that OHMSETT refers to as "harbour chop", and their previous boom-testing experience has established it as their most severe test of a boom's oil-retention capability.

A system of other booms in combination with six water jets were used to trap lost oil and to gather it for measurement. The amount of oil lost per run was determined by measuring the area and thickness of the contained slick, and the results of some of the tests indicate that errors were made.

It follows that the oil preloads, which were produced by adding oil to replace the measured loss for the previous run, were probably also somewhat in error; however, neither error is considered important as far as the loss-speed determinations are concerned.

However, under the shorter length waves comparable to those at the top of the sea state 1 range, the performance of the boom is reduced appreciably.

Contrary to the observation reported from the trials at sea off St. John's, no splashover occurred during the tank runs. The failure mechanism throughout this test program was almost exclusively shedding, with under-skirt-draining developing at the critical speed and continuing at increasing rate as speed was increased. The critical speed, or speed at which gross loss occurs, is readily apparent to an observer.

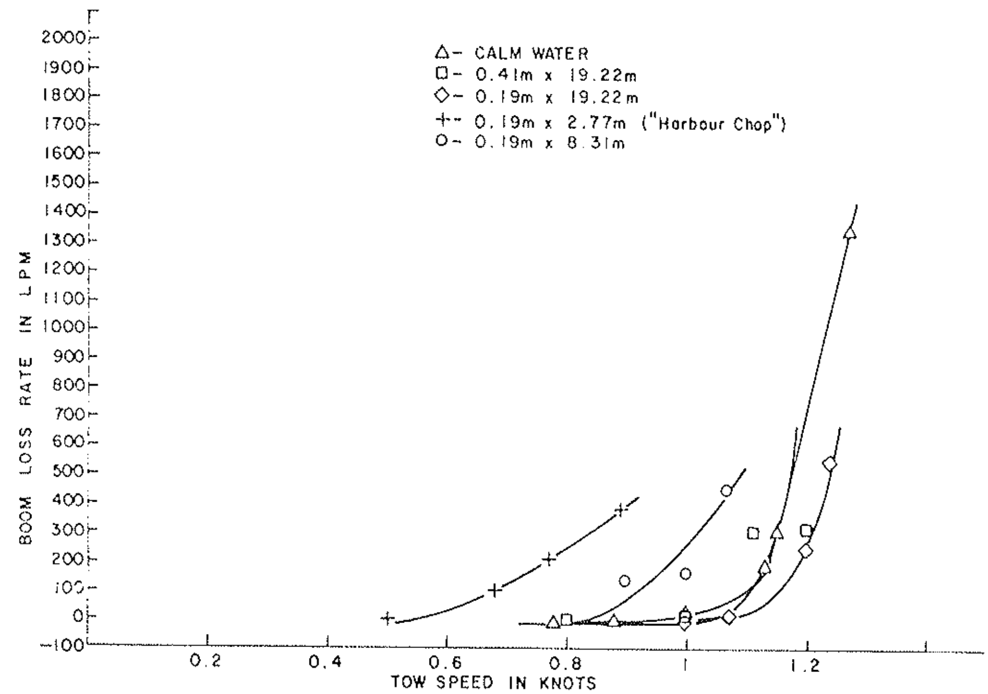

FIGURE 1 ZOOOM BOOM LOSS RATES FOR A CONTAINED SLICK OF 3.89 m^3 IN CALM WATER AND REGULAR WAVES (M. BORSK)

Excellent water clarity during the tests made it possible to photograph the under-side of the contained slick and thereby document the loss of oil. The development of pressure ridges was observed (a phenomenon that may be a determining factor for the maximum no-loss speed), but there was no indication of the downward wave-induced current as reported from the St. John's trials, even under the most severe "harbour chop" condition.

CONCLUSIONS

The self-inflating boom as exemplified by the Zooom boom and the AMOP/McAllister design can effectively contain oil in currents in excess of 0.5 knot (maximum 1.2 knots) under sea state 2 conditions with a properly adjusted tension member.

The booms, except for the choice of connector, are essentially durable, well-planned and constructed oil barriers.

There are some relatively minor faults such as twisted fabric and leaking check valves, but these should easily be remedied in production.

The cause of the rapid oil-loss experienced during the sea trials was not found during the tests under the controlled, simulated conditions at OHMSETT and hence, regardless of its good performance at OHMSETT, some uncertainty remains regarding the performance of the boom under actual offshore conditions, this uncertainty can only be removed by conducting further trials with oil at sea.

FUTURE INTENTIONS

All the boom and the deployment module used during the reported trials have been transferred to the custody of the CCG at St. John's, Newfoundland, and no further testing is currently planned pending a detailed review of the requirement for such a boom under the current circumstances.

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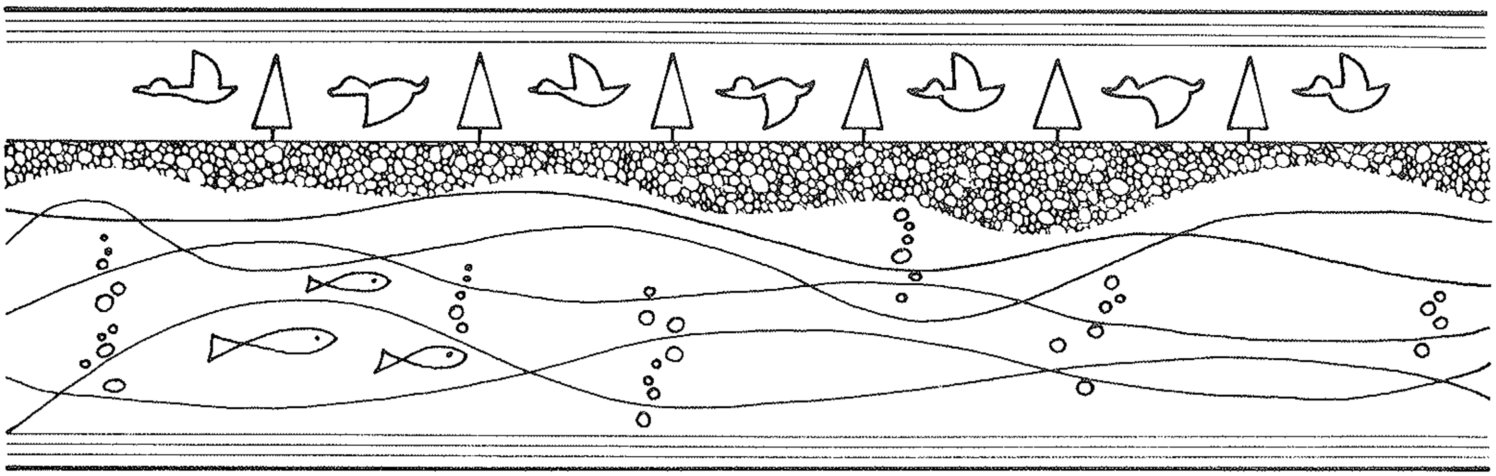

Table of Contents

INTRODUCTION

The first two articles of this issue are by Shawn Gill of the Canadian Coast Guard. The first is on an offloading exercise conducted in St. John's, Newfoundland. The second article describes an aerial application of dispersants conducted at Suffield, Alberta. These tests revealed that with a modified delivery system and with good atmospheric conditions, it is possible to achieve a dosage rate of up to 20 gallons per area, a value several times the rate achieved by earlier systems. The last article of this issue is by Ian Buist of Dome Petroleum and is a description of an experiment conducted in the Beaufort Sea to assess the behaviour of and countermeasures for oil and gas released under first-year ice. The results confirm earlier findings that a large portion of oil released in this type of situation will migrate through the brine channels during the melting period and thus can be burned or recovered manually on the ice surface. These results are interesting in that a large percentage of the oil involved in this experiment was either burned or recovered manually.

REPORTS AND PUBLICATIONS

● The Environmental Emergency Branch has recently released seven contractor's reports, the titles of which appear below. These reports are unedited and have not undergone rigorous technical review but will be distributed on a limited basis to transfer the results to people working in related fields. For copies of these reports contact: Publications Coordinator, Environmental Impact Control Directorate, Environmental Protection Service, Ottawa, Ontario, K1A 1C8.

- "Arctic Field Trials of the DREV/AMOP Incendiary Devices" (EE-17)
- "In Situ Permeability Testing for Petroleum Product Containment Dykes" (EE-18)
- "The Design of an Analytical System for the Detection and Monitoring of a Number of Hazardous Materials" (EE-19)
- "A Survey of Self-Contained Breathing Apparatus and Totally-Encapsulated Chemical Protection Suits" (EE-20)
- "A Bibliography on Freshwater Oil Spills" (EE-21)
- "A Bibliography on Oil Spills; 1974-1980" (EE-22)
- "Quantified Performance Testing of the Zooom Boom" (EE-23)

● The following reports are available from the U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia, 22161, Telephone (703) 487-4650. Most reports are also available on Microfiche at $3.35 each (U.S.A. Price). Canadian buyers add $2.50 to each paper copy and $1.50 for each microfiche report. Prices are quoted in U.S. dollars.

<u>Oil and Petroleum</u>

"Long Term Effects of the Barge Florida Oil Spill." H.L. Sanders, F.J. Grassle, G.R. Hampson, L.S. Morse and S. Garner Price. Woods Hole Oceanographic Institution, Massachusetts. January, 1981. 225 p. PB81-144792 $17.00

"Summary of U.S. Environmental Protection Agency's OHMSETT Testing, 1974-1979." G.W. Smith and H.W. Lichte. Mason and Hanger-Silas Mason Co., Inc., Leonardo, New Jersey. February, 1981. 365 p. PB81-163743 $26.00

"Cold Climate Oil Spills: A Terrestrial and Freshwater Research Review." J.D. Mckendrick, J.D. Laperrier and T.E. Loynachan. Alaska University, Palmer. February, 1981. 93 p. PB81-159121 $9.50

"The Fate and Effects of Crude Oil Spilled on Subarctic Permafrost Terrain in Interior Alaska." L.A. Johnson, C.M. Collins, E.B. Sparrow, T.F. Jenkins and C.V. Davenport. Cold Regions Research and Engineering Lab, Hanover, New Hampshire. December, 1980. 77 p. AD-A095 491/7 $9.50

"Some Effects of Petroleum on Nearshore Alaskan Marine Organisms." D.G. Shaw, L.E. Clement, and D.J. McIntosh. Alaska University, Fairbanks. February, 1981. 93 p. PB81-159147 $9.50

Other Hazardous Materials

"Protocol for Assessment of Human Exposure to Airborne Pesticides. User's Guide." R.G. Lewis, M.D. Jackson and K.E. MacLeod. Health Effects Research Lab., Research Triangle Park, North Carolina. August, 1980. 58 p. PB81-158404 $8.00

"Material Development Study for a Hazardous Chemical Protective Clothing Outfit." J.V. Friel, M.J. McGoff and S.J. Rodgers. MSA Research Corp., Evans City, Pennsylvania. August, 1980. 141 p. AD-A095 993/2 $12.50

BRIEF NOTES

Small businesses and independent inventors who have developed oil spill cleanup equipment will be given the opportunity to demonstrate their designs in the U.S. Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT). The sponsor of the program which is scheduled for October and November 1981, is a committee representing several governmental agencies concerned with oil spill problems and is called the OHMSETT Interagency Technical Committee (OITC).

Candidate devices for 1981 must be ready for testing and a working model must exist as no development funds will be provided. The inventors must be prepared to submit technical specifications, including photographs or drawings, for review by OITC. Independent inventors and small businesses will be given preference over large, established companies. The size of the tank limits devices to maximum dimensions of 40 feet wide, 60 feet long and a maximum saltwater draft of 7 feet. Total weight of the empty device should not exceed 9 tons.

Replies must be received no later than 25 September, 1981. Interested parties should immediately contact: Mr. Michael Borst, U.S. Environmental Protection Agency, OHMSETT Facility, P.O. Box 117, Leonardo, New Jersey, 07737, Telephone (201) 291-0680.

A CANADIAN COAST GUARD EMERGENCY TANKER OFFLOADING EXERCISE

Submitted by: S.D. Gill
Canadian Coast Guard
Ottawa, Ontario

In a paper entitled "A Perspective of Practical Difficulties Encountered in Oil Spills", delivered at the June 1980 AMOP Seminar in Edmonton, mention was made of the development of an emergency tanker offloading capability for Canadian navigable waters. Such a capability represents a contingency against tanker groundings where lightening is required, or in cases where a total power failure precludes cargo stabilization. Such emergencies are represented by the METULA, URQUIOLA, and CRISTOS BITAS incidents.

Where maritime traffic supports a healthy salvage industry, this capability can readily be found within the private sector, e.g., Smit International. In Canada, however, Coast Guard must assume this responsibility where traffic does not support a viable salvage industry.

The initial step was to develop a set of operating standards and procedures for the safe placement of pumping equipment, personnel, and ancillary hardware aboard the casualty, using a heavy lift helicopter. These standards were drawn up by RMEO (Regional Marine Emergency Officer) Newfoundland, Bill Ryan, with a view to minimizing the risk of explosion in a high volatile environment.

Having developed a set of rudimentary guidelines for the safe conduct of such an operation, the St. John's Marine Emergency Team set about assembling the required equipment in modules that could be put aboard a vessel by a Voyageur Helicopter from the 103 Search and Rescue Squadron based in Gander, Newfoundland. Although the FRAMO offloading system formed the basis of the pumping system, the focal point of the hardware package was the tanker boarding package. This unit contained the four-man life rafts, survival suits, breathing apparatus, oxygen and vapor testers, generator, VHF communications pack, mobile telephone, and appropriate gaskets, hose adaptors and tools.

Working in cooperation with the 103 Squadron and Golden Eagle, Ryan scheduled an exercise aboard the tanker GOLDEN FALCON moored semi-permanently at the Holyrood refinery terminal where it provides an extended berthing face for larger vessels. For exercise purposes, only water would be pumped from the cargo tanks with simulated inerting, assuming the availability of compressed nitrogen.

On April 7, 1981, representatives from the petroleum industry, USCG, and Federal Government, witnessed the prototype exercise staged from an area adjacent to the refinery. A Command Centre was established in a mobile trailer ashore where all communications and flight times were recorded. Despite a clear sky, winds were gusting up to 35 knots by the time the first flight took off from a nearby staging area on the refinery property.

As the first flight approached the GOLDEN FALCON, a static line was lowered to the water's surface to neutralize any electrical potential difference that existed between the ship and the aircraft. When the first man was aboard, his immediate task was to survey the area with a vapor analyser to determine whether the operation should continue. Wearing flight helmets with an 81A Communications link to the helicopter and Command Post located ashore, the helicopter could be recalled should conditions aboard the vessel warrant. As a general rule, a wind speed of 3 knots over the deck was a prerequisite for safe operations.

The second flight was devoted to placement of the 1500 pound tanker boarding package in a safe position aboard the ship - well removed from the working area - possibly aft of the bridge. Each load of equipment was fitted with a 60 foot grounding chain (complete with weak link) that was lowered into the water as the cargo was being put aboard the ship.

Flights 3 and 4 consisted of 1300 pound cargo nets, containing the pumps and shear legs, while the 5th flight placed the discharge hoses and nitrogen inerting manifold aboard the casualty. Then, two flights were required to position the 2 FRAMO powerpacks, each weighing 4,000 pounds on the leeward side of the vessel. Subsequent flights would be required 45 gallon drums outfitted to serve as fuel tanks for the powerpacks, and appropriate lengths of floating discharge hose.

> (The 4000 lb. powerpacks represented the maximum payload for the Voyageur, and this weight severely limits the range and operating flexibility of the aircraft. While these components would likely be placed aboard the casualty from a nearby tender, it would be highly desirable to further reduce the weight of the powerpacks).

Having received all the equipment aboard, and securely fastened all the grounding clamps, an ullage plate was removed and fitted with a special flange, through which the extension hose of an oxygen analyser was passed. This cap was also fitted with a port that would receive nitrogen from the inerting manifold. When it was ascertained that the oxygen was well below the 8% maximum, a tank top and butterworth plate was removed and shrouded with a custom fitted cover lined with flame arresting screen. Pumps were then lowered into the tanks using the shear legs that supported the power recovery blocks. The blocks were operated hydraulically from an attachment fitted to the FRAMO powerpack and the use of these devices afforded the added advantage of preventing the discharge hose from crimping as it passed over the combing of the tank top. With the pumps in place, the draw-strings and zippers on the covers were closed tightly around the discharge hoses in an attempt to maintain a slight positive pressure on the tank, thereby discouraging the ingress of oxygen.

The exercise employed a TK-6 pump (tank top opening), and a TK5 (passed through a butterworth opening), which represented a discharge rate of some 6-700 tons per hour. Realistically, however, the discharge rate would be governed more by the ability to inert the tank than by the pump discharge rate. This exercise assumed the availability of two 40,000 cubic foot nitrogen gas tankers available from Canadian Liquid Air in St. John's. It would have been necessary to transport these trailers alongside the casualty aboard an OSV with N_2 being fed to the casualty via flexible hose. Assuming that 40 cubic feet of

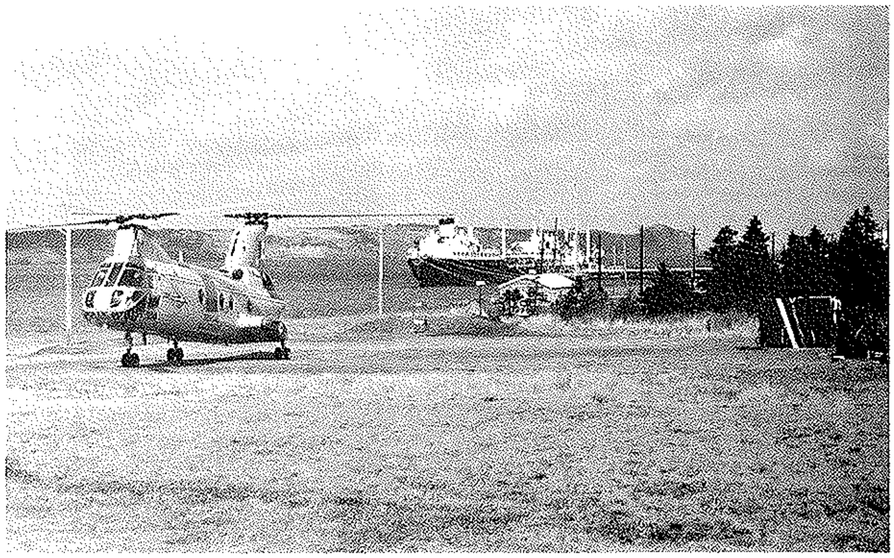

FIGURE 1 VOYAGEUR SAR HELICOPTER AT STAGING SITE ON REFINERY PROPERTY, THE **GOLDEN FALCON** IS IN THE BACKGROUND

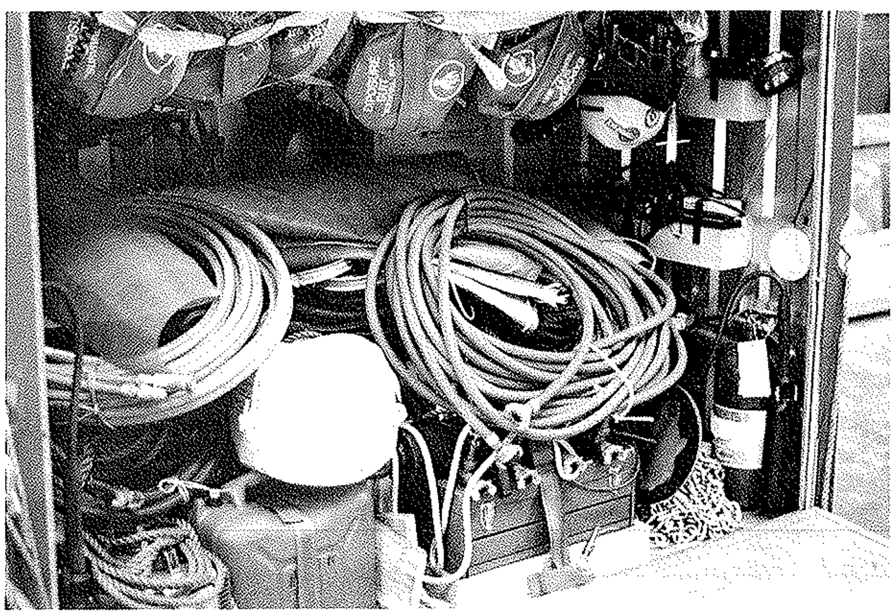

FIGURE 2 TANKER BOARDING PACKAGE CONTAINING EXPOSURE SUITS, INERT GAS MANIFOLD, FLAME ARRESTING SCREEN, OXYGEN AND VAPOUR TESTERS AND ASSORTED GEAR

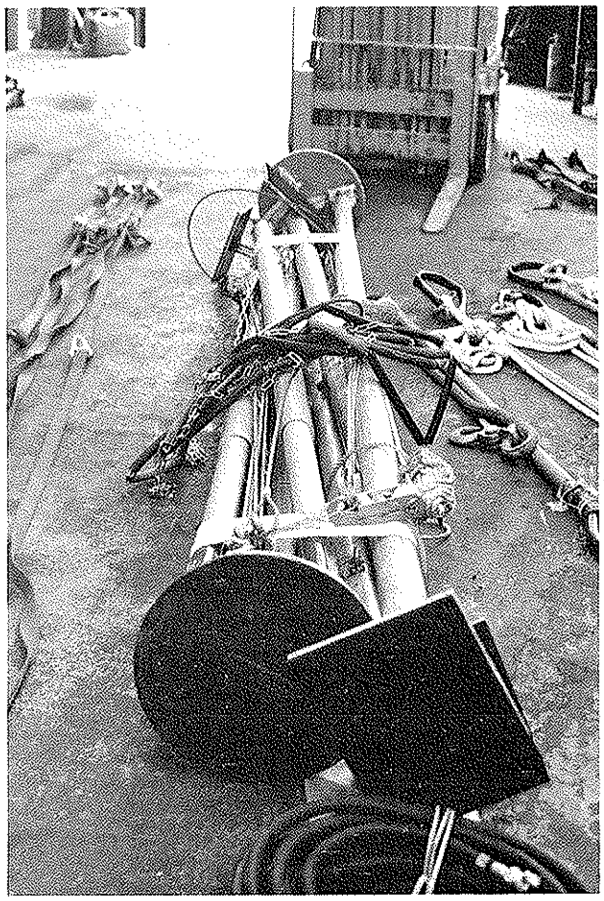

FIGURE 3 ADJUSTABLE HEAVY DUTY SHEAR LEGS FABRICATED TO SUPPORT THE OFFLOADING PUMPS

nitrogen represents the displacement of one ton of oil, the nitrogen available could only sustain a 2,000 ton discharge - less if the cargo was cooling. However, this may be a conservative estimate, in view of the volatile nature of crude oil, that would tend to maintain a positive pressure in the tank, minimizing the requirement for nitrogen to prevent the entry of oxygen. Of course, it is possible that the inert gas generator aboard the casualty may be available to the offloading team.

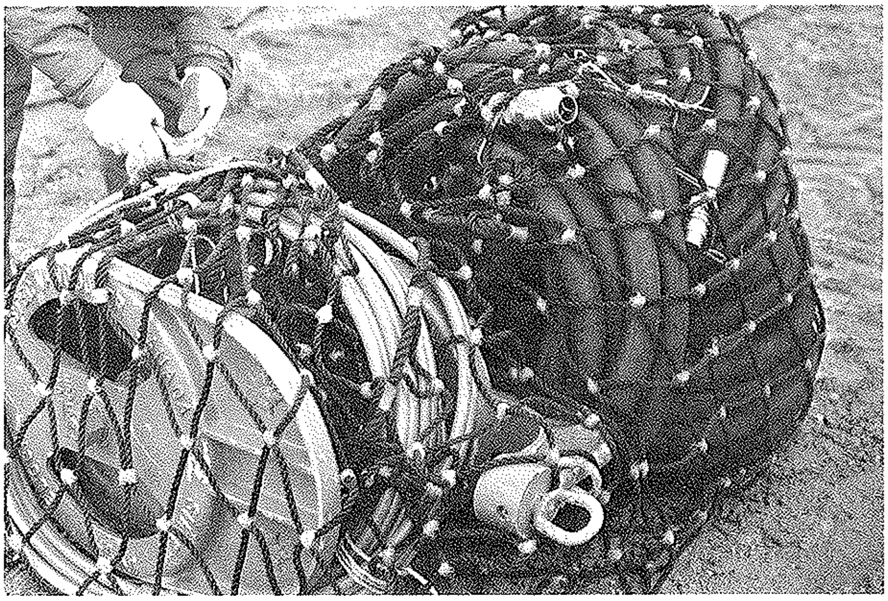

FIGURE 4 CARGO NET CONTAINING POWER RECOVERY BLOCK AND TK6 HYDRAULIC LINES

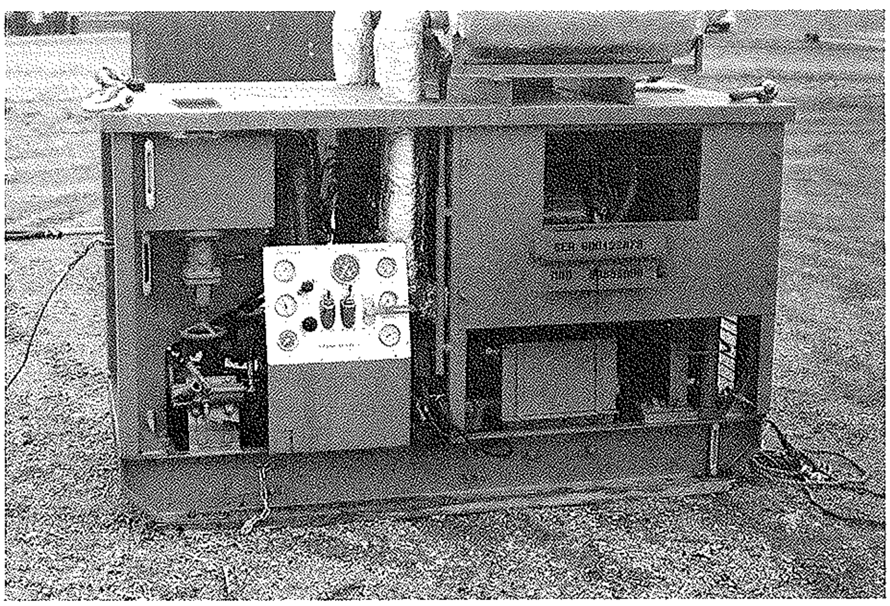

FIGURE 5 FRAMO OFFLOADING POWER PAC FITTED WITH WOODEN SKIDS AND GROUNDING CHAIN

At the debriefing session held the following day, a number of equipment and procedural recommendations were made. For example, it was suggested that the nitrogen fittings on the Butterworth/Ullage caps be fitted with valves and pressure gauges so as to facilitate hose changes, and, if possible, monitor tank pressure. (Indeed Frank Mohn A/S has recently developed a gas sluice that bolts to a Butterworth opening. A TK6 pump can pass through the chamber enclosed by a removable packing box fitted with pressure gauges and a sluice valve, completely sealing off the tank from the outside environment). In addition, a tank scope would be a valuable asset for remotely monitoring conditions inside the cargo tanks.

An offloading capability may be required to stabilize a disabled vessel or remove some or all of the cargo of a grounded ship. In the case of the URQUIOLA, it was an after-the-fact requirement to remove residual cargo from the broken and burnt out VLCC. In the case of the METULA, it consisted of a lightening operation to facilitate ship salvage.

Within the range of these possibilities, the April 7th exercise was realistically staged, with the exception that volatile gases were not present. Improvements to the procedure are being pursued along with adaptations to the pumping system, primarily to decrease its weight and render it safer to operate in an explosive environment. In addition, a training manual is being prepared in order to formalize the step-by-step procedures necessary for the safety of personnel.

The comments and input from the readership would be welcomed. Dr. S.D. Gill, Science Officer, Canadian Coast Guard Emergencies, Tower A-12, Place de Ville, Ottawa, K1A 0N7, Canada.

A REVIEW OF THE SUFFIELD AERIAL DISPERSANT APPLICATION TRIALS

Submitted by: S.D. Gill
Canadian Coast Guard
Ottawa, Ontario

AUTHOR'S NOTE

Work sponsored by the Canadian Offshore Dispersant Aerial Applications Task Force (CODAAT) with representation of E. Birchard, R. Goodman and D. Cameron, IOL, A. Cormack, BP, C. Ross, Mobil, J. Swiss, EPS and S. Gill, CCG.

The following account is a summary of the results from the September 1980 Suffield dispersant application trials, of which a more comprehensive version will be published by PACE (Petroleum Association for the Conservation of the Canadian Environment).

INTRODUCTION

The use of large aircraft for the application of oil spill dispersant concentrates with obvious logistical advantages over vessels of opportunity[1], is particularly appealing to the Canadian environment where countermeasure operations must be extended over a coastline of some 140,000 (often remote) miles. The possible offshore development of the Hibernia field, and eventual year-round navigation in the northwest passage, suggests that this technique may be the most cost effective approach to oil spill control, short of the do-nothing option.

Initial work carried out by Lindblom and Barker[2], with a DC-4 aircraft suggested that the technique was indeed feasible, the spray pattern being very much a function of the operating parameters. Subsequent work carried out in Abbotsford in March of '79,[3], concentrated on dispersant effectiveness using sea water test tanks placed under the flight path of a DC-6B, owned by Conair.

This study again demonstrated the variability of dispersant coverage depending upon atmospheric conditions, and shear forces created by the delivery system, that in turn, appear to govern the droplet size distribution.

Laboratory studies[4], had indicated that the concentrated dispersants themselves were worthy of further investigation because of their ability to disperse some fresh crude oils with a minimum of mixing energy. However, the final verdict remained to be drawn from sea trials where the effect of sea state conditions and aircraft dispersant delivery could be created. As work in the UK[5] and USA[6] has demonstrated, effectiveness becomes a function of dispersant coverage, sea state, oil type and condition, and experimental design.

A review of this data indicated the necessity of obtaining a better understanding of the mechanics of dispersant distribution as a contingency against using this countermeasure operationally or in a sea trial designed to assess the value of the technique.

It was felt that it would be impossible to assess the effectiveness of a particular dispersant under a given set of circumstances (or at least relate the test to laboratory results), without reliable dosage information. Furthermore, it was deemed advisable to be able to achieve a dosage rate in excess of 5-6 US gallons/acres, primarily used in the Abbotsford work[3]. It was, therefore, decided to stage an overland trial with a view to achieving the following objectives.

1. To achieve a more uniform distribution of dispersant by:

   (i) Orienting the aircraft into the wind instead of having to align it with a runway (as in the Abbotsford trials of '79), thereby reducing lateral dispersant drift;

   (ii) Generating larger mean droplet sizes via the use of the 3 pipe system recommended in the Abbotsford report and the use of Delevan raindrop nozzles.

2. To correlate lateral drift with droplet size distribution and crosswind data.

3. To compare two dispersant ground sampling methods.

4. To determine the effect of different dispersant viscosities on mean droplet size and coverage.

MATERIALS AND METHODS

It was decided to use Conair's DC-6B system, (the firm being Canada's largest aerial spraying operator), thus providing a commonality with previous work. The delivery system consisted of 7 550 U.S. gallon internal tanks and hydraulically operated pumps fitted with three dispersant discharge openings (2 in. in diam), two on the outboard ends of over-the-wing airfoil booms, and the third directly aft of the vertical stabilizer. Conair found it necessary to install an additional pump to service this third outlet. The over-the-wing booms extended 10.6 feet either side of the fuselage, and could be fitted with 35 Delevan "raindrop" nozzles (each side) as an alternative to the three 2" open pipe configuration. In the latter case, the distance between the two outboard open pipes, allowing for the width of the fuselage, was 32 feet.

The Defense Research Establishment at Suffield, Alberta was chosen as a test site, since it permitted low level flying on almost any heading. A 300 foot tower was equipped with instrumentation, courtesy of Esso Resources, enabling the Task Force to monitor wind speed, direction, turbulence and temperature.

The dispersants used in this study represented a 10 fold range in viscosity.

Product	Temperature	Viscosity (in Centistokes)
Corexit 9527	32°F	196
	70°F	57
BP1100WD	32°F	47
	70°F	19
BP Experimental	32°F	14
	70°F	7

In preparation for this trial, the flight line was marked off with survey stakes according to the best-guess estimate of the wind vector over the test site. Since a 20 minute interval was required to distribute sampling devices along a 1000 foot transect at right angles to the flight path, (Figure 1), an alteration in the wind direction usually meant that the aircraft was not flying directly into the wind by the time preparations had been completed. The lie of the test site was determined from the aircraft heading as indicated by magnetic compass and the Omega navigation system and compared to wind direction readings provided by the meteorological tower about a mile away.

Dispersant application rates at ground level were measured by the shallow pan method[3] (SP), and by a similar technique involving circular filter papers (CF) (19.155 sq. in.), affixed to squares of plywood. These papers were then immersed directly into 50 ml. of methylene chloride to elute the Oil Red B liquid dye that was added to the dispersant prior to loading the aircraft. The % transmittance on this 50 ml. aliquot (or appropriate dilutions thereof) was determined, and through comparison to standard curves prepared from dilutions of the original dyed dispersant, a dosage rate expressed in US gallons per acre was obtained.

Droplet size distribution measurements employing Kromecoat cards (K) suffers from the disadvantage that the outline of discrete droplets is obscured where overlapping droplets occur at heavy application sites. In an attempt to overcome this problem, three rotating droplet collectors (RDC) were developed, one positioned on the flight path and 50 feet either side of the centre line. These instruments consisted of a record turntable fitted with a Kromecoat disc. The unit was covered by a plexiglass lid with a pie-shaped opening adjustable to 10°, 20°, and 30° openings. In this manner, droplets entering the narrow opening were spread out over the entire disc.

Although the exercise was primarily intended to characterize spray pattern, an opportunity existed to conduct several effectiveness tests using the U. of Toronto portable (5.8 US gallon) "oscillating hoop" tank. A known quantity of Alberta crude oil was applied to simulated sea water which was subsequently sampled at 15 and 30 min. intervals. Oil-in-water dispersion was determined by IR spectrophotometry. Results are summarized in Table 2.

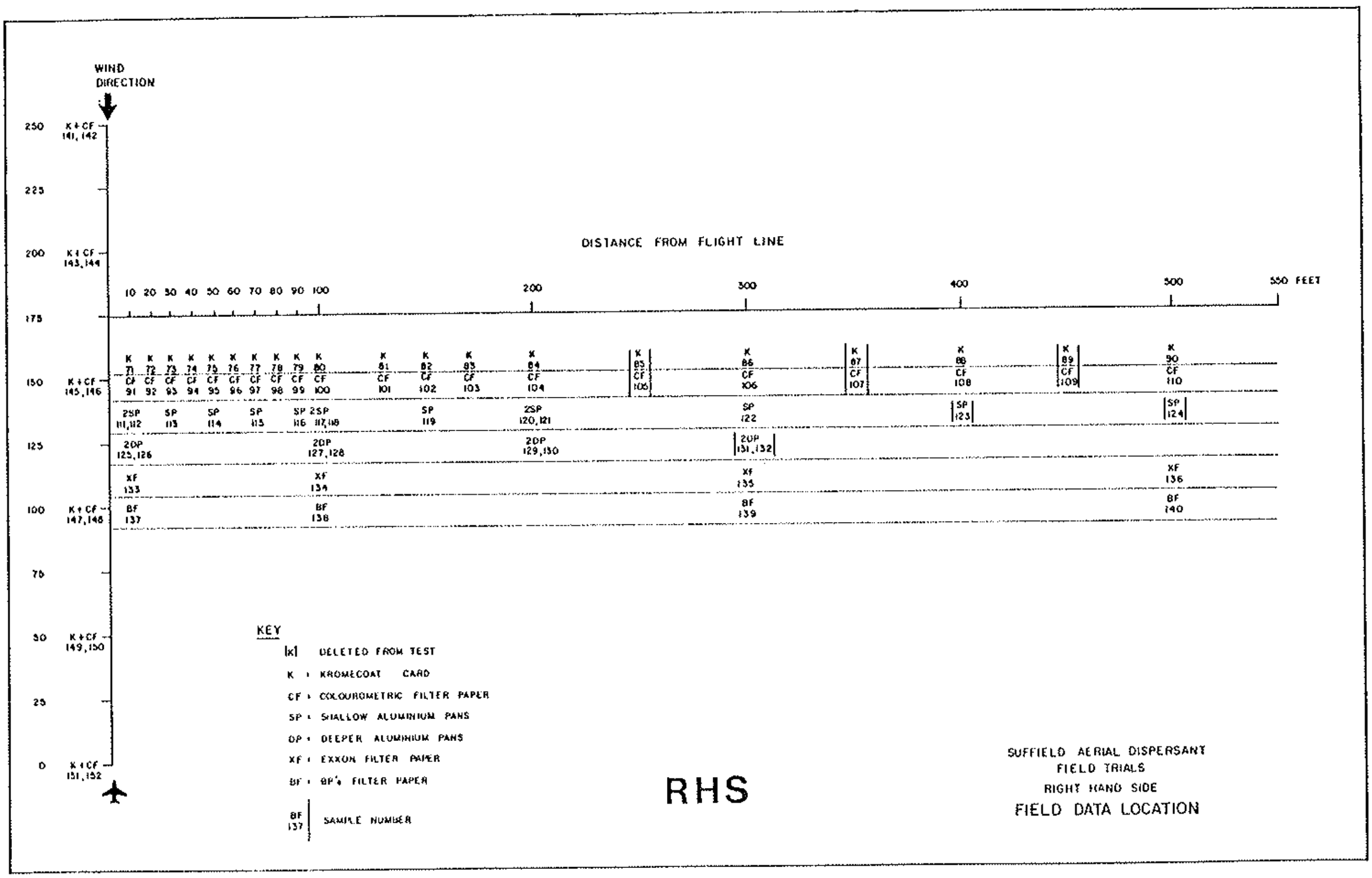

FIGURE 1 FIELD DATA LOCATION - RIGHT HAND SIDE OF APPLICATION PATH

Dispersants were applied at two rates (10 and 22 US Gal/Acre), using both pipe and nozzle spraying configurations. Conair computed flow rate calculations based on a swath width of 100 feet. All flights were flown at 110-130 knots, at an altitude of 50 feet with a 20° flap setting.

RESULTS

A summary of the experimental protocol is presented in Table I, while Figures 2-7 illustrate the dispersant application profiles from left (LHS) to right (RHS), along the transect, 200 feet either side of the centre line. The designation of LHS and RHS are made as the pilot would see the test site as he aligned his aircraft.

TABLE 1 TEST NUMBER AND PARAMETERS EMPLOYED

TEST	EQUIPMENT	NOMINAL DOSAGE	PRODUCT	R value Percentage	VMD in microns K CARDS	RDC's
16-1	3 pipes	10 USGPA	9527	42%	225	385
16-2	3 pipes	10 USGPA	9527	54	275	417
16-3	3 pipes	10 USGPA	9527	68	252	305
16-4	3 pipes	22 USGPA	9527	80	235	287
16-5	3 pipes	22 USGPA	9527	79	327	365
16-6	3 pipes	22 USGPA	9527	52	252	326
16-7	70 nozzles	10 USGPA	9527	94	134	210
16-8	70 nozzles	10 USGPA	9527	73	-	238
16-9	70 nozzles	10 USGPA	9527	81	207	210
17-1	70 nozzles	22 USGPA	9527	92	-	-
17-2	70 nozzles	22 USGPA	9527	93	-	-
18-1	70 nozzles	10 USGPA	BP-WD	99	143	140
18-2	70 nozzles	10 USGPA	BP-WD	112	126	148
18-3	70 nozzles	22 USGPA	BP-WD	111	118	183
18-4	70 nozzles	10 USGPA	BP-EX	67	147	115
18-5	70 nozzles	10 USGPA	BP-EX	52	112	149
18-6	2 pipes	10 USGPA	BP-EX	60	178	194
18-7	3 pipes	10 USGPA	BP-WD	101	158	166
18-8	3 pipes	10 USGPA	BP-WD	117	170	228
18-9	3 pipes	10 USGPA	BP-WD	83	186	253

TABLE 2 DISPERSANT EFFECTIVENESS TEST*

FLIGHT	RATIO OF OIL TO DISPERSANT	% OIL DISPERSION AT 15 MIN	30 MIN
16-2	58	26	32
16-3	29	19	26
16-6	29	36	48
16-7	25	26	37
17-1	15	42	57
18-1	37	21	32
18-3	29	37	50
18-7	58	17	28
18-9	37	14	20

* Tank located at centre point of test site. Results are summarized, and appear in more detailed form in the PACE report.

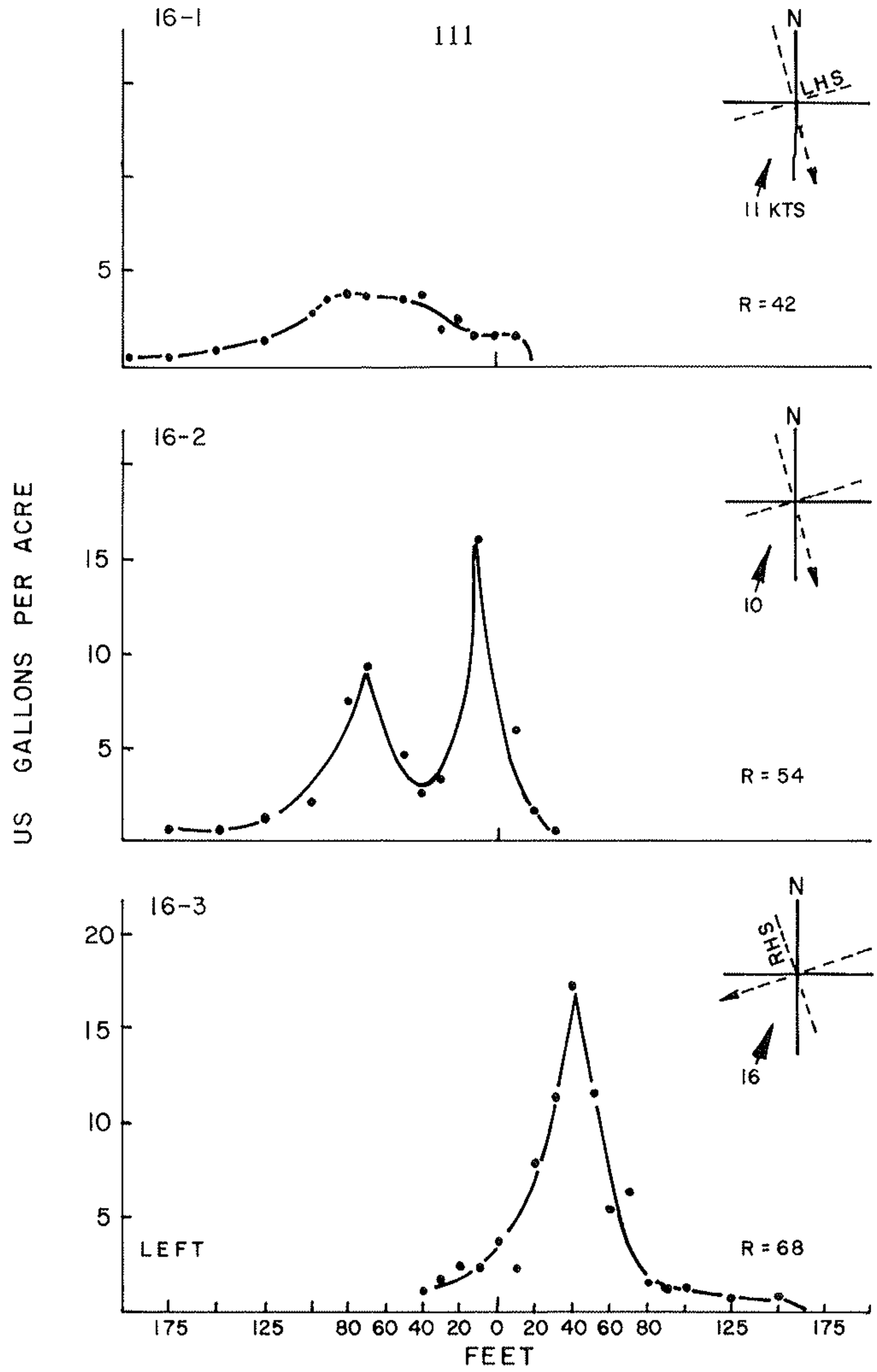

FIGURE 2 DISPERSANT APPLICATION RESULTS, TESTS 16-1, 16-2 AND 16-3

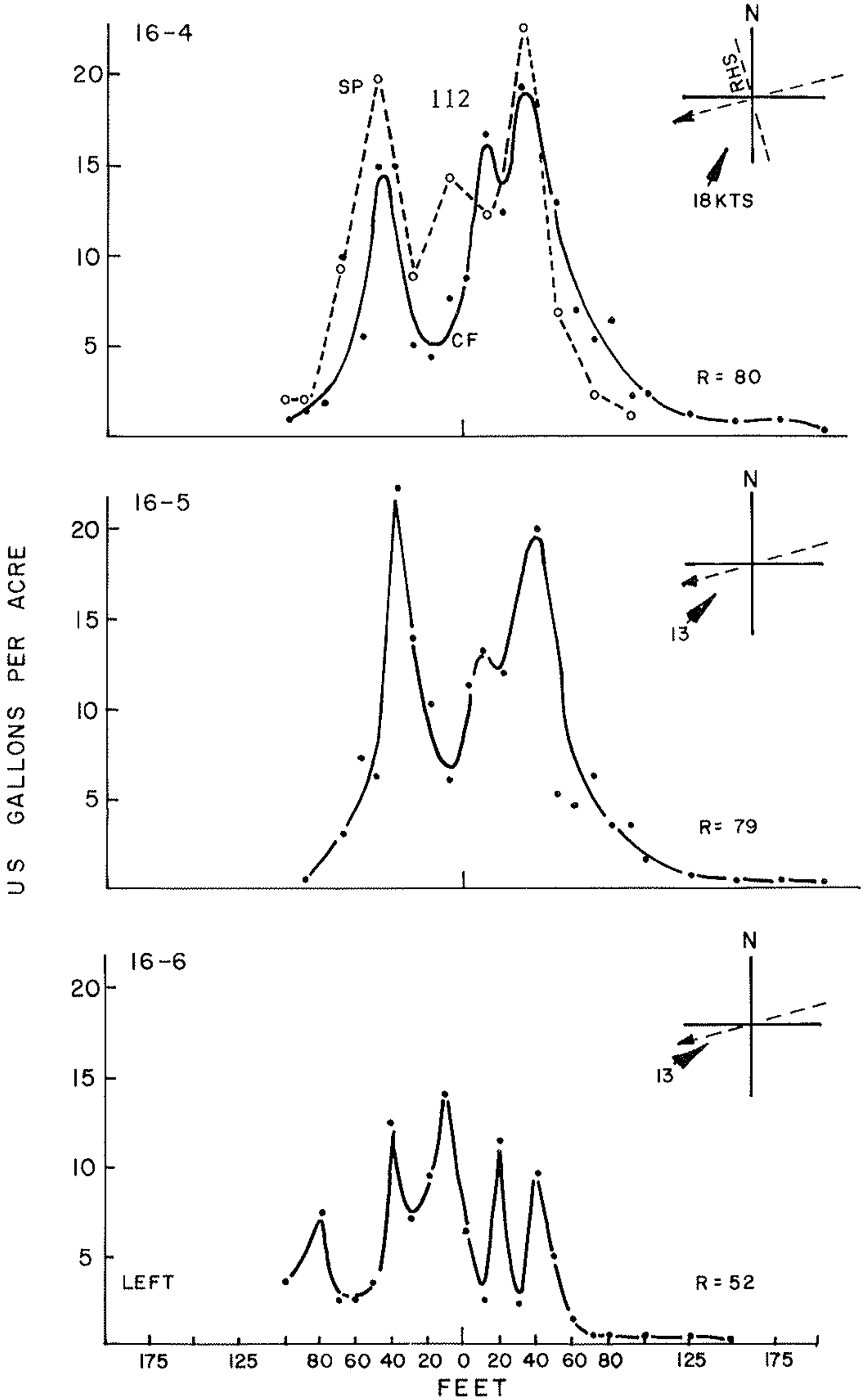

FIGURE 3 DISPERSANT APPLICATION RESULTS, TESTS 16-4, 16-5 AND 16-6

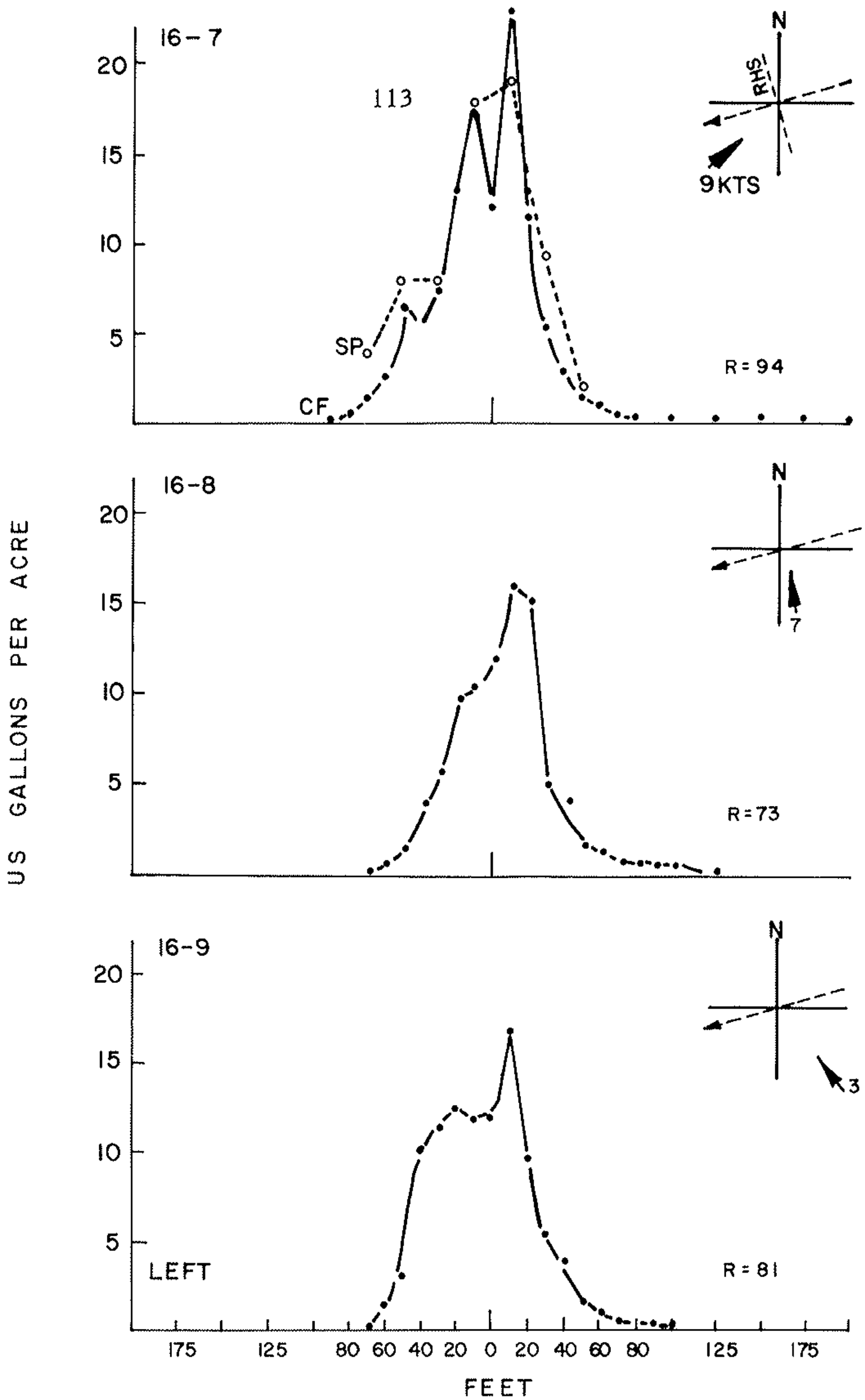

FIGURE 4 DISPERSANT APPLICATION RESULTS, TESTS 16-7, 16-8 AND 16-9

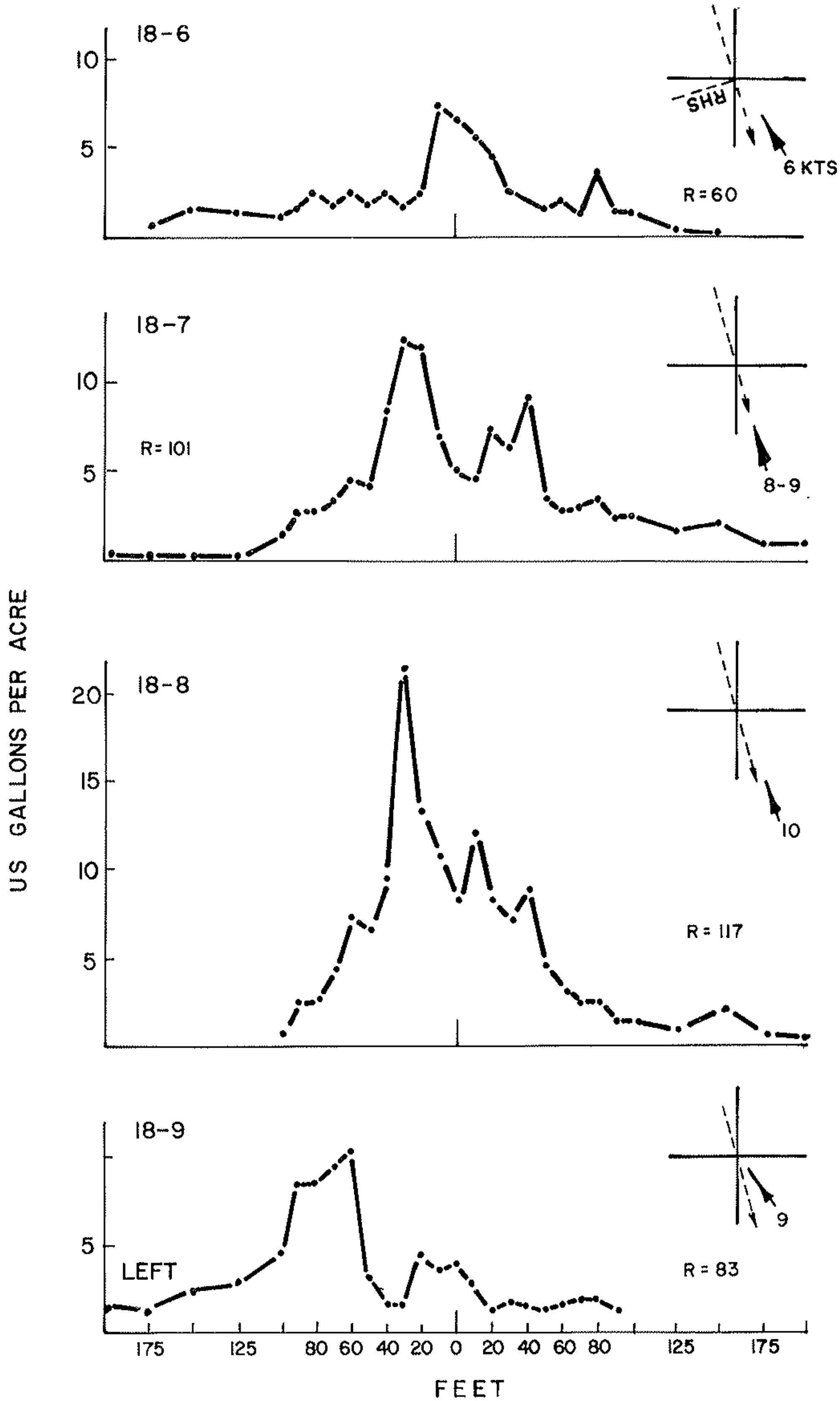

FIGURE 5 DISPERSANT APPLICATION RESULTS, TESTS 17-1, 17-2, 18-1 AND 18-2

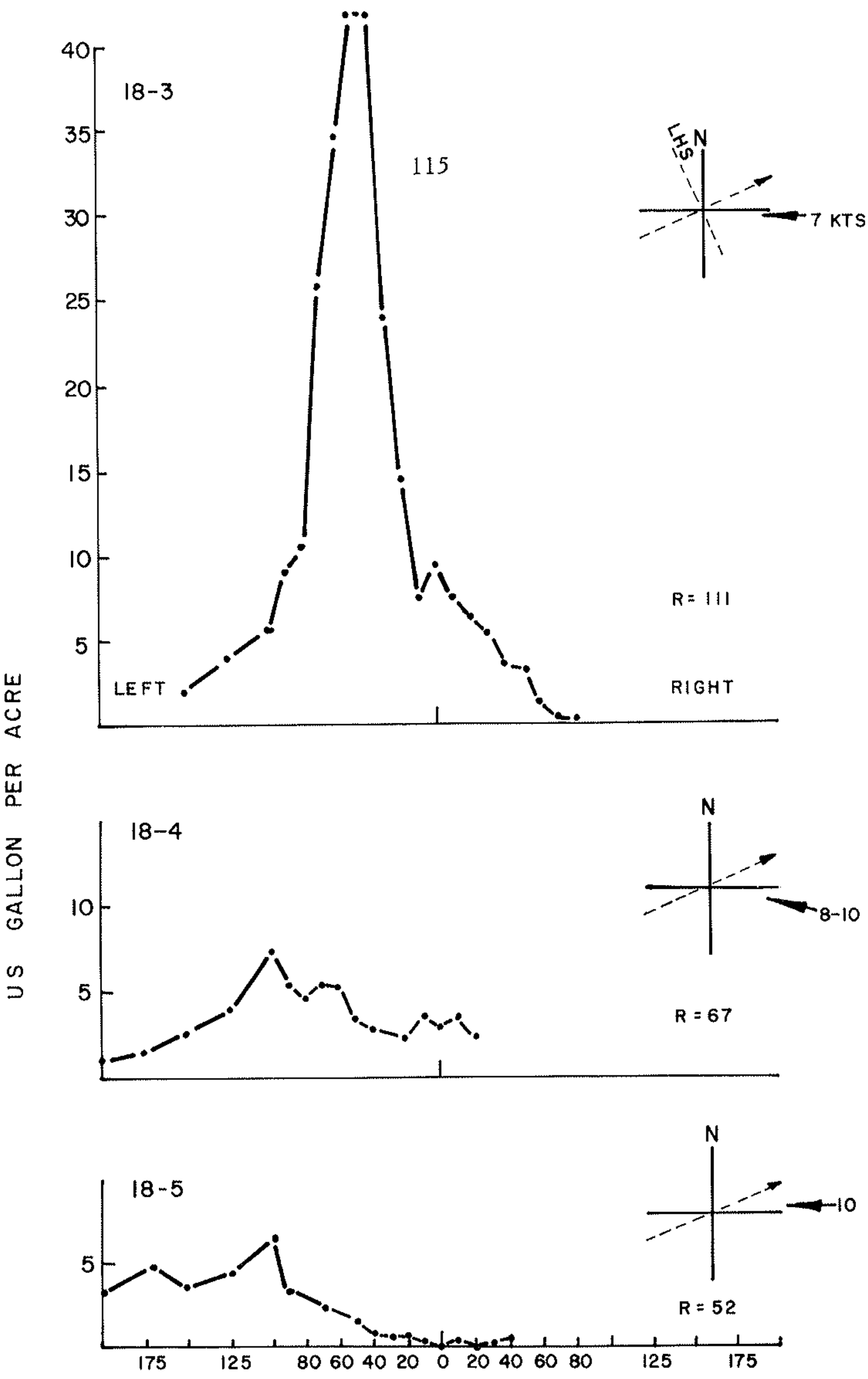

FIGURE 6 DISPERSANT APPLICATION RESULTS, TESTS 18-3, 18-4 AND 18-5

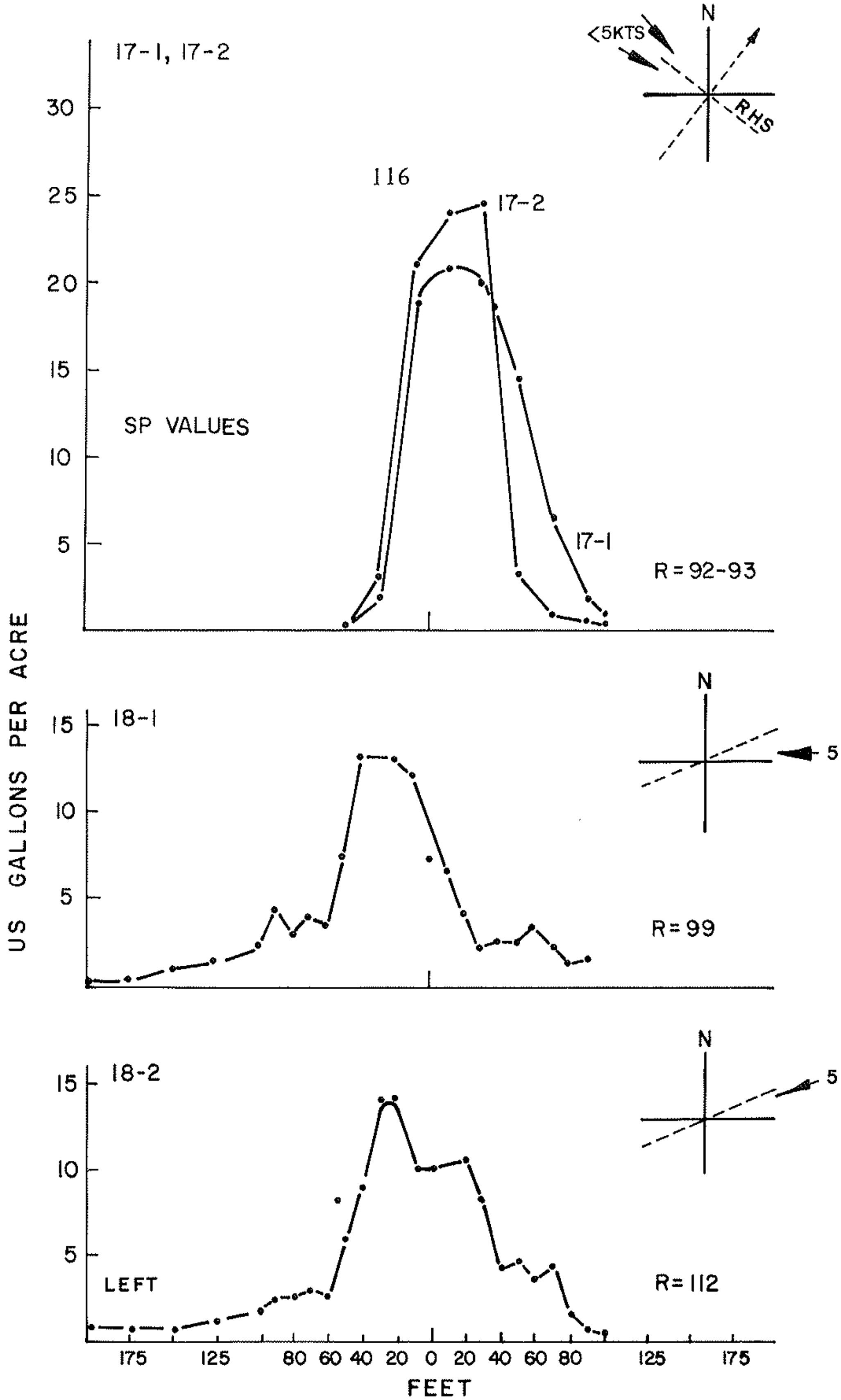

FIGURE 7 DISPERSANT APPLICATION RESULTS, TESTS 18-6, 18-7, 18-8 AND 18-9

By consulting the directional diagram accompanying each profile, it can be seen that dispersant was displaced from the centre line, depending upon the direction and force of the crosswinds. The coverage figures (US gal/acre) are taken from CF values. In general, profiles drawn from SP values corresponded quite well to the CF curves e.g. flights 16-4 and 16-7, but do not provide as comprehensive a picture since fewer shallow pans were distributed for each flight.

Also presented in each profile is an R value which refers to the percentage of dispersant measured at ground level compared to the volume released by the aircraft.

The size distribution of droplets appearing on the Kromecoat cards and the RDC's were subjected to extensive analysis. Unfortunately, Kromecoat cards were only readable at the extremeties of the dispersant swath where dosages are greatly reduced. Because of the susceptibility of smaller droplets to drift, one could expect droplet volume mean diameters (VMD) calculated from laboratory calibration of stain size and spread factor, to be less than VMD values obtained from RDC's located at the centre of the flight path. Droplet volume mean diameters from these two sources are presented in Table 1, the flights being grouped according to the chronology of the field trial.

DISCUSSION

Initial impressions from this work are recorded here, with a more detailed treatment of the results appearing in the PACE Report.

The R value for flight 16-1 is unusually low, suggesting that water remaining in the lines from the previous days preparations reduced the amount of Corexit 9527 when it was first applied.

Although the coverage of dispersant using the 3 pipe system (flights 16-2 and 3) was not as uniform as anticipated, neither did it exhibit marked susceptibility to the 16-18 knot crosswinds experienced in flights 16-3 and 4.

As the aircraft pump rate is doubled using the 3 pipe system, there is a hint of some in-filling, flights 16-4, 5 and 6, not seen in the final run of the Abbotsford trials.

Changing from the 3 pipe system to 70 raindrop nozzles appeared to result in a more uniform distribution of dispersant about the centreline, with a capture rate of 73-94%. However, by this time, (flights 16-7, 8 and 9) winds had decreased to the 3-9 knot range.

The following day, when flights 17-1 and 2 were conducted, winds had dropped to less than 5.0 knots, resulting in a remarkably confined spray pattern that accounted for some 92-93% of the fluid released from the DC-6B. Because there was a slight rain at the time, K cards and RDC's were not deployed across the transect. It is unfortunate that similarly stable conditions did not exist for the earlier 3 pipe flights to allow direct comparison of application profiles.

Nevertheless, relatively light winds persisted on September 18, for the first two flights (18-1 and 2), resulting in only moderate dispersant drift. The immediate impression of the field party was that the use of a lower viscosity product resulted in a finer spray. VMD values from K cards and RDC's substantiated this impression, and likely explains the shoulders found in these profiles. Flight 18-3 was observed to be some 20-50 feet to the left of the centre path, accounting for peak of that profile being dislocated.

As the crosswinds increased to 10 knots from 30° off the flight path (18-4 and 5), the experimental formulae exhibited a tendency to drift, presumably because of a shift towards smaller droplet size distribution. This assumption appears to be borne out by flight 18-9, compared to headwinds parallel to the flight path. Certainly, when conditions are such as to permit flight directly into the wind, a minimum of lateral drift occurs.

A brief inspection of summary data presented in Table I indicates that mean droplet diameters tended to decrease with viscosity. While this has obvious implications for the control of the spray plume during moderate crosswinds, a fine spray appears to have some advantages from an effectiveness point of view[7]. Furthermore, this aspect may be countered by a lower-slower delivery system than the DC-6B employed in this exercise.

CONCLUSIONS

1. In some respects, this work was an extension of the Abbotsford '79 exercise that was primarily designed to assess the effectiveness of 9527 using a series of 40 sea water test tanks located beneath the flight path. Although meteorological conditions were not recorded accurately, the '79 exercise notes indicate relatively calm conditions (winds not exceeding 5 knots). A comparison of the first five spray patterns from the Abbotsford exercise and those in this report substantiates the impression obtained from this work, that stable meteorological conditions are more influential in achieving uniform dispersant coverage than alterations in nozzle design. (Abbotsford work employed 125 1/8" nozzles vs. Suffield's 70 3/4" nozzles).

2. Of an average of 20 flights, ground assays accounted for 80.5% of the dispersant released from the aircraft. This represents an improvement of 24% over the '79 exercise, and can be attributed to a wider sampling transect being used in this study.

3. Depending upon atmospheric conditions, it is possible to achieve a nominal dosage rate of 20 US gallons per acre with either nozzles or pipes, an option that may be useful when dealing with heavy concentrations of oil that have formed windrows.

4. Although variability in meteorological conditions prevents direct comparison of flight results, there is some indication that droplets generated from the 3 pipe system are larger than those created by the Raindrop nozzles.

5. Based on dispersant deposition profiles and droplet size distribution, it is concluded that a decrease in dispersant viscosity can be associated with a reduction in droplet size.

6. The ground sampling technique of using filter papers (CF) that can be inserted into prepared sample vials was deemed preferable to the use of shallow pans (SP), since the latter involved the time consuming process of eluting the contents into the sample vial using an exact aliquot of methylene chloride.

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DOME PETROLEUM'S OIL AND GAS UNDERSEA ICE STUDY

Submitted by: I.A. Buist
W.M. Pistruzak
Dome Petroleum Ltd.
Calgary, Alberta

D.F. Dickins
D.F. Dickins Engineering
Vancouver, British Columbia

Notwithstanding the summer, fall and winter periods of time, the main cleanup of an oil spill originating from a late season oil well blowout, in the Beaufort Sea, would take place in the springtime. It is at this time that the oil, trapped in and under the ice, would surface to accumulate in melt pools on top of the ice.

To tie all the previous work on oil migration and in situ burning together, Dome undertook a major oil spill experiment during the winter of 1979/80 in the Beaufort Sea. Dome's objective in this field experiment was to determine how successful burning would be as a countermeasure and to optimize burning techniques for oil and gas released from a Beaufort Sea blowout under ice. The experiment had the following main goals:

1. To further understand how the oil behaved in the ice, and especially what effect gas had on under-ice spreading and on the rate the oil migrated to the surface in the springtime during the melt period.

2. To elucidate, if possible, the optimum time for burning of oil contained in melt pools so that environmental damage could be minimized.

3. To test under realistic conditions devices which could ignite the oil so that it could be burned in situ.

4. To measure how much oil was burned, how much remained as a residue and to obtain data on the chemical nature of the residue.

5. To provide information on the combustion products associated with the burning of oil contained in the melt pools.

6. To provide some answers with respect to the plume dynamics under the ice.

7. To determine if an emulsion would be formed, and if so, its behaviour.

The experiment took place in three phases, approximately eight kilometres offshore in McKinley Bay in the Beaufort Sea, in first-year sea ice. Approximately 19 m^3 of crude oil were discharged under the ice in conjunction with gas (air). This oil surfaced in the spring in pools thick enough to burn. Some 80% of the oil discharged was removed from the marine environment.

INTRODUCTION

Dome Petroleum Limited (Dome), through its wholly owned subsidiary, Canadian Marine Drilling Limited (Canmar) has been drilling for hydrocarbons in the Canadian Beaufort Sea for the past five summers. Significant potential, estimated by the Geological Survey of Canada at 95 billion barrels of oil and oil equivalent of gas, exists in this area (Gallagher, 1979).

The offshore area where Dome drills with its ships is ice free from late June to late September, when the incoming permanent polar ice pack and plummeting temperatures begin to cover the sea with ice. By mid-November the drillships are safely frozen in their winter anchorage until the next spring's breakout.

Although the probability of a subsea uncontrolled flow of oil is extremely remote, it is finite. Should such an event occur, it is perceived that it could have a major environmental impact on the Beaufort Sea.

As part of the joint industry/government effort to safely produce oil and gas from the Canadian Beaufort Sea, the Arctic Petroleum Operators Association (APOA) and the Canadian Petroleum Association (CPA) sponsor yearly Arctic Environmental Conferences to discuss issues relating to northern development. At the 1978 conference it was recognized that experimental spills were a necessary part of the investigation into the fate, behaviour and effects of oil spilled in an Arctic environment. The Canadian Government's Department of the Environment, through its Arctic Marine Oilspill Programme (AMOP), agreed to identify such experimental spills as were required. One of their suggested spills was a simulated subsea blowout under first-year sea ice (AMOP, 1979).

In mid-1979 it became apparent that the AMOP programme did not have sufficient funds to proceed with this particular spill and Dome Petroleum Limited stepped in to assume the responsibility for carrying out the experiment. Several other member companies of the APOA with interests in the Beaufort Sea, namely Esso Resources Canada, Gulf Canada Resources and Texaco Canada, agreed to participate in the project. As well, the Centre for Cold Ocean Resources Engineering (C-Core) agreed to provide some funding along with technical support.

The project has since been accepted for funding by the Canadian Offshore Oil Spill Research Association (COOSRA), an organization set up in 1980 by oil companies with Canadian offshore interests.

Three subsea discharges of oil and gas were carried out during the winter of 1979/80 in the Beaufort Sea to meet the objectives. The discharges occurred in December 1979 (Phase 1), April 1980 (Phase 2) and May 1980 (Phase 2A) under first-year sea ice. During May, June and July of 1980 (Phase 3) a large field program was mounted to monitor and clean up the oil.

This paper documents the conduct and findings of this experimental oil spill. It covers the objectives, site selection, discharges, methods used to collect data, the results and a discussion thereof and the major conclusions arising from the study.

OBJECTIVES

The experimental discharge of oil and gas under first-year Beaufort Sea ice had the following primary objectives:

1. to further understand how the oil behaved in the ice, and especially what effect gas had on the rate the oil migrated to the surface in the springtime during the melt period;

2. to elucidate, if possible, the optimum time for burning of oil contained in melt pools so that environmental damage could be minimized;

3. to test under realistic conditions devices which could ignite the oil so that it could be burned in situ;

4. to measure how much oil was burned, how much remained as a residue, and to obtain data on the chemical nature of the residue;

5. to provide information on the combustion products associated with the burning of oil contained in the melt pools;

6. to provide some answers with respect to the plume dynamics under the ice; and

7. to determine if an emulsion would be formed, and if so, its behaviour.

EXPERIMENTAL DESIGN

Oil and Gas Flow Rates

Based on geological surveys of the Beaufort Sea a "standard" Beaufort Sea blowout rate of 398 m^3/day (2 500 bbl/day) with a gas to oil ratio (G.O.R.) of approximately 140:1 had been suggested by Logan et al. (1975). This flow rate was chosen as a reasonable compromise for the experimental spill. Three discharges under various ice conditions were undertaken as well as several small control spills of oil alone, and a water-in-oil emulsion. The first discharge was preceded by a "dry-run" discharge of air only to check the system and monitor the effect of the gas pockets on the ice sheet.

Site Location

The major criteria for a site were firstly, that it be in the landfast ice zone; secondly, that the water depth be approximately 20 m; and thirdly, that it be remote from environmentally sensitive areas. After lengthy discussions with the northern people and the various regulatory agencies, a site was chosen 8 km northeast of the winter anchorage in McKinley Bay on the Beaufort Sea, as shown in Figure 1. This location proved ideal as

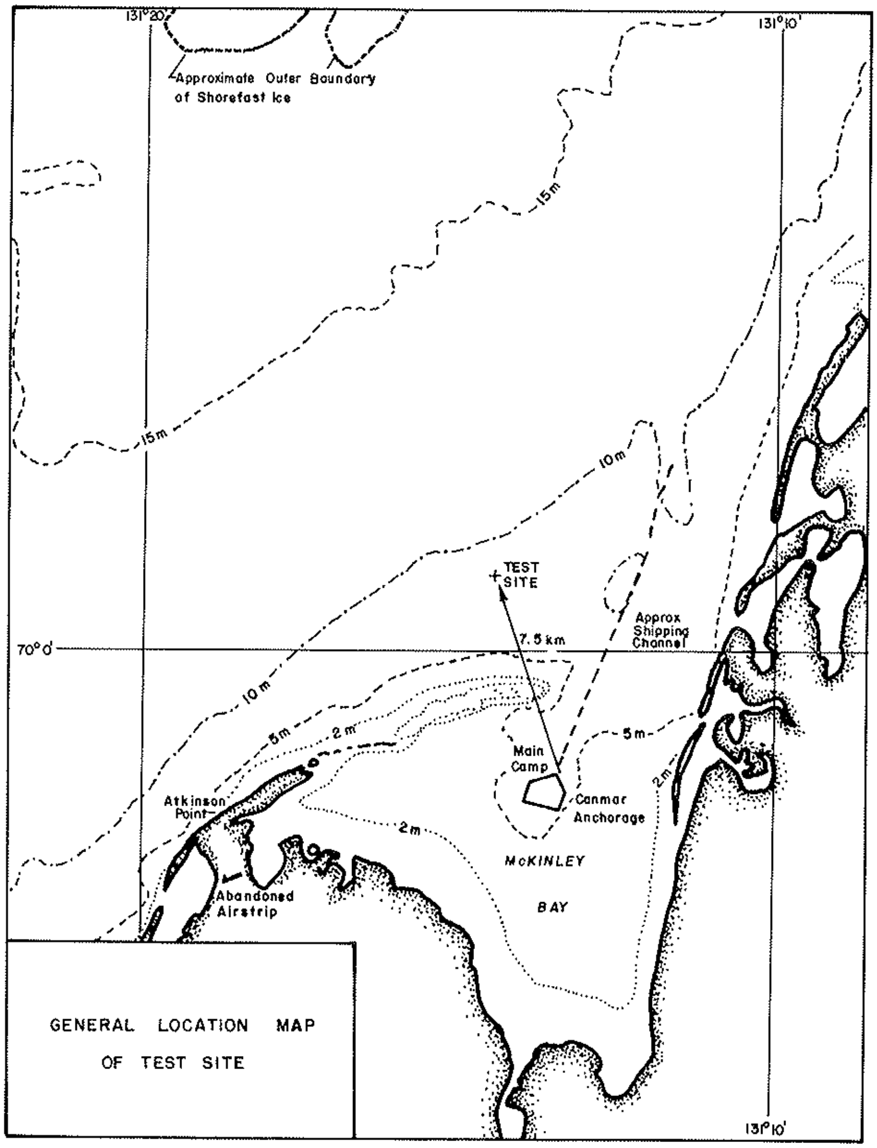

FIGURE 1 TEST SITE

the winter anchorage provided a comfortable base camp with communications facilities and an ice air strip for logistics support.

The spill site was located just southwest of an abandoned Esso artificial island (Kannerk G-42) in the borrow pit used to construct the island. Water depths at the site ranged from 10 m at the pit perimeter to 25 m in the center. The presence of the artificial island caused the ice to pile up into a rubble field on the island providing an anchoring point for the ice sheet, thus extending its life in spring. As well, ice ridges formed around the entire perimeter of the site, providing a convenient natural barrier to the flow of any surface oil.

Discharge Location

To provide a safe working platform, Canmar's Pollution Barge was frozen in over the borrow pit in early December and the three discharge sites were located on the basis of water depth, unbroken ice cover and distance from the barge.

Oil and Gas Utilized

This experiment used Prudhoe Bay crude oil provided by the Atlantic Richfield Company in Alaska. Two discrete batches of Prudhoe Bay crude were used, the first for the Phase 1 and 2 discharges and the second for the Phase 2A discharge. This oil has properties (shown in Tables 1 and 2) quite similar to that of oil found in the Beaufort Sea. For safety and logistics reasons, compressed air was substituted for natural gas as the discharge gas.

Discharge Equipment

The major pieces of equipment used to discharge the oil and gas under the ice, as shown in Figure 2 (Fenco, 1980) were:

1. A 7 600 litre heated oil storage tank in which the oil was stored and heated to improve its flow characteristics and to simulate hot oil from a geological formation.

2. A "Moyno" progressive cavity pump.

3. One 17 m^3/min and one 34 m^3/min rotary screw compressor.

4. One orifice air flow meter and one turbine oil flow meter.

5. 550 m to 7.62 cm reinforced Arctic hose.

6. Various valves and manifolds to provide flow control.

7. Various power generators.

8. A discharge sled designed to support a 12.7 cm diameter discharge pipe (as detailed in Figure 3) and provide sufficient negative buoyance to ensure a stable platform on the sea bottom during the discharge and still be capable of being towed into position on the bottom by means of a cable attached to two "SkiDoo's".

TABLE 1 PRUDHOE BAY CRUDE, PHYSICAL PROPERTIES

Volume % Weathered	Density (g/cm^3 @ 20°C)	Viscosity			Pour Point	IBP (°C)	Flash Point (°C)	Fire Point (°C)
		0°	15°	25°C	(°C)			
0	0.884	50	26	17	-27	67	30	35
10.4	0.902	108	62	37	-16	102	71	86
16.0	0.910	204	105	61	-3	192	84	91

TABLE 2 PHASE 2A PRUDHOE BAY CRUDE

Volume % Weathered	Density (g/cm^3 @ 20°C)	Viscosity		
		0°	15°	25°C
0	0.885	75.5	45.8	29.5

Discharge Monitoring Equipment

Before, during, and after each discharge, environmental conditions (air, ice and water) were monitored using anemometers, current meters, thermistor chains, ice thickness profiles, salinometers, ice cores and fluorometers.

Before and after biological sampling was performed by taking bottom sediment grab samples and epontic (under ice) samples from cores.

During the discharges induced and residual currents were measured with both vane and electromagnetic current meters and echo sounder profiles were made of the discharge plume. As well, a low light TV camera was mounted on or near the discharge sled to record the plume as it exited the discharge pipe.

Under ice surveys, to map the ice and record the oil and gas distribution, were performed by divers with the TV system both before and after each discharge. Cores were also taken to delineate the oil distribution, and polypropylene ropes were hung across the site to record water column distributions of oil. Figure 4 illustrates a typical placement of the monitoring equipment at a discharge site.

Numerous oil samples were collected for extended gas chromatographic analysis.

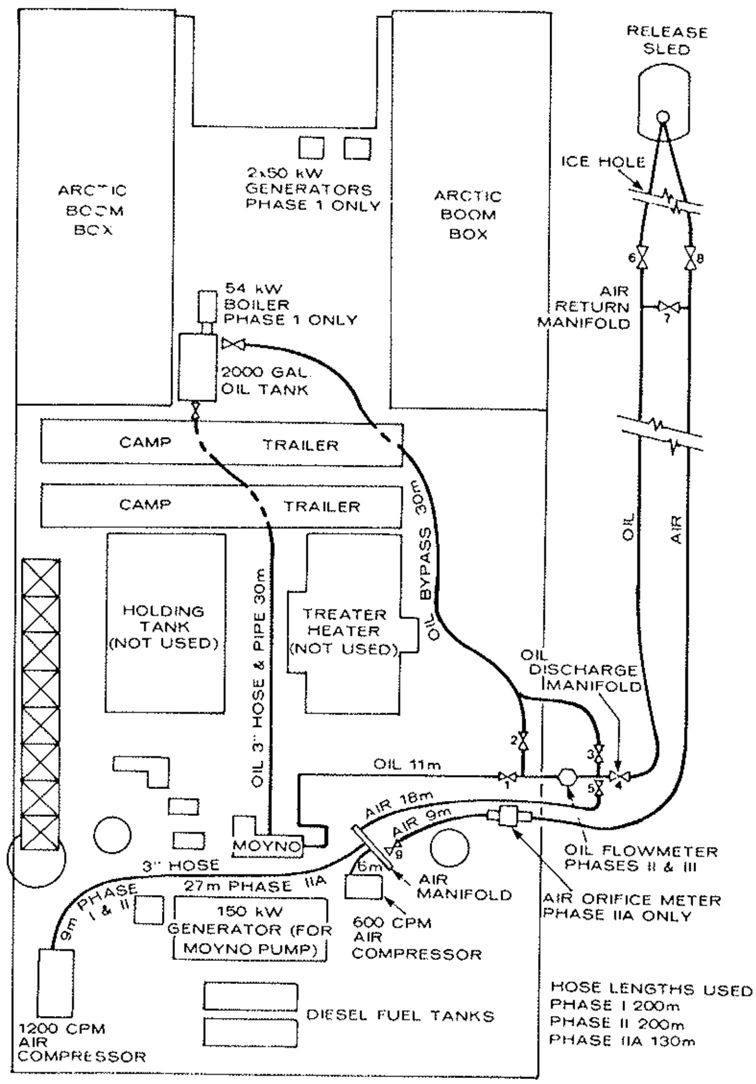

FIGURE 2 OIL AND AIR DISCHARGE SYSTEM PIPING

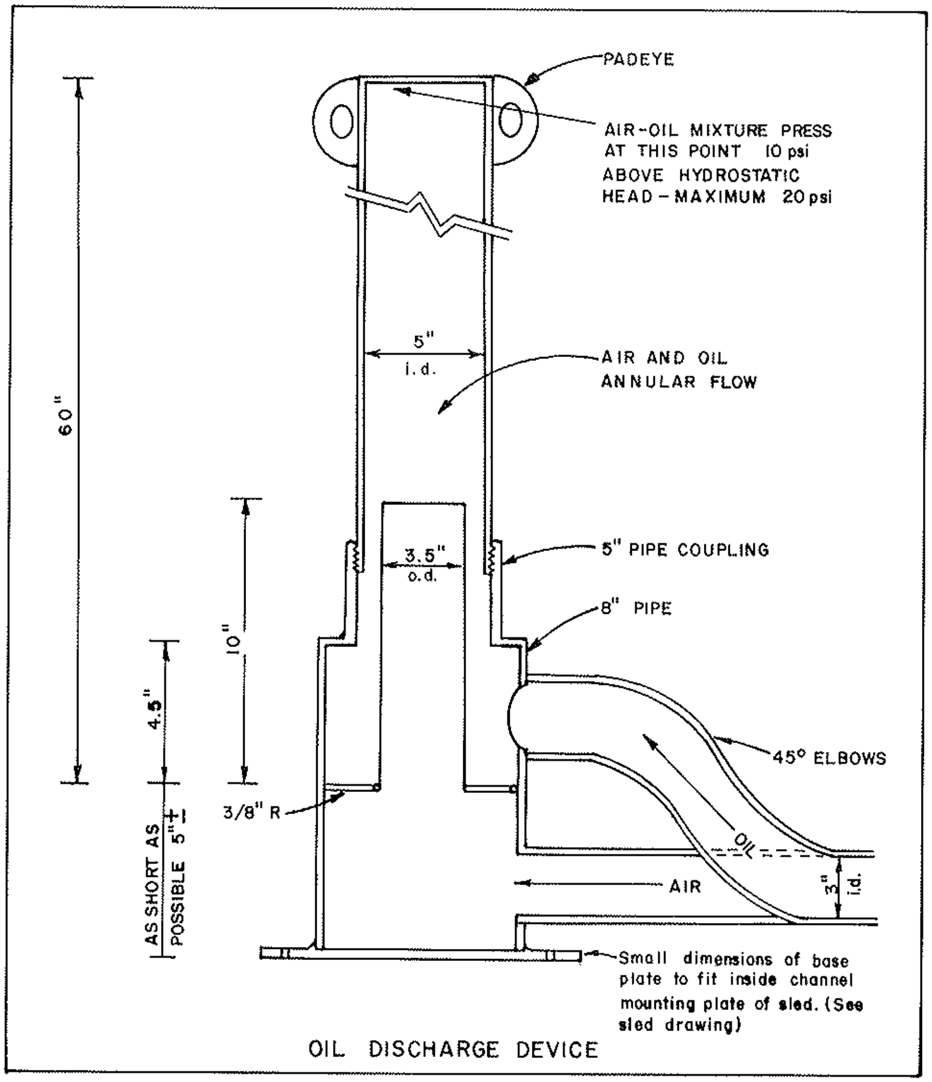

FIGURE 3 OIL DISCHARGE DEVICE

Spring Cleanup Equipment

The major objective of this experiment was to determine the effectiveness of in situ burning of oil on ice as a countermeasures technique. As such, the primary tools for the spring cleanup were three types of air deployable ignitors, one developed by Dome Petroleum and two developed by Canada's Department of National Defence (DND) for AMOP.

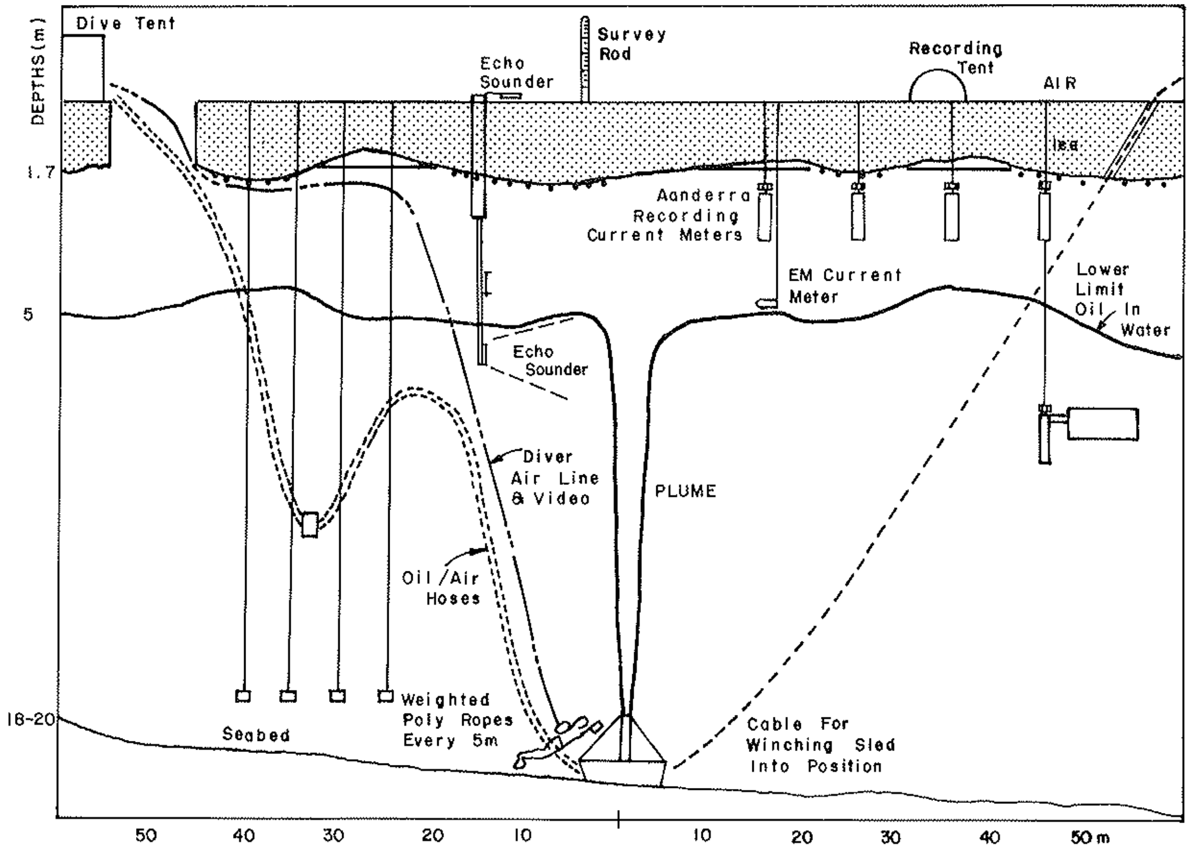

FIGURE 4 SCHEMATIC CROSS-SECTION THROUGH TYPICAL TEST AREA (not to scale)

Other equipment used in the cleanup included pumps, a hand skimmer (weir type) and various sorbent materials.

Extensive measurements were taken of the extent of oil contamination by aerial photography, slick thickness devices and innumerable still and time-lapse photographs. Hundreds of oil, ice and snow samples were taken for chemical analyses to determine oil weathering, soot fallout, polyaromatic hydrocarbon content, oil fractionation in ice and burning efficiencies. Sixteen millimetre movies and still photographs were taken of the smoke plumes to document atmospheric dispersion.

RESULTS AND DISCUSSION

Discharges

Table 3 gives the time, location, amounts and flow rates of the three discharges completed at the site as well as the dry run and the control spills. It should be noted that prior to the Phase I oil and gas discharge, the ice above the discharge sled was augered and trenched, simulating an icebreaker track, to investigate the effect of venting the gas on the subsequent distribution of the oil.

As can be seen from Table 1 the Phase II discharge was performed at a reduced air flow rate. This fact was not discovered until after the discharge was completed. The cause of the reduced airflow was concluded to be an ice blockage in the air line where the hose entered the water. As a result of this, the discharge was repeated as Phase II-A in a different area of the test site.

Plume Dynamics

Figure 5 (Arctic Labs, 1980) shows the mean plume induced currents measured 1 m below the ice surface for one of the discharges. it can be seen that the currents drop off rapidly with increasing radial distance from the plume centerline.

Figure 6 (Dickins and Buist, 1981) illustrates the interaction of the oil, gas and water during one discharge as "seen" by the various monitoring devices.

As the gas/oil mixture left the discharge pipe the violent turbulence at the exit broke the oil into droplets. At the same time the gas flow set up an inward current around the discharge pipe that drew in some silty sediments from the sea floor. The rising gas carried with it the oil droplets and entrained sediment as it rose in a cylindrical "jet" towards the surface.

Approximately 6 m above the discharge pipe an upwards and outwards water current was generated by the rising gas "jet". This outward current or plume carried with it some of the oil particles and sediment. The sediment settled out of the plume and the oil droplets rose due to their buoyancy.

When the jet stream rose to within 7 m of the ice/water interface it began to spread radially outwards creating turbulent eddies which decayed within 15 to 20 m to a laminar outward flow. The gas quickly rose to the ice/water interface and the oil droplets floated up, but much more slowly, to impinge on the ice or collect in gas pockets. The entrained sediment "rained" out of the plume. No distinct "wave ring" was observed; however, it was noted that at a radius of between 15 and 20 m from the discharge centre the bottom water entrained by the gas began to flow downwards from the surface, presumably due to its higher density. During the period of maximum airflow for the Phase 2 discharge a slight inwards current at 5 m was recorded at a distance of 45 m from the discharge centre.

TABLE 3 DISCHARGE DATA

	PHASE 1			PHASE 2			PHASE 2a
	Dry Run	Simulated Blowout	Control	Simulated Blowout	Controls		Simulated Blowout
Date (y,m,d)	79/12/17	79/12/18	79/12/19	80/04/10	80/04/11	80/04/12	80/05/02
Total Oil Discharged (m^3)	0	5.85	0.14 (60% H_2O)	6.56	0.08	0.16 (60% H_2O)	6.8
Total Air Discharged (m^3) (ambient conditions)	950	1 711	0	≃435	0	0	1 219
Elapsed Time of Oil Discharge (min.)	0	17	N/A	24	N/A	N/A	25.5
Elapsed Time of Air Discharge (min.)	20	36	0	32.5	0	0	30
Mean Flowrate of Oil (m^3/min.)	0	0.34	N/A	0.270	N/A	N/A	0.267
Mean Flowrate of Air (m^3/min.) (ambient conditions)	48	48	0	7.1	0	0	48
Calculated G.O.R. (m^3/m^3) (during flow)	N /A	210 (292 if air blowback taken into account)	N/A	25 (66 if air blowback taken into account)	N/A	N/A	180 (224 if air blow-back taken into account)
Oil Temp (Tank)		+39°C		36°C			34°C
Oil/Air Temp @ Exit	0	≃ +25		+25			+20*

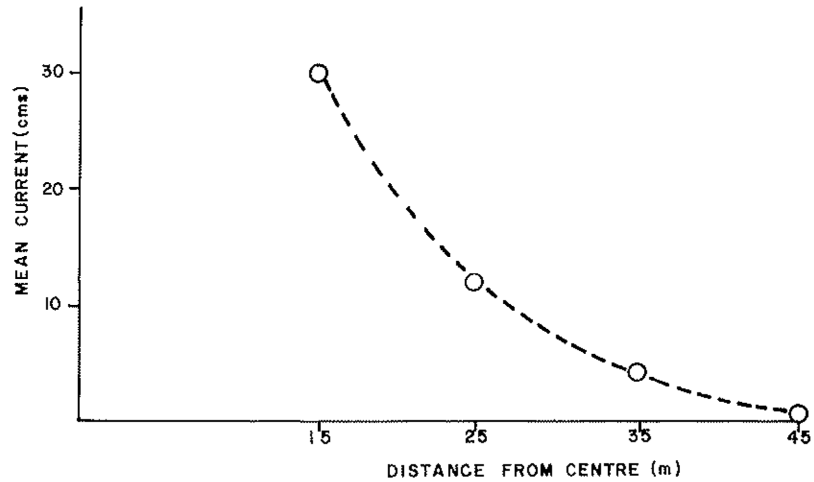

FIGURE 5 MEAN CURRENTS (1 m below ice)

Oil/Gas/Ice Interaction

As the gas rose out of the jet stream it quickly collected in pockets under the ice. Once collected under the ice the gas would flow "uphill" following natural under ice contours and a slight tilt in the ice sheet until it reached a point of equilibrium.

During the Phase 1 dry run, when the ice was only some 65 cm thick, the gas pocket pushed the ice up in a dome some 50 m wide and 1 m high. The domed ice cracked and vented off the gas. The domed area was located some 65 m west of the discharge site.

The oil droplets rose out of the plume with velocities in relation to their diameter. Once the oil had risen out of the plume and impinged on the underside of the ice it was not advected by either the gas flow or water currents. Those droplets sufficiently small to have low rising velocities and thus a significant residence time in the water column were carried by the residual currents to impinge on the under ice surface up to 350 m from the plume centerline. Figure 7 shows the results of a particle size and density analysis performed on the droplets from cores taken downstream of the December discharge. It can be seen that the droplet size decreases dramatically with increasing distance from the discharge centre, and that the majority of the large drops, containing 90% of the volume of the oil (Topham 1975; Dickins and Buist, 1981) impacted the ice sheet within a 50 m radius of the discharge centre. It is interesting to note that the maximum particle density (number/cm^2) was at a radius of 200 m. Figure 7 also shows the fit to the data of a simple laminar flow droplet distribution model based on Stokes Law. The horizontal distribution of droplets was derived using the criteria that a droplet can only move downcurrent in the time it takes for it to rise from a given depth to the under-ice surface.

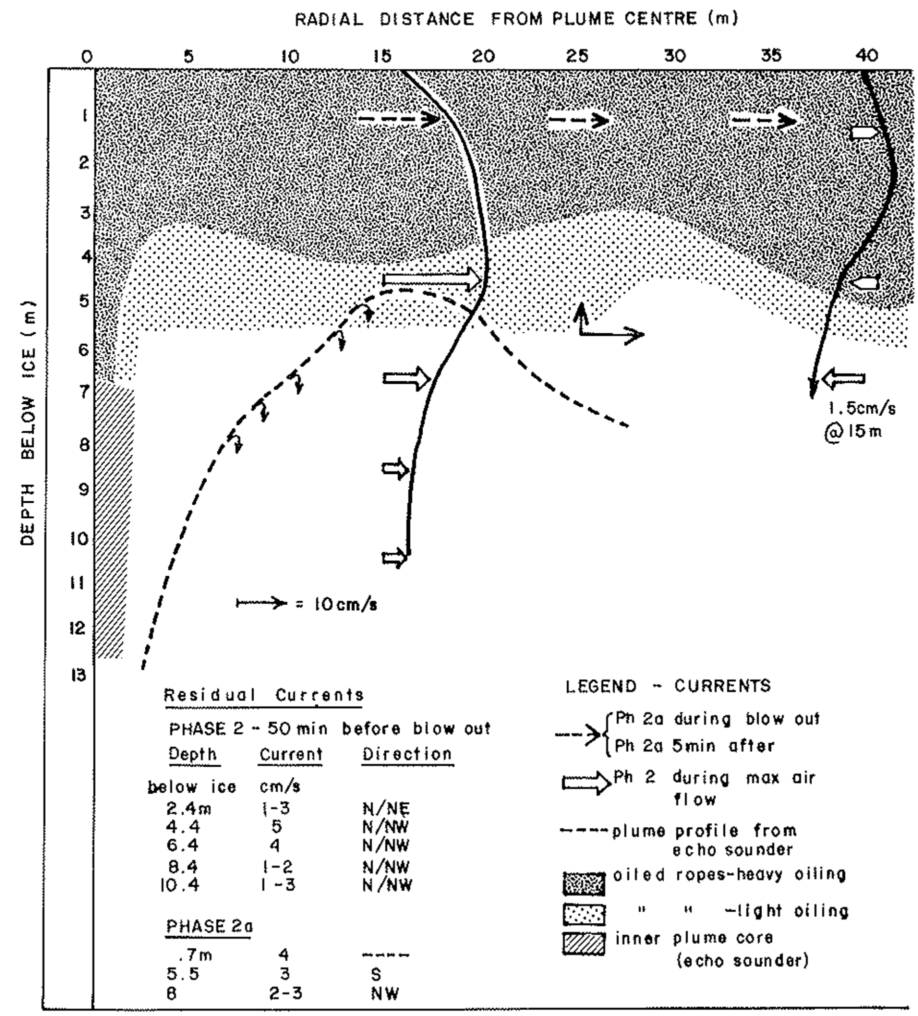

FIGURE 6 COMPOSITE ON ALL AVAILABLE PLUME DATA

Once oil and/or gas had impinged on the underside of the ice it was quickly encapsulated by the growing ice sheet, even in May.

Figure 8 shows the distribution of the oil from the discharges as delineated by a subsequent coring program and observation of the spring melt. Note the reduced area of heavy contamination for the Phase 2 discharge, presumably due to the greatly reduced air flow during the discharge.

During the Phase I discharge an estimated 80% of the gas vented through the auger holes and carried with it water and some 0.5 m^3 of oil which pooled on the surface and quickly froze. This venting had no effect on the areal distribution of the oil as compared to the

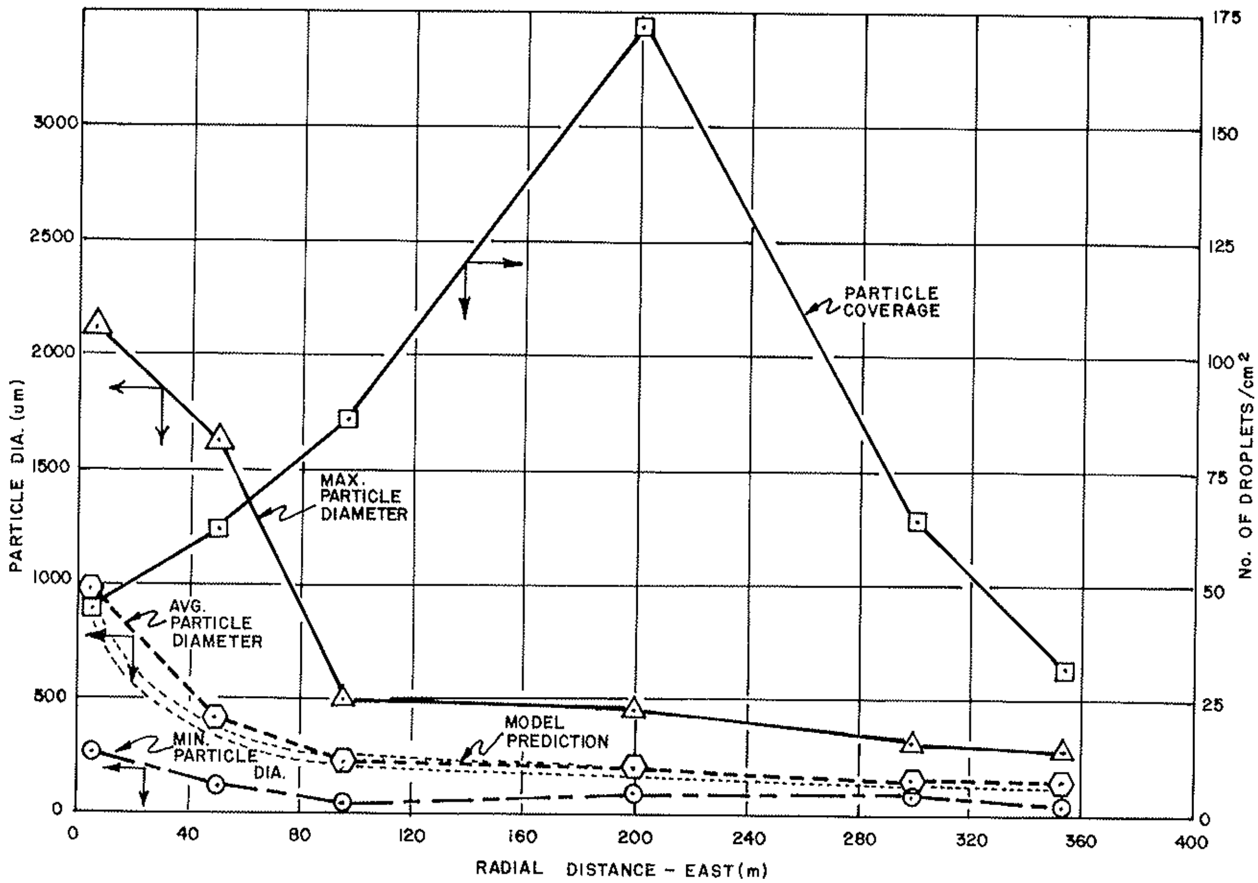

FIGURE 7 OIL DROPLET DISTRIBUTION PHASE 1 SITE

May discharge, leading to the conclusion that the size of the contaminated area is controlled by the flow of gas and oil in the water column, rather than a surface phenomenon relating to the presence of an ice cover that prevents gas venting.

The oil configuration in both the Phase II and II-A discharges was different than the Phase I discharge. In December the under ice surface was relatively smooth, being newly formed, thus most of the oil was observed as discrete particles and few pockets of oil and gas were found. In April and May the under ice surface was typically "wavy", caused by differential freezing due to the insulating effects of snow drifts, and much of the oil and gas collected in the "pockets" under the ice.

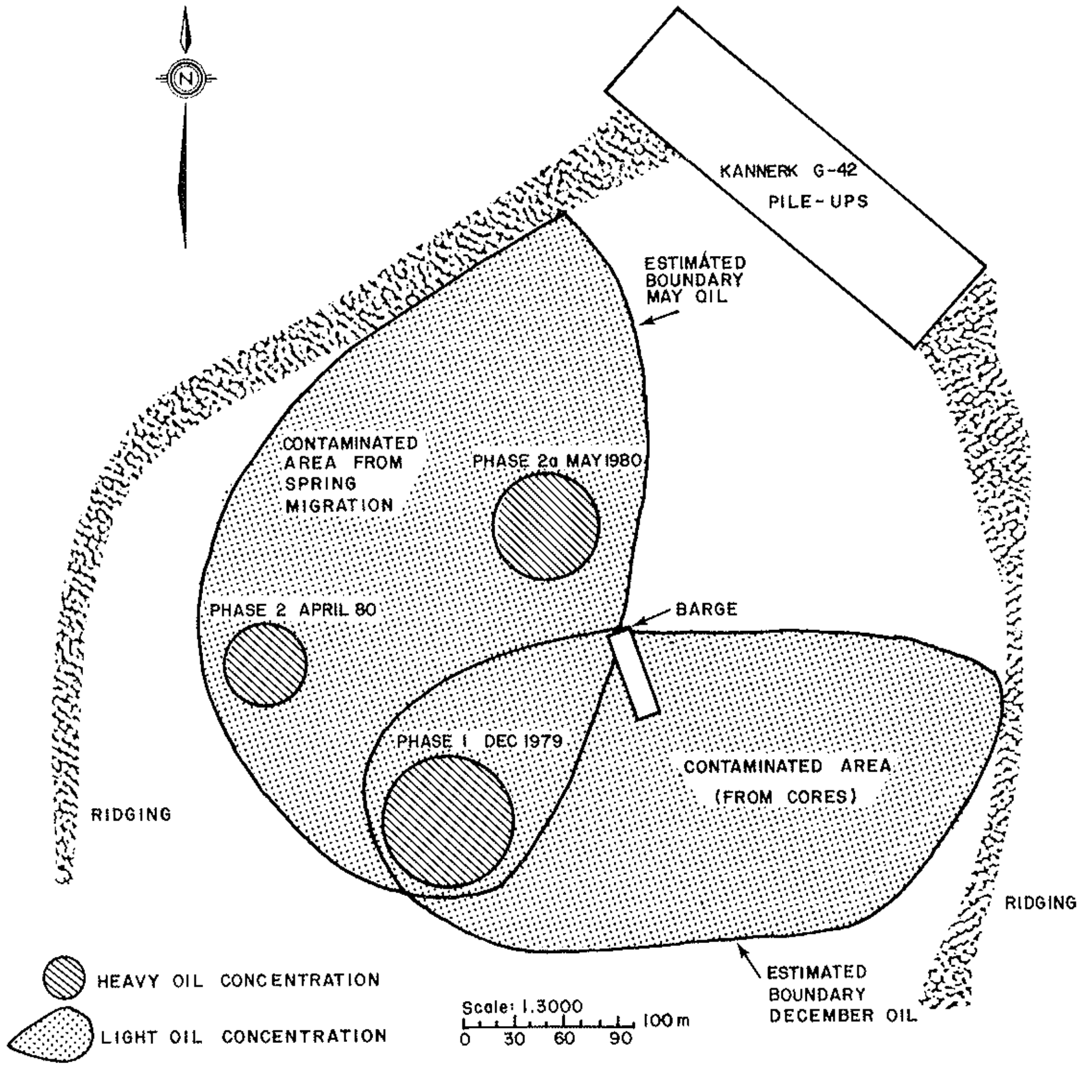

FIGURE 8 OIL DISTRIBUTION

Surfacing of Oil in Spring

There were two competing mechanisms observed whereby oil appeared on the ice surface during the spring melt. The first of these was the process of the ice sheet ablating down to where the oil was "sandwiched" in the ice sheet. This process was responsible for exposing the majority of the oil in the Phase I test site as this discharge took place under relatively thin ice.

The second mechanism was one of oil migration through brine channels. As seawater freezes it excludes its salt forming brine pockets throughout the ice sheet. In spring, as the ice sheet warms, these brine pockets melt before the rest of the ice due to the freezing point depression effect of the salt, and interconnect to form pathways through the ice. If one of these brine channels intercepts a pool of oil, it gives the oil a pathway to the ice surface. The oil rises to the surface of the meltwater pools on the ice due to its buoyancy in water.

This oil surfacing mechanism was primarily responsible for the appearance of the oil in the heavily contaminated areas of the spring discharges, as the oil there had been pooled in the under ice undulations. Not surprisingly, the most dramatic migration took place in the Phase II area where the oil was highly concentrated due to the lower air flow rate during the discharge.

The timing of the appearance of oil on the ice surface is illustrated in Figure 9. Two facts were apparent, firstly, that the oil began to surface slowly and then in a matter of days the majority was exposed; and secondly, that the oil's surfacing seemed to be dependent on the time of year (i.e. ice thickness) when it was spilled under the ice, the earlier it was spilled the earlier it appeared. Prior to breakup approximately 80% of the oil had surfaced. None of the oil rising from the ice sheet was in an obvious emulsified (water-in-oil) form. Figure 10 shows the size distribution of the oil pools at each of the three sites. It is obvious that the majority of the pools were less than 20 m^2 in area with the largest number at each site in the 1-5 m^2 range; however, it is worth noting that the majority of the oil, particularly at the spring discharge sites, was contained in the larger pools. The slick thickness was generally 1 cm due to the effects of wind herding.

Oil Weathering

It was determined, through GC and gravimetric analysis that, because of the use of air as the gas, the oil had lost some of its light ends during and immediately subsequent to the discharge. The volumetric loss was calculated to range from 3% for the April discharge to 7 and 10% for the May and December discharges respectively. Presumably this loss during discharge would not occur to such an extent had the gas been in equilibrium with the oil, as would be the case in the event of a real blowout.

Little or no weathering took place while the oil was encapsulated in the ice sheet, but samples taken from December oil on the surface indicated that in 33 days the oil had lost all its compounds up to C_{14}.

Significant losses of light ends began to occur once the oil appeared on the ice surface in spring. The conservatively calculated volume losses for each of the 3 discharges were:

December	-	25%
April	-	23%
May	-	20%

These losses were lower than expected, due presumably to the thickness of the slicks and the relatively high viscosities of the weathered oil (100-400 mPa•s).

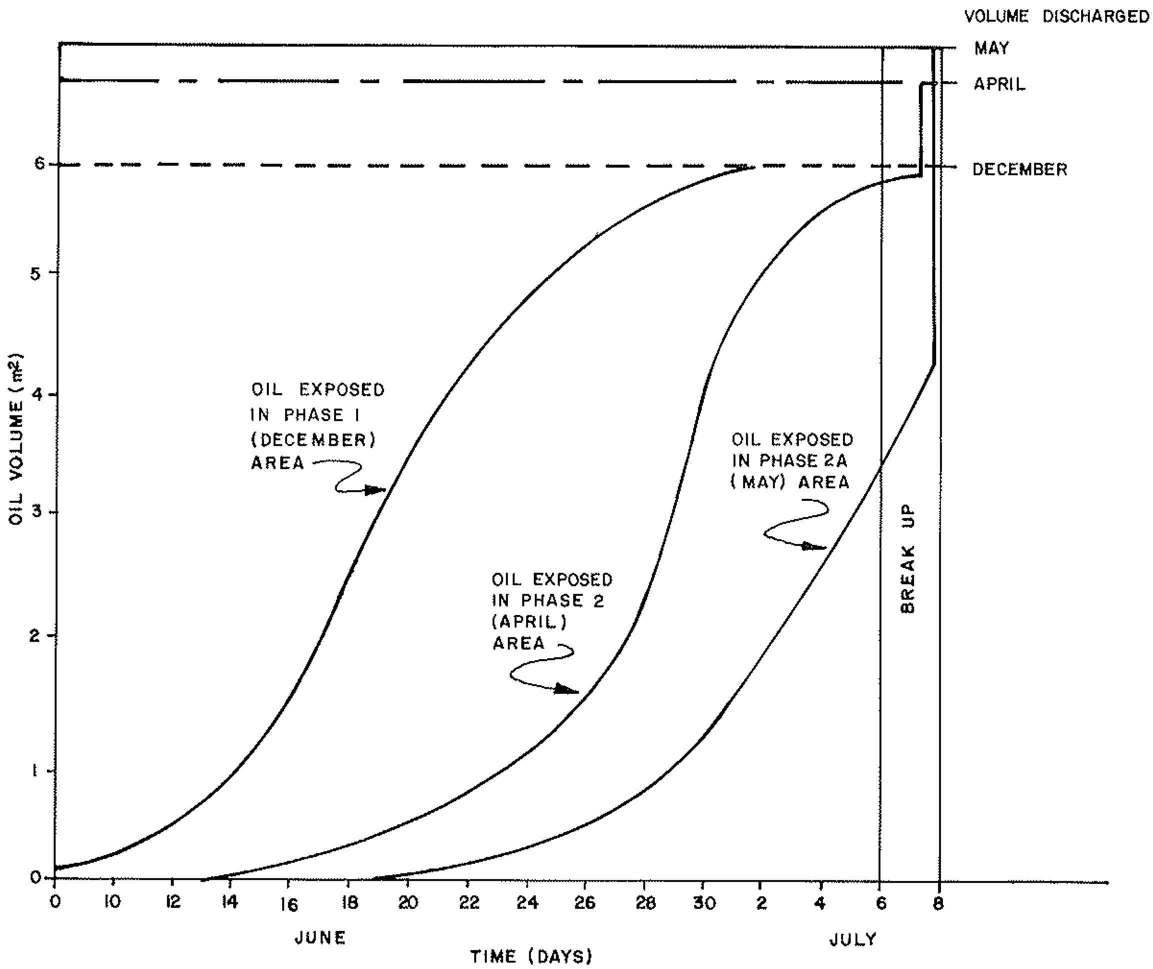

FIGURE 9 TIMING OF OIL EXPOSURE IN SPRING

It should be noted that the oil exposed in the lightly contaminated areas was highly weathered, presumably due to its higher surface to volume ratio. Figure 11 shows the rate of evaporation of the crude oil in a control pool.

Some emulsification of the surface oil was evident; however, closer examination of the slicks revealed that this was, in fact, a surface phenomenon affecting only a thin skin of the oil. This emulsified skin "broke" as the day progressed due to the increased

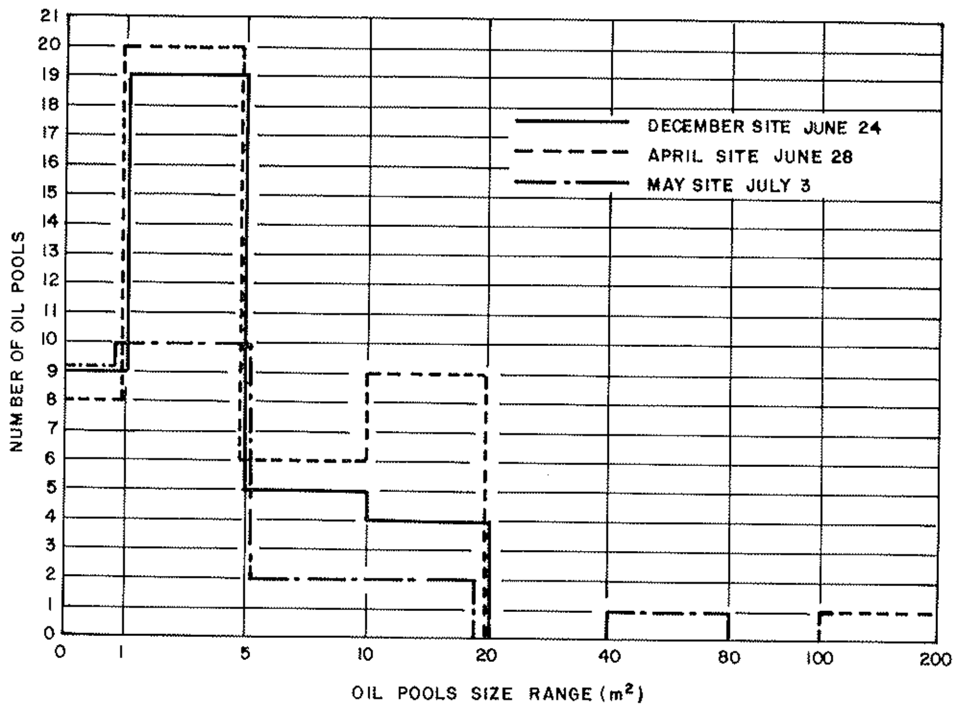

FIGURE 10 OIL POOL SITE AND DISTRIBUTION

temperature and solar radiation. The oil exposed in the lightly contaminated areas due to its highly weathered condition, did, on occasion, form a stable water-in-oil emulsion.

Countermeasures Assessment

In Situ Burning. In total, some 125 individual burns were carried out at the three discharge sites. Twenty Dome igniters, 20 AMOP cannister igniters and 10 AMOP sandwich igniters were used as ignition sources, as well as small quantities of gasoline and matches. The results of the testing of the AMOP devices has been reported elsewhere (Meikle, 1981).

During sequential deployment trials with the Dome igniter (Bell 206 helicopter flying at 2-5 km/h at a 5 m altitude between pools) a deployment accuracy of 80% was achieved. As well, an ignition success rate of 94% was achieved. No difficulties were observed in igniting slicks exposed for up to three weeks. Combining the two (deployment accuracy x ignition success rate) results in an overall success rate of approximately 75%.

The results of the in situ burning are summarized in Table 4 and Figures 12, 13 and 14 illustrate the timing of these burns.

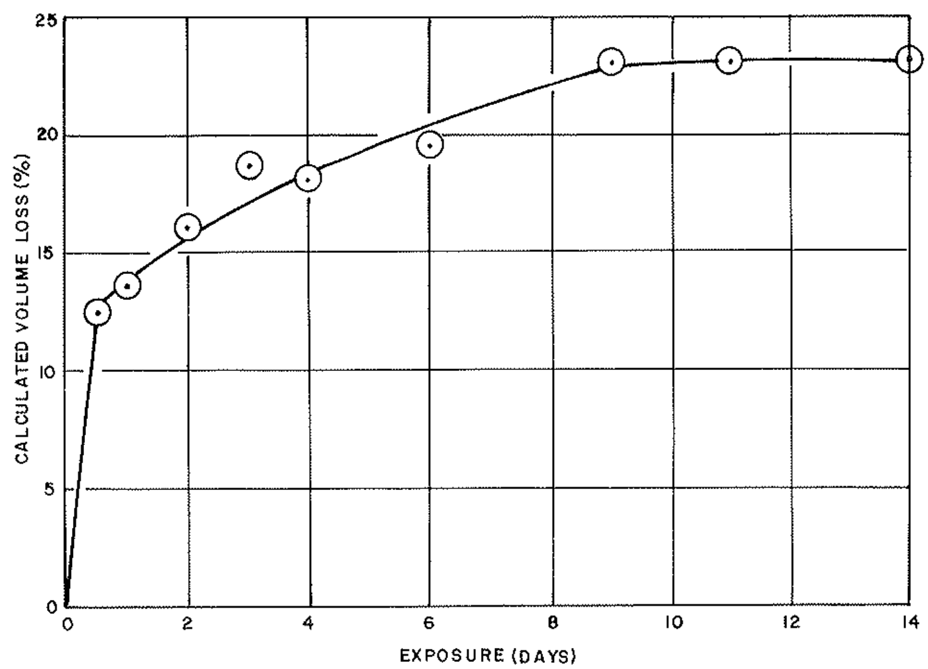

FIGURE 11 CONTROL POOL EVAPORATIVE LOSS

Several points are worth noting. The first is that the configuration of the oil in the ice seems to drastically affect in situ burning. Oil contained in pools in the ice, as after the spring discharges, is much more amenable to burning than oil contained in droplet form as after the December discharge. Secondly, the volume of gas associated with the discharge may affect the overall efficiency of in situ burning. The reduced gas flow during the April discharge resulting in a more concentrated oil distribution may account for some of the increased efficiency over the May site results. Thirdly, the timing of the oil's appearance plays a significant role in the efficiency of in situ burning, some of the difference in results between the April and May sites may be explained by the fact that by breakup some 87% of the oil at the April site had appeared while only 59% had appeared at the May site.

Finally it is interesting to observe that the average individual burning efficiencies did not vary significantly among the three sites despite the differences in site conditions, indicating that in fact burning efficiencies are dictated by slick thickness rather than pool area, volume or oil age.

Manual Cleanup. Using crews with fire pumps, skidoos and sleds to collect and incinerate oiled sorbent material picked off the ice, an overall manual cleanup efficiency of 28% was achieved, ranging from 51% for Phase 1, to 14% for Phases 2 and 2a. The latter figure would have improved substantially, if breakup had not halted further ice operations.

TABLE 4 SUMMARY OF BURN RESULTS

Site	No. of Burns	Volume Burned (m^3)				Recorded Burn Efficiencies			
		Total	Min.	Avg.	Max.	Overall	Min.	Avg.	Max.
Dec.	35	0.8	0.001	0.023	0.166	81	33	81	91
April	43	3.4	0.002	0.079	1.30	77	15	77	91
May	17*	2.0	0.003	0.118*	1.11*	63	23	82	93

* Note: burns conducted on July 4, 5 and 6 were not recorded individually but as totals for the day.

Manual cleanup was very labour intensive, involving six men working ten hour shifts for over two weeks (approximately 0.7 man days/barrel, or 350 man days per square kilometre).

Oil Budget

Site surveys were made periodically throughout Phase 3 to estimate the amount of oil on the ice surface in each of the three discharge sites. Based on the results of these surveys, the data on oil weathering, in situ burning, manual cleanup and the volumes of oil discharged, the oil budget was calculated and is shown in Table 5. The timing of the appearance of oil on the ice, in situ burning, manual cleanup and evaporation prior to breakup is illustrated in Figures 12, 13 and 14 for each of the discharge sites.

The major points to note are:

1. prior to breakup 81% of the oil spilled had surfaced;
2. of this oil on the surface 23% evaporated leaving a total of 12.14 m^3;
3. of this 12.14 m^3, 51% was disposed of by in situ burning and 28% by manual cleanup;
4. at breakup 21% of this oil was left on the ice surface; and
5. after breakup, taking into account further evaporation of the oil left on the ice and evaporation of the oil still in the ice 21% of the oil was left to be naturally dispersed. This was equivalent to 79% of the oil discharged being removed from the marine environment.

Environmental Effects

Water. Fluorometer profiles conducted within one hour of the April and May blowouts, resulted in only two samples with readings above background. These had concentrations of less than 5 ppm oil in water, too low to be of any significance (Arctic Labs, 1980).

TABLE 5 OIL BUDGET

	December	April	May	Controls	Total
Fresh Oil Discharged (m^3)	5.85	6.56	6.8	0.22	19.43
Oil Evaporated Before Spring (m^3/%)	0.59 (10%)	0.23 (3.5%)	0.48 (7%)	-	1.3 (6.7%)
		PRIOR TO BREAKUP			
Weathered Oil On Ice (m^3)	4.39	4.40	3.20	0.15	12.14
Equivalent Fresh Oil On Ice (m^3)	5.85	5.71	4.0	0.20	15.76
Total Evaporative Loss (m^3/%)	1.46 (25%)	1.31 (23%)	0.8 (20%)	0.05 (23%)	3.62 (23%)
Oil Burned In-Situ (m^3)	0.8	3.4	2.0	-	6.2
Manually Cleaned Up (m^3)	2.22	0.63	0.47	0.03	3.35
Overall Burning Efficiency (% of weathered oil on ice)	18%	77%	63%	-	51%
Overall Manual Cleanup Efficiency (% of weathered oil on ice)	51%	14%	15%	-	28%
Weathered Oil Left On Ice (m^3/%)	1.37 (31%)	0.37 (8%)	0.73 (23%)	-	2.59 (21%)
Oil Left In Ice (m^3)	0	0.82	2.6	-	3.42
Equivalent Fresh Oil Left In Ice (m^3/% of discharged)	0 (0%)	0.85 (13%)	2.8 (41%)	-	3.67 (19%)
		AFTER BREAKUP			
Evaporative Loss (Weathered Oil Left On Ice to 40% and 40% of Equivalent Fresh Oil Left In Ice (m^3))	0.27	0.42	1.28		1.97
Weathered Oil Naturally Dispersed (m^3/% of discharged)	1.1 (19%)	0.8 (12%)	2.25 (33%)		4.15 (21%)
Removal Efficiency	81%	88%	67%		79%

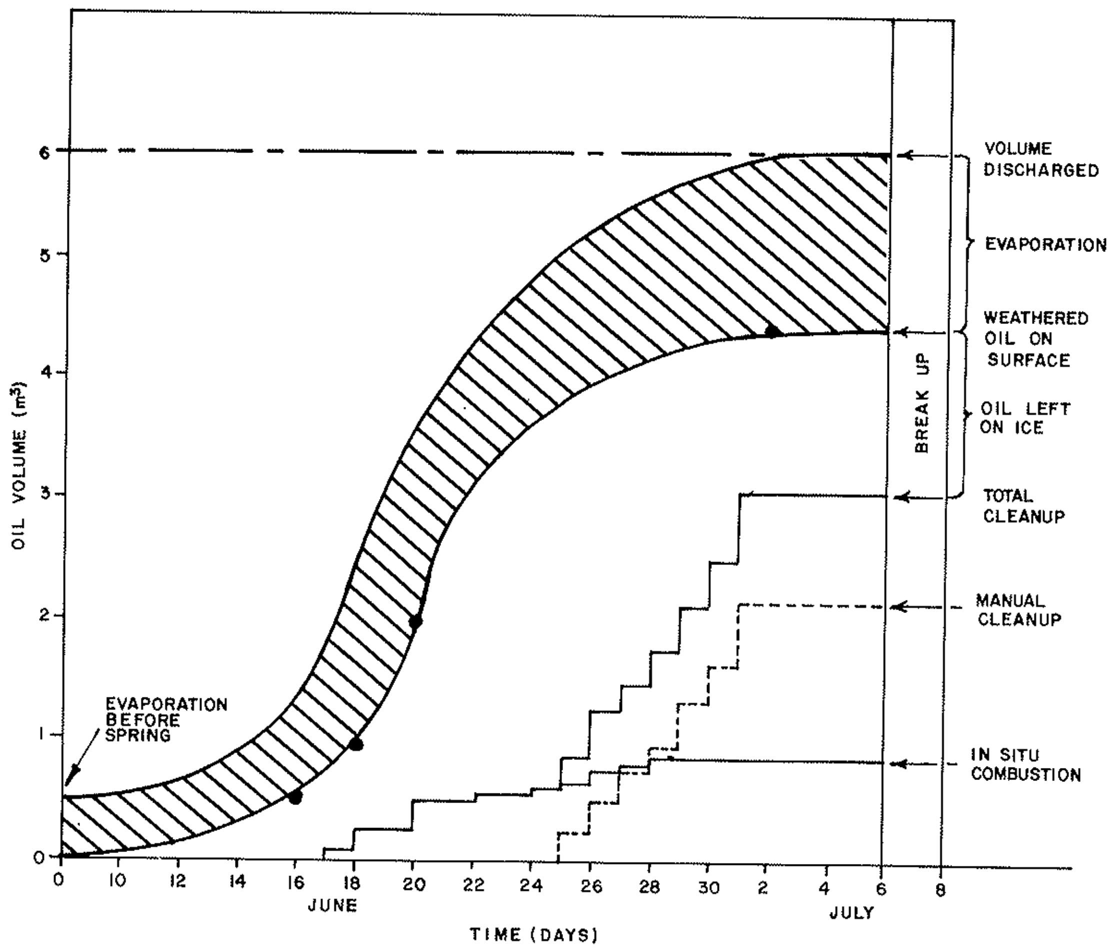

FIGURE 12 DECEMBER SITE OIL BUDGET PRIOR TO BREAKUP

Benthic samples obtained before and after all three discharges, revealed no measurable petrogenic hydrocarbon material.

Air. Three separate programs were conducted to monitor the effects of in situ combustion, these were: photography of selected smoke plumes to document plume dispersion; collection of snow samples for the determination of soot fallout concentrations; and an analysis of the burn residues and ash to determine their polyaromatic hydrocarbon contents.

It was observed that the mixing heights were quite low (<300m) and that horizontal dispersion of the plume was quite pronounced, but that within up to a kilometre downwind

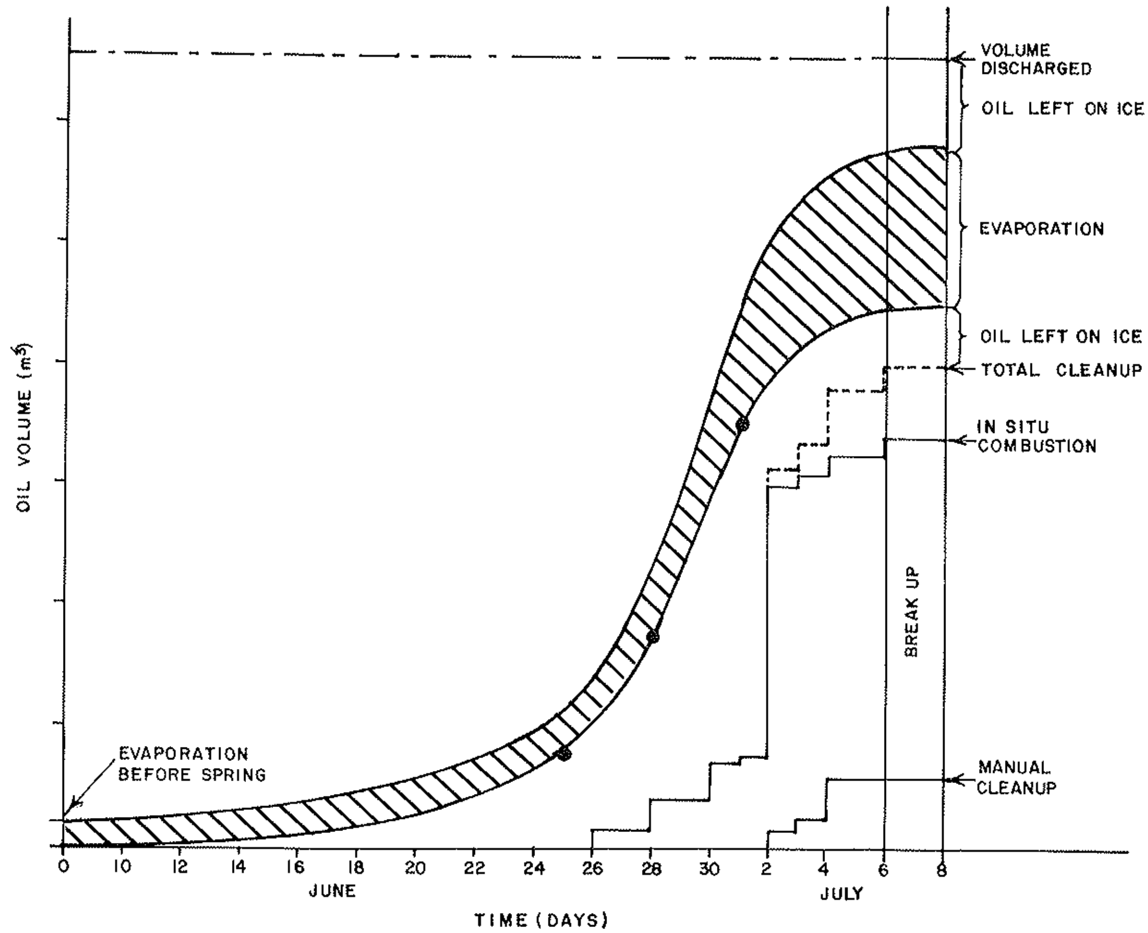

FIGURE 13 APRIL SITE OIL BUDGET PRIOR TO BREAKUP

the plume still significantly obscured visibility. For this reason it was recommended that sequential burning of meltpool oil proceed in an upwind or crosswind manner (Energetex, 1980).

Table 6 shows the results of the soot fallout studies for three individual burns.

This data indicates that there was no measurable fallout from in situ burning at distances greater than 50 m downwind of the burn site. This was supported by visual examination of the downwind areas after burning.

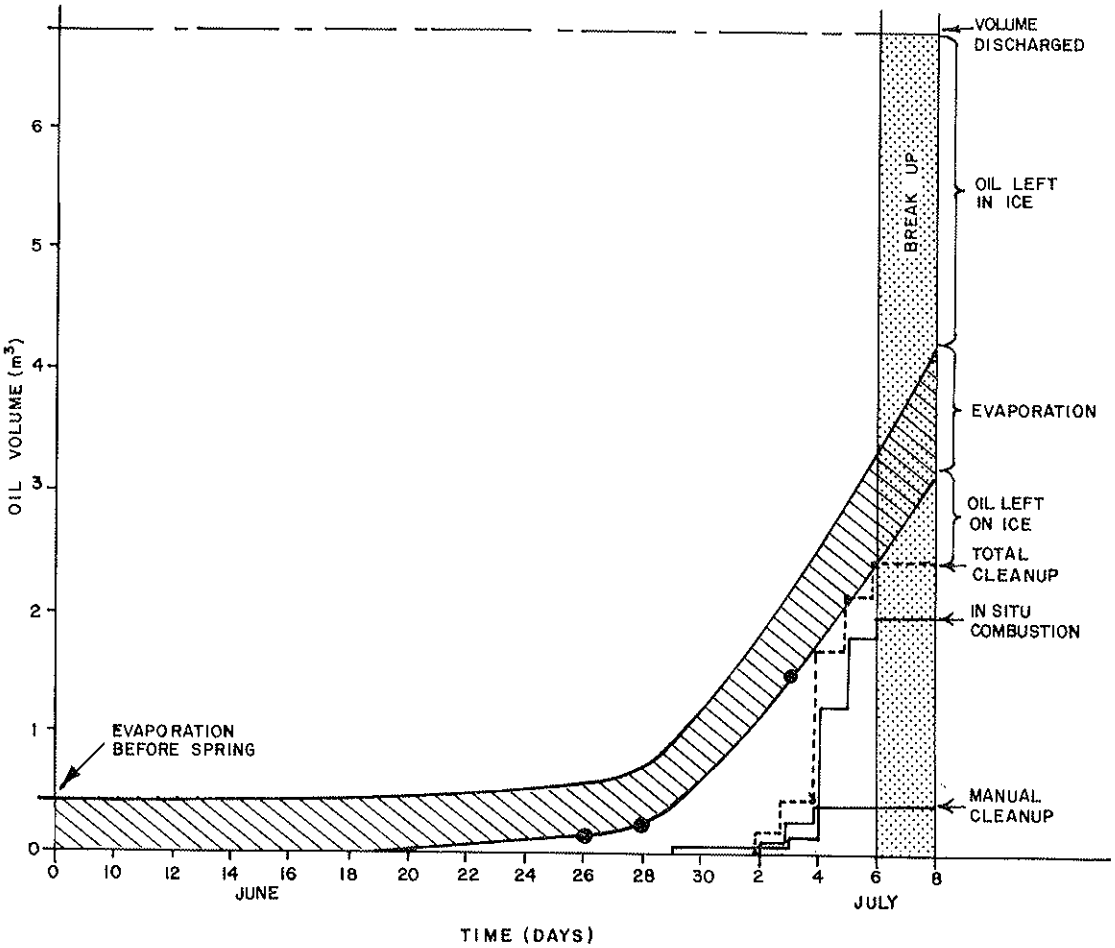

FIGURE 14 MAY SITE OIL BUDGET PRIOR TO BREAKUP

Table 7 shows the result of the polyaromatic hydrocarbon analyses performed on burn residue and soot samples (C-CORE/MUN, 1980).

The results in Table 7 indicate that the weathered oil contained 20% more aromatics than the fresh oil, probably due to the preferential evaporation of the more volatile components thus concentrating the less volatile ones. The burn residue was found to contain approximately 40% more aromatics than the fresh crude (17% more than weathered oil) probably due to the preferential evaporation/combustion of the more volatile fractions.

The one sample of ash analyzed indicated an increase in aromatics of approximately 60% over fresh crude (35% over weathered crude).

As well as the above, the NMR spectra of the samples indicated that new compounds were present in the ash, presumably due to combustion.

Mutagenicity tests indicated that both the residue and ash were mutagenic although no comparison with fresh or weathered crude was reported and no data was generated regarding LC_{50}'s. For this reason it is recommended that work of this type on the products of in situ combustion continue.

It should be kept in mind that even though aromatic concentrations were increased in both burn residues and ashes, that the volumes of residue (as little as 7% of the original weathered oil) and ash (on the order of 6% of the original oil (Day et al., 1979) are greatly reduced. This reduction coupled with the slight increases in aromatics may result in a significant net decrease in the amounts of aromatics that would be bioavailable.

Ice. Surface albedo changes significantly with the onset of thawing air temperatures. This in turn leads to over a 50% increase in radiation absorption and subsequently rapid ablation of the ice cover from the top down. The difference in albedo between a naturally formed melt pool and oil on the ice was typically less than 10%. A comparison of ice thickness readings from cores taken July 3 showed that the mean contaminated ice depth remaining in the April and May test areas was 54.5 cm with no detectable difference between the two sites (9 cores total). On the same date, uncontaminated level ice between the December and April test areas was 63 cm thick. The ice sheet broke up on July 8 when there was still 30 cm of ice left in some places. Once the ice was severely candled in early July, a difference in thickness between contaminated and clean sites of less than 10 cm would not effect local breakup patterns in the Beaufort Sea.

The environmental impact of the oil spill tests on the ice cover growth and/or deterioration was not significant.

CONCLUSIONS

1. The majority of the oil from the discharges was carried upwards through the water column by the gas plume and impinged on the under ice surface in an area 50 m in radius directly above the discharge point. A small percentage of the oil, in the form of small droplets, was carried by the residual currents and impinged on the ice surface downcurrent. A reduction in gas flow rate and GOR resulted in a much reduced area of contamination. Oil discharged under newly formed flat ice tended to retain its droplet configuration and was exposed in spring by ice ablation, oil spilled under older, undulating ice tended to pool and be exposed by brine channel migration in spring.

2. Of the oil discharged, approximately 80% appeared on the ice surface prior to breakup.

3. Of the oil discharged, approximately 80% was removed from the marine environment and only some 20% dispersed naturally.

4. Approximately 50% of the oil on the ice surface prior to breakup was successfully burned off using air deployable ignitors.

5. A further 30% of this oil was recovered using manual cleanup techniques.

TABLE 6 BURN FALLOUT CONCENTRATIONS

Date	Oil Pool Size (m^2)	Volume Burned (m^3)	Burn Time (min:s)	Fallout* (mg/m^2)				
				1m	10m	50m	100m	200m
June 20	11	0.1	20:00	450	-	0	0	0
July 2	135	1.3	7:20	-	4 070	0	0	0
June 28	13	0.105	22:20	-	2 070	0	0	0

* Includes both soot and unburnt hydrocarbons soluble in isopropanol

TABLE 7 CONCENTRATIONS OF AROMATICS/PAH'S FOUND IN BURN RESIDUES AND SOOT SAMPLES

Concentrations of Aromatics/PAH's (wt %)

Date	Fresh Crude	Weathered Oil Just Prior to Ignition	Burn Residue	Ash
June 7 (demonstration burn)	24	-	34	39
June 20	24	-	34	-
June 22	24	29	34	-

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SPILL TECHNOLOGY NEWSLETTER

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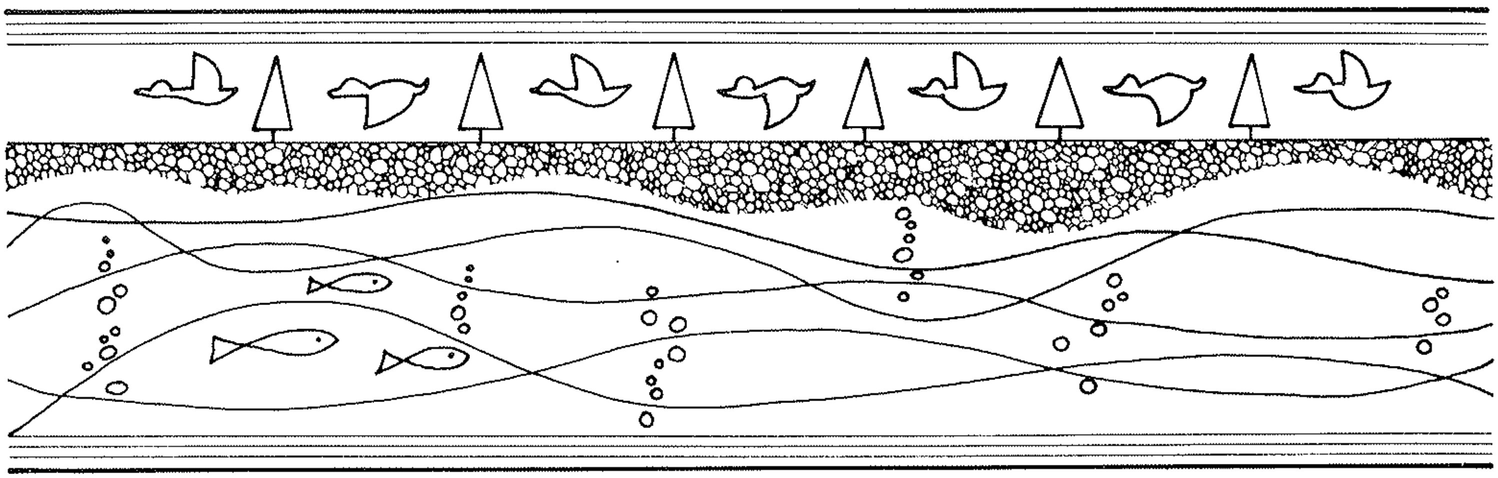

Table of Contents

Spill Technology Newsletter

EDITORS

Mr. M.F. Fingas and Dr. D.E. Thornton

Research and Development Division
Environmental Emergency Branch
Environmental Impact Control Directorate
Environmental Protection Service
Department of the Environment
Ottawa, Ontario
K1A 1C8

Phone: (819) 997-3921

The Spill Technology Newsletter was started with modest intentions in 1976 to provide a forum in Canada for the exchange of information on oil spill countermeasures and other related matters. The interest in it was such that we now have over 2,500 subscribers in Canada and around the world.

To broaden the scope of this newsletter, and to provide more information on industry and foreign activities in the field of oil spill control and prevention, readers are encouraged to submit articles on their work and views in this area.

INTRODUCTION

Readers may have noticed that the previous two issues of the Newsletter arrived only recently. This was due to a long strike in the Canadian post office. Our apologies for this delay and also in responding to requests for information and publications; these were delayed by the strike as well.

This issue of the Newsletter has two articles, the first by Ken Meikle describes a workshop on the subsea containment of offshore oil and gas well blowouts. The second article by Ian Buist describes the development and testing of a fireproof containment boom. The testing has shown that the device meets or exceeds design criteria.

We again remind readers that we always welcome articles, information, etc. which are suitable for the Newsletter.

REPORTS AND PUBLICATIONS

- The journal, "Environment International", has dedicated the volume 3, number 2 issue to the topic of oil spills. "Environment International" is a publication of Pergman Press, Headington Hill Hall, Oxford, United Kingdom, OX3 OBW or at Maxwell House, Fairview Park, Elmsford, New York, 10523. The price of the single issue is $12.80 (U.S. Funds).

- CONCAWE (The Oil Companies' International Study Group for Conservation of Clean Air and Water - Europe) has released two new reports, "Revised Inland Oil Spill Clean-up Manual" - report no. 7181 and "A Review of the Investigation of a Kerosene Spill at Strasbourg - Entzheim Airport, France" - report no. 8181. Information on these reports can be obtained by contacting CONCAWE, van hogenhouchlaan 60, 2596 TE, Den Haag, Netherlands, Telephone 31 70 24 50 35.

- The Environmental Emergency Branch has recently released three contractor's reports, the titles of which appear below. These reports are unedited and have not undergone rigourous technical review but will be distributed on a limited basis to transfer the results to people working in related fields. For copies of these reports contact: Publications Coordinator, Environmental Impact Control Directorate, Environmental Protection Service, Ottawa, Ontario, K1A 1C8.

  "The Sublethal Effects of Water Soluble Hydrocarbons on the Physiology and Behaviour of Selected Marine Fauna" (EE-16).

  "A Catalogue of Oil Spill Utility Pumps" (EE-24).

  "Remote Sensing of Oil During the Kurdistan Spill" (EE-25).

- The Baffin Island Oil Spill (BIOS) project has recently released five working reports, the citations of which appear below. These reports have not undergone rigorous technical review but will be distributed on a limited basis to provide the results to those working in related topics. For copies of these reports contact: Publications Coordinator, Environmental Impact Control Directorate, Environmental Protection Service, Ottawa, Ontario, K1A 1C8.

  Green, D.R., 1981, Chemistry: 1. Field Sampling and Environmental Chemistry - 1980 Study Results. (BIOS) Baffin Island Oil Spill Project Working Report 80-1: 93 p.

  Eimhjellen, K., Sommer, T., and Sendstad, E., 1981, Microbiology: II. Biodegradation of Oil -1980 Study Results. (BIOS) Baffin Island Oil Spill Working Report 80-6: 33 p.

  Cross, W.E., and Thompson, D.H., 1981, Macrobenthos - 1980 Study Results. (BIOS) Baffin Island Oil Spill Working Report 80-3: 81 p.

  Boehm, P.D., 1981, Chemistry: 2. Hydrocarbon Chemistry - 1980 Study Results. (BIOS) Baffin Island Oil Spill Working Report 80-2: 184 p.

  Woodward-Clyde Consultants, 1981, Shoreline Countermeasures - 1980 Study Results. (BIOS) Baffin Island Oil Spill Working Report 80-4: 83 p.

●The following reports are available from the U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia, 22161, Telephone (703) 487-4650. Most reports are also available on Microfiche at $3.35 each (U.S.A. Price). Canadian buyers add $2.50 to each paper copy and $1.50 for each microfiche report. Prices are quoted in U.S. dollars.

Oil and Petroleum

"Handbook for Oil Spill Protection and Cleanup Priorities." J.D. Byroade, A.M. Twedell and P.J. Leboff. Rockwell International, Anaheim, California. February, 1981. 145p. PB81-183394 $12.50.

"Simultaneous Boiling and Spreading of Liquefied Petroleum Gas on Water." H.R. Chang and R.C. Reid. Massachusetts Institute of Technology, Cambridge. April, 1981. 38p. DOE/EV/04548-1 $6.50.

"Oil Spills and Oil Pollution in the Arctic and Antarctic. January, 1970 - May, 1981 (Citations from Pollution Abstracts)." National Technical Information Service, Springfield, Virginia. 38p. PB81-866592 $30.00.

Other Hazardous Materials

"Fire Control Agent Effectiveness for Hazardous Chemical Fires: Carbon Disulfide." D.W. Johnson, W.D. Cavin, H.P. Lawson and J.R. Welker. Applied Technology Corp., Norman, Oklahoma. January, 1981. 101 p. AD-A098 552/3 $11.00.

"Behaviour of LNG (Liquefied Natural Gas) Vapor Clouds: Tests to define the size, shape and structure of LNG Vapor Clouds." R.N. Meroney, D.E. Neff and K.N. Kothari. Colorado State University, Fort Collins. 93 p. PB81-201907 $9.50.

UPCOMING CONFERENCES

- The next Institute of Petroleum/Warren Spring Laboratory oil pollution course has been arranged for 10-14 May, 1982, in the Copdock Hotel, Ipswich, England. The purpose of the course is to provide both practical and theoretical training in oil spill control technology. Further details can be obtained from Miss Irene McCann, Institute of Petroleum, 61 New Cavendish Street, London, W1N 8AR, Telephone 01-6361004, Telex 264380.

BRIEF NOTES

- The Environmental Emergency Branch has let a contract for the preparation of information reviews on fifty selected hazardous materials. Each information review will eventually be published as an independent publication and would be on the order of 40 pages in length. The purpose of the project is to collect all data which would be useful in the event that the substance is spilled. Information will be obtained from literature and manufacturer's information as well as from interviews with individuals who have dealt with spills of the material. The manuals will be used to provide a complete source of information in spill incidents, for contingency planning and for the continued development of countermeasures for spills of these materials. The reviews will be organized into 13 sections as follows; summary, physical and chemical data, commerce and transportation, behaviour in the environment, leak and dispersion nomograms, environmental data, human dangers, material compatability, countermeasures, analytical information, other spill experiences, anciliary information, and references.

Literature, verbal information, spill experiences, etc. would be welcomed on the substances being reviewed. Comments and information can be provided to: Merv Fingas, Environmental Emergency Branch, Environmental Protection Service, Ottawa, Ontario, K1A 1C8, phone (819) 997-3291 or Mike Scott, M.M. Dillon Limited, 50 Holly Street, Box 219, Stn. K, Toronto, Ontario, phone (416) 482-5656.

The substances upon which this study is based are the fifty highest priority materials as selected by the Environmental Emergency Branch. The substances are as follows (in alphabetical order):

Acetic Acid
Acetic Anhydride
Ammonia
Ammonium Nitrate
Ammonium Phosphates
Benzene
Calcium Carbonate
Calcium Chloride
Calcium Oxide/Hydroxide
Carbon Dioxide
Chlorine
Dimethyl Ether
Ethylbenzene
Ethylene Dichloride
Ethylene Glycol
Ethylene Oxide
Ethylene
Ferric Chloride
Formaldehyde
Hydrogen Chloride/Acid
Hydrogen Fluoride/Acid
Hydrogen Sulfide
Naphthalene
Natural Gas
Nitric Acid
Phenol
Phosphoric Acid
Phosphorous
Potash (Potassium Chloride)
Propylene Oxide
Propylene
Sodium Chlorate
Sodium Chloride
Sodium Hydroxide
Sodium Hypochlorite
Styrene (Monomer)
Sulfur Dioxide
Sulfuric Acid (and Oleum)
Sulfur
Tetraethyl Lead
Titanium Dioxide
Toluene
Urea
Vinyl Chloride

Mercury
Methanol
Morpholine
Xylenes
Zinc Sulfate
2-Ethylhexanol

SUBSEA CONTAINMENT WORKSHOP REPORT

Submitted by: K.M. Meikle
Environmental Protection Service
Ottawa, Ontario

INTRODUCTION

A 2-day workshop in Toronto, Ontario, was convened 11 February 1981 as a joint industry-government undertaking. Participants were responsible for their own travel and living expenses, while the cost of the facilities provided and the subsequent publication of proceedings (Anon., 1981) was shared by the Arctic Petroleum Operators' Association (APOA), the East- Coast Petroleum Operators' Association (EPOA) and the Environmental Protection Service (EPS) of the Canadian Department of the Environment (DOE).

Participation was by invitation only as selected jointly by the APOA/EPOA Oil Spill Committee and the Environmental Emergency Branch (EEB) of the EPS. Twenty-six scientists, engineers and other specialists from universities, government and industry in Norway, Canada and the United States took part. Unfortunately, the two Mexican officials who had agreed to contribute their experience with the Sombrero device were unable to attend because of conflicting priorities.

The format combined prepared briefings with open discussion by the group as a whole; sub-working-groups were not used. Only the closing remarks by Dr. Kingham were recorded and an edited transcript is included in the proceedings. The proceedings, available on request from EEB, also include papers as provided by those who made presentations, and a summary of the discussion sessions prepared from notes and sketches. Participants were encouraged to take their own notes and to form their own conclusions to supplement the proceedings.

BACKGROUND

One of the studies that preceded the use of drill-ships for exploratory drilling for oil in the southern Beaufort Sea described a concept involving a submerged steel dome to collect the escaped oil and gas in the event of a seabed blowout.

To apply that basic dome principle without the constraints imposed by a rigid structure, Canadian Marine Drilling Ltd. evolved the Sandome concept of a fabric dome anchored by a sand-filled ring forming the base. Engineering studies indicated that the stresses could be accommodated, but further development was shelved pending examination of possible alternatives. To that end, Lockheed Petroleum Services Ltd. of Vancouver, B.C. performed a limited feasibility study under contract to the EPS (Chen, 1979). Subsequently, the Sombrero device was evolved for PEMEX and used with only partial success at the IXTOC I blowout in the Gulf of Mexico in 1979.

Despite these activities and the supporting research that has been ongoing for a number of years, it is still not possible to state conclusively that subsea containment is feasible, or even potentially feasible, and it is equally impossible to rule it out as a viable countermeasure for a seabed oil well blowout.

OBJECTIVES

The stated objectives of the workshop were to:

a. identify the areas of uncertainty and the work required to resolve the remaining unknowns regarding the feasibility of subsea containment of oil in the event of a seabed blowout in offshore waters under Canadian jurisdiction;

b. priorize the tasks involved; and

c. suggest appropriate research and sources of expertise.

A further objective was to foster a better awareness of what others are doing and enable research scientists from the participating countries to compare and discuss the results of their work with each other and with engineers and other specialists having related knowledge or expertise.

SUMMARY OF PRESENTATIONS

NOTE: The following summaries were prepared in the main from notes taken during the presentations and in some cases include input from others beside the speaker.

Oil and Gas Under Sea Ice and Fireproof Boom Trial - I. Buist, Dome Petroleum Ltd.

Observations relevant to the feasibility of subsea containment of oil were provided from the two projects, both of which are the subject of detailed reports (Dickins et al., 1981; McAllister and Buist, 1981). The objectives of the under-ice study included the provision of some answers with respect to the plume dynamics under the ice and the determination of whether or not an emulsion would be formed and, if so, its behaviour. The results from the contained burning of oil on the surface of the water during the testing of the fireproof boom could have relevance to the design of the surface component of a subsea containment system.

The under-ice experiment was described as having been designed to simulate a 2500 barrel/day blowout with a gas: oil ratio of 140:1. Water depth was approximately 20 m and Prudhoe Bay crude oil was used for all three releases, and compressed air was used to simulate natural gas. Other information presented included:

a. Oil was released for about 20 minutes on each occasion and steady state conditions were approximated but never quite reached;

b. Flow rates for oil and gas were approximately 0.25 m^3/min and 50 m^3/min respectively;

c. Gas and oil velocities in the annular two-phase flow produced were 30 m/s and 0.03 m/s respectively;

d. Water-in-oil emulsion formation was observed at the exit orifice and sampled;

e. There was no evidence of emulsion formation during the remainder of the rise to the surface; and

f. No wave ring was observed.

Large-scale Plumes and Hydrate Formation - D. Topham, Institute of Ocean Sciences

The main findings from previous work regarding the effects of hydrate formation on plume dynamics (Topham and Bishnoi, 1980) were briefly outlined, including the conclusion that about 500 m was the critical depth from which a gas bubble would not reach the surface because of hydrate formation.

Some ideas on plume stability were then presented relating to the observation that the surface pattern of a plume varies in both level of activity and in geographic location. A possible explanation outlined included the suggestions that:

a. as the plume diameter increases, a point is reached at which the bubbles no longer interact and they continue their rise as discrete single bubbles, that is, similarity of intervals disappears; and

b. above a quasi-similarity region there is a "cylinder of instability" that may re-stabilize and de-stabilize alternately with continued rise causing rafts of bubbles that surface in different places to give the appearance of lateral plume movement.

Emulsion Formation- D. Mackay, University of Toronto

The opening remarks included the following:

a. experimental work has shown that injecting dispersant into the jet can dramatically reduce bubble size and greatly increase water column oil content with correspondingly reduced surface oiling; and

b. it is still only partially possible to determine the gas/oil mass balance at points in the plume, that is, determine where the oil is at any given time.

Regarding the formation of emulsions in a plume, Dr. Mackay summarized his conclusions from his observations as follows:

a. emulsion does not form in the plume;
b. one certainly forms near the surface;
c. one may form in the well bore; and
d. as borne out at IXTOC I, burning removes components that prevent emulsification and hence increases the formation of emulsion.

On-site observers of the IXTOC I event and others present collectively provided the following information:

a. the emulsion at the exit was oil-in-water;
b. at the surface it was water-in-oil; and
c. gas chromatograph analysis of samples of IXTOC I emulsion collected immediately downstream of the plume showed that all volatiles had disappeared.

It was suggested that the probable sequence of events was that the oil-in-water emulsion that formed initially coalesced to burn and then the water-in-oil emulsion was formed as a product of the combustion process.

Norwegian Laboratory Tests and Containment Studies - K. Sjoen and P. Teigen.

Scale model work in a 10 m deep tank at the Norwegian Hydrodynamic Laboratories, Trondheim were described and illustrated with slides and motion pictures, and the results of other primarily paper analyses were reported.

Conclusions reached from an evaluation of the comparative effectiveness of surface devices versus in-plume devices versus those placed at the source were:

a. A surface device (semi-submersible bell) was self-centering and followed shifting bubbles; however, moderate environmental forces will overcome the centering effect by an order of magnitude. There was a large fluid outflow but gas was collected.

b. An intermediate depth device (bell) seems to be of little value; position keeping was difficult because of current and variations in buoyancy, and the high flow rate through all but extremely large devices would preclude any settling.

c. A bell-shaped rigid device over the source shows the most promise, but a tight fit is required at the seabed, well head access would be restricted, differential pressure control would be difficult and slugging would be a problem. However, water flow would be restricted considerably, fluid volume would be similar to the blowout flow rate, pressure would fluctuate less, the device would be relatively small (less than 50 m diam. at the base), environmental loads would not be a problem, and it might serve for any depth.

The model experiments used a device 1.3 m high with a base 1.16 m diameter (scale 1:15). Severe pulsations in the flow through a fabric riser eventually resulted in fabric failure; when a 30 cm diameter tube was substituted for the 10 cm diameter tube used initially, the tube walls collapsed to close off excess space and pulsed bulging occurred as in the smaller tube. The experiments indicate that the pressure differential across the riser wall could be a major problem and that hard-walled riser conduits will be necessary.

MIT Laboratory Experiments - J.H. Milgram and J. Burgess

A series of experiments using conical inverted-funnel collector models with different base to height ratios have indicated that the details of collector geometry are of lesser importance; the critical factors for high collection efficiency are the height of the collector above the source and the ability of the riser system to pump fluid. The scale used was about 1:25, with three of the models having a base diameter of 45.7 cm (18 in) and heights of 21.6 cm (8.5 in), 35.6 cm (14 in) and 81.3 cm (32 in) respectively; the fourth having a base diameter of 22.9 cm (9 in) and a height 26.7 cm (10.5 in).

Results of a theoretical analysis and computer modelling of the fluid mechanical structure of plume flow above the zone of flow establishment were presented. The assumption was made that because plumes are intrinsically unsteady, the radial distributions of density defect and velocity may not be gaussian at any particular instant of time. One of the points brought out was that since instantaneous velocity changes are not necessarily gaussian and can be very different from long-term averages, forces and instant buoyancy changes can be much greater than would be expected based on averages.

SUMMARY OF DISCUSSION

Topics Discussed

Stimulated by Dr. Milgram's illustrated unscheduled review of his on-scene observations of the deployment of the Sombrero device, it was agreed that the discussion phase should address in turn:

1. The limiting parameters of the target blow-out.

2. The three main components of the system (collector, riser and surface receiver) including;

   a. the forces involved;
   b. the environmental constraints;
   c. the research requirements;
   d. the appropriate scale for model testing; and
   e. the handling, installation, operation and support constraints.

3. The overall system in terms of cost, time, geographic applicability, and effectiveness.

4. Future intentions and potential areas for cooperation.

Limiting Factors

It was agreed that only a point source emission would be considered, but estimates of the probable rates of flow varied. A "worst case" situation was finally chosen as 30 000 barrels per day of oil accompanied by 900 cubic feet per barrel of gas, ie., 27 000 000 cubic feet per day) of gas at atmospheric pressure.

It was also agreed to consider water depths to a maximum of 200 metres and accept the fact that the system would have only limited tolerance for debris on the seabed. It was also accepted that a system would probably require ice-breaker support in the presence of ice; its on-board storage capacity would probably be limited to about 20 days of continuous and unabated flow; construction would be a long-lead-time undertaking; and the probable high unit capital cost coupled with maintenance and operator-training requirements would virtually rule out site-specific designs in favour of one good, cooperatively-owned all-purpose system.

The Collector

The shape of the collector was not specifically addressed, but no alternatives were suggested in lieu of the conical shape adopted for the Sombrero and for the Norwegian and United States laboratory scale experiments. Discussion centred on whether or not the base of the cone must provide a seal at the seabed interface. For primarily economical reasons (in that the lower the water content the easier it is to dispose of recovered oil) Norway favoured a seal and expressed confidence that it could be achieved in practice. The desirability of having a seal was recognized, but it was agreed that the need to be able to respond effectively to a wide range of situations dictated that the system must be effective without a seal at the seabed. In support of that conclusion it was noted that a seabed production template could be about 50 m (150 ft) high.

It was agreed that not enough was known about the internal and external forces that would act upon the structure and that further research was required, probably including the use of larger scale models at greater depths.

It was anticipated that riser constraints would preclude a satisfactory common path to the surface for both oil and free gas, and that the collector would, therefore, have to separate the two phases and direct them into separate conduits. A concept for a separating collector suggested by Mr. T.G. Starr is depicted by Figure 1. It was agreed that subsea separation is a research problem that has still to be addressed and frothing was identified as a potential critical factor in the separation process.

Handling, installation, operation and support requirements were seen as being well within the capacity of current drilling technology as constrained by sea state and ice-cover. Similar ocean-going support ships would be required.

The Riser

While comparable risers are in current use, most participants were agreed that two-phase flow in the riser required research. As previously indicated, the need for a multi-conduit riser was anticipated (at least two, each having a diameter of 60 cm or more). There was agreement that system efficiency would be primarily dependent upon the efficiency of the riser, and that some further research was needed on the forces acting on the riser.

Environmental constraints were expected to be no more severe for the riser than for the collector, and handling, installation and operation would be well within the current capability as developed for offshore drilling using drillships, platforms and semi-submersibles.

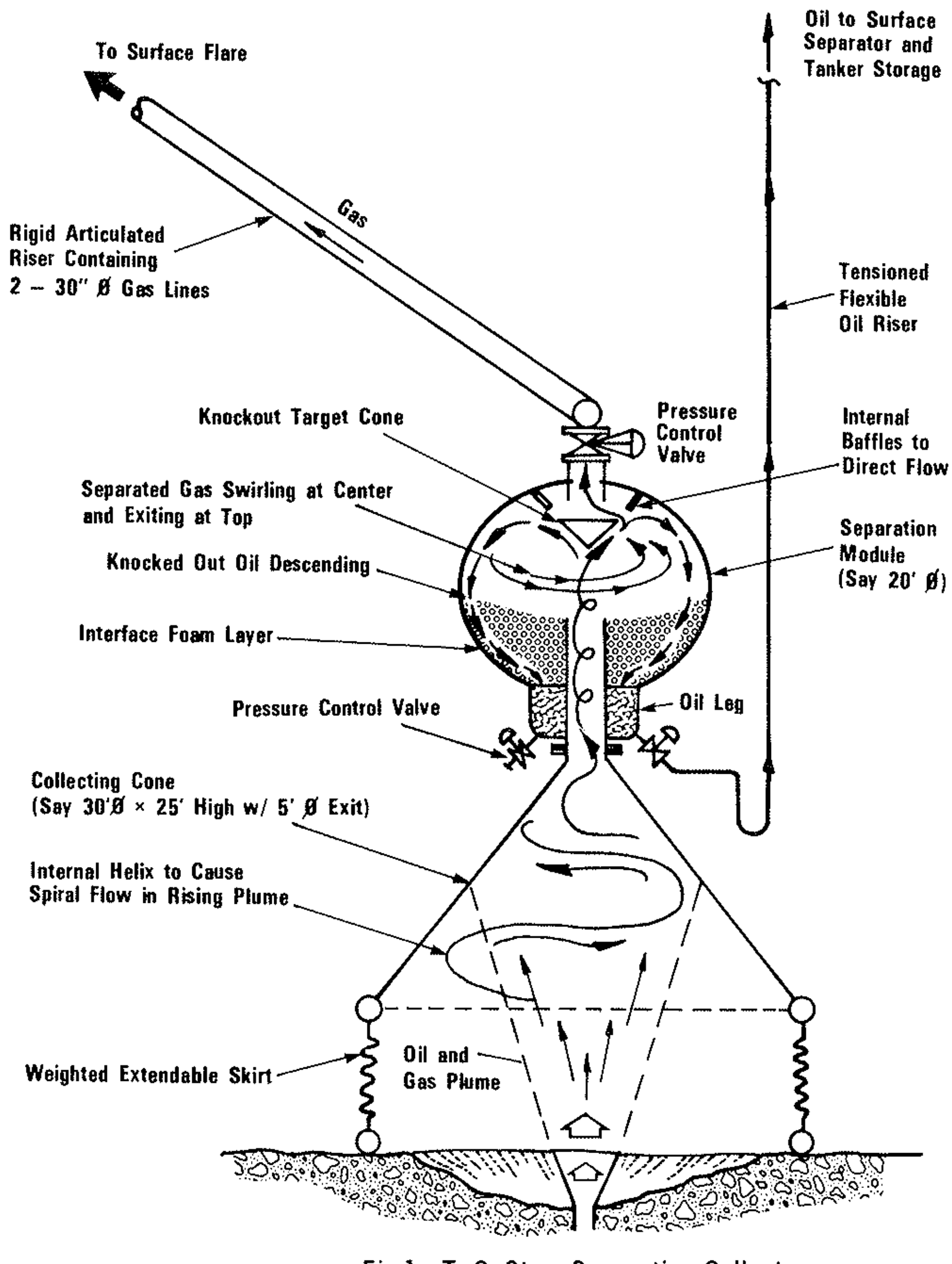

Fig.1 - T. G. Starr Separating Collector

Surface Component

The requirement for an ocean-going vessel to deploy the collector and the riser, and recognition of the need for special capabilities such as fire suppression and operation for extended periods in a toxic or potentially explosive or flammable environment, led to the conclusion that a specially equipped sea-going vessel was the most logical choice for the surface component of a general-purpose subsea containment system. A concept suggested by Capt. T. Robinson based on the use of a modified 100 000 DWT tanker equipped with handling equipment similar to that fitted on drillships is illustrated in Figure 2. Such a ship would have onboard storage capacity for 15 days of operation without off-loading, even with a 50:50 water: oil emulsion.

Opinion was divided as to the operational viability of ships (including lightering vessels) entering and remaining in the immediate vicinity of a subsea blowout, and it was agreed that a thorough safety analysis would have to confirm that this could be done with an acceptable margin of safety before making any substantial expenditure commitments.

Despite reservations, no other alternative was suggested for the surface component of a system with the widest possible range of application. Assuming that the question of operation in the plume area can be favourably resolved, it was agreed that current environmental constraints on drilling operations would apply equally to the deployment of such a subsea containment system and that it would be able to remain on station in ice-free waters in all but the most extreme weather conditions.

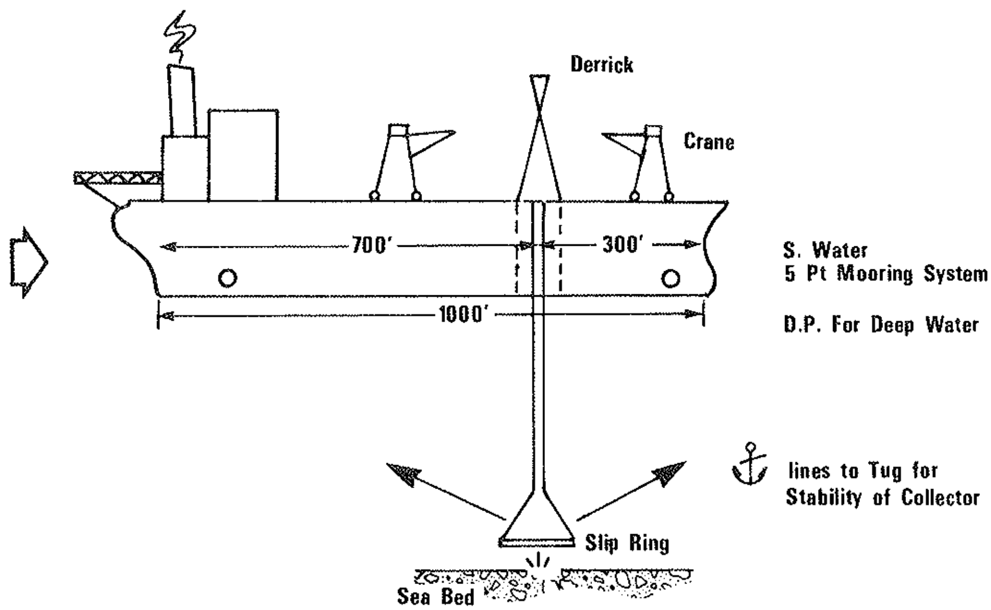

Fig.2. - T. Robinson 100,000 DWT Tanker and Subsea Containment System Concept

Situations where ice-cover would preclude the use of the ship-based system were only briefly considered and no firm conclusions were reached. However, there seemed to be a general acceptance that if a system could be evolved for the open-water situation, an adaptation for ice would follow. As an example of a possible approach, Mr. I. Buist sketched a moored open-ended buoyant cylinder for combustion of the oil and gas brought to the surface via a collector and riser assembly as envisaged for use with a ship.

System Considerations

It was estimated that a 10 m diameter cone with anchoring, sealing and gas separation capabilities would cost about $3 million, and a flexible hard-walled multiple riser bundle would probably cost $5 million. A modified 100 000 tonne tanker equipped to handle the riser and collector assembly; deal with fire and a hazardous gas environment; and off-load collected fluid would cost perhaps $25 million; an incinerator spar for Arctic use might cost $5 million. Therefore, the total estimated costs for the main system and a possible Arctic derivative were $35 million and $15 million respectively, allowing another $2 million for associated research requirements.

The estimated time required to arrive at the operational hardware stage was at least three years and perhaps as much as five or six depending upon the degree of urgency assigned to the program. The detailed design and construction phases would take about a year, and at least two years would be needed to complete the necessary research, develop the design concept, and do essential model testing.

The small-scale work done so far suggests that system effectiveness could approach 100% under ideal circumstances, but it was generally agreed that it would be premature to attempt to make a realistic projection before the research already in progress has been completed. There was also general agreement that a dedicated trained crew would be essential for an effective system.

The geographic applicability of the system was only briefly considered and no attempt was made to arrive at a concensus. However, no one took exception to a suggestion that a single ship complete with five-point mooring and dynamic positioning systems could serve the Atlantic area from the Gulf of Mexico to Labrador, and perhaps even the North sea, or that ice strengthening would further extend the area.

Future Intentions and Cooperation

Research requirements were summarized as follows in descending order of priority:

1. Problem definition;
2. Gas separator cone design;
3. Analysis of two-phase flow in the riser;
4. Mechanical design for the riser;
5. Identification of system forces, both internal and external;
6. Surface handling and processor design;
7. Mooring system arrangements; and
8. An operational system analysis, including an overall safety analysis.

Although interest was expressed in future co-operative effort and the benefits to be gained by avoiding duplication were recognized, no specific arrangements were made. Those currently doing research expressed the intent to complete that work and to share the results to the extent that proprietary interests would permit. There was also general agreement to keep other researchers informed of any new initiatives that might be undertaken cooperatively.

CONCLUSION

There was unanimous agreement that the workshop had been both timely and very beneficial. There was also unanimous agreement that the participants should endeavour to meet again in six months to a year to compare and discuss the results obtained from work done in the interim, and to discuss any proposed follow-on work.

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DOME PETROLEUM'S FIREPROOF BOOM - DEVELOPMENT AND TESTING TO DATE

Submitted by:

I.A. Buist
Dome Petroleum Ltd.
Calgary, Alberta

I.R. McAllister
McAllister Engineering Ltd.

INTRODUCTION

In situ combustion of oil on water can be an effective countermeasures technique if the floating oil slick can be contained and thickened to burnable thicknesses.

Dome Petroleum has designed, built and tested a prototype section of a fireproof boom. It is constructed of 310 stainless steel flotation chambers of pentagonal cross-section with a "sail" to provide freeboard and a PVC-coated nylon skirt to ensure containment of floating oil. The combined draft and freeboard of the boom is 1.8 m.

The floatation chambers are connected with 321 stainless steel flexible connector sections to allow the boom to follow waves.

The boom has been successfully tow-tested in both straight line and catenary configurations in waves of 1 metre. A two hour burn of crude oil was conducted with the boom used to contain the burning oil also. Of the 1 545 litres of oil pumped into the area enclosed by the boom, 99.87% was combusted. The boom survived intact and there was no effect on the structural integrity of the boom sections.

The boom was subsequently tested at the OHMSETT facility where it demonstrated excellent stability in a catenary in two speeds up to 2.5 knots and waves 0.4 m high x 19 m long. The boom contained oil in all the test waves with the first loss occurring at a two speed of 0.75 knots. Successful burns, with efficiencies estimated to be in excess of 90%, were accomplished in calm water with two speeds of 0.3, 0.5, and 0.75 knots. Successful burns were also carried out in 0.2 and 0.4 m high x 19 m long swell. It was observed that the volume of residue left increased with increasing swell height, but the combustion was still as vigorous as the calm water runs. Burning in choppy, breaking waves was not very successful as the breaking waves extinguished the flames.

Future testing of the boom will consist of the construction of a further 60 m of the boom for offshore durability, containment and burning trials.

The use of booms to contain and thicken oil so it can be burned in situ on a water surface has been investigated in several previous Canadian studies (Purves and Daoust, 1978; Roberts and Chu, 1978 and McAllister, 1979). Each proposed design, however, failed to be an operationally feasible device for one reason or another.

As a result of work on a "quickie" fireproof boom, Dome Petroleum decided to undertake a project to research, develop, construct and test a fireproof boom that has the following design criteria:

i. the ability to withstand flame temperatures of 980°C for extended periods of time in a salt-water environment and be reuseable;

ii. the ability to contain oil in a "U-shaped" configuration in a sea state 4 and survive a sea state 5;

iii. be as compact as possible and remain flexible down to -20°C and storable to -50°C;

iv. have good abrasion resistance so as to be able to withstand frequent handling and some contact with ice;

v. easily deployed, if possible manually, using standard rig supply vessels and easily towed at 2 knots; and

vi. have a tensile strength of at least 110 000 newtons.

This project, which commenced in the fall of 1979, has been funded by the Canadian Offshore Oilspill Research Association, an organization of oil companies with interests in Canada's offshore waters, and by AMOP who provided funding for a portion of the OHMSETT trials.

This article deals with the development and design of a prototype section of fireproof boom, the results of the preliminary towing trials, the fire testing and subsequent OHMSETT trials and the conclusions and recommendations arising from the test programs to date. Proposed offshore tests are also reviewed.

BOOM DESIGN

In order to meet the design criteria an extensive search for suitable materials of construction was instituted, using Roberts and Chu (1978) as a starting point. It became apparent that there were very few materials that could meet the design requirements and that only two were relatively inexpensive; these being high chromium stainless steels, such as type 309 and 310 (Perry and Chilton, 1973) and a refractory blanket material manufactured by the Carborundum Company, "Fibrefax L144" which is a cloth material woven with a Nichrome wire.

Using these materials a 12 m section of prototype boom was constructed, consisting of vented stainless steel flotation units of pentagonal cross-section with a "sail" to provide freeboard and a PVC coated nylon skirt underwater to provide draft (see Figure 1). To provide wave conformation, each 1.5 m long flotation unit was joined to a 0.75 m long flexible panel constructed of stainless mesh encased "Fibrefrax" blanket connected to a further section of PVC coated nylon skirt.

Tension members, consisting of 9.5 mm diameter stainless steel cables were added to ensure no tension loads were placed on the flexible panels. The overall height of the boom was 1.77 m, with 0.66 m being the freeboard in calm water.

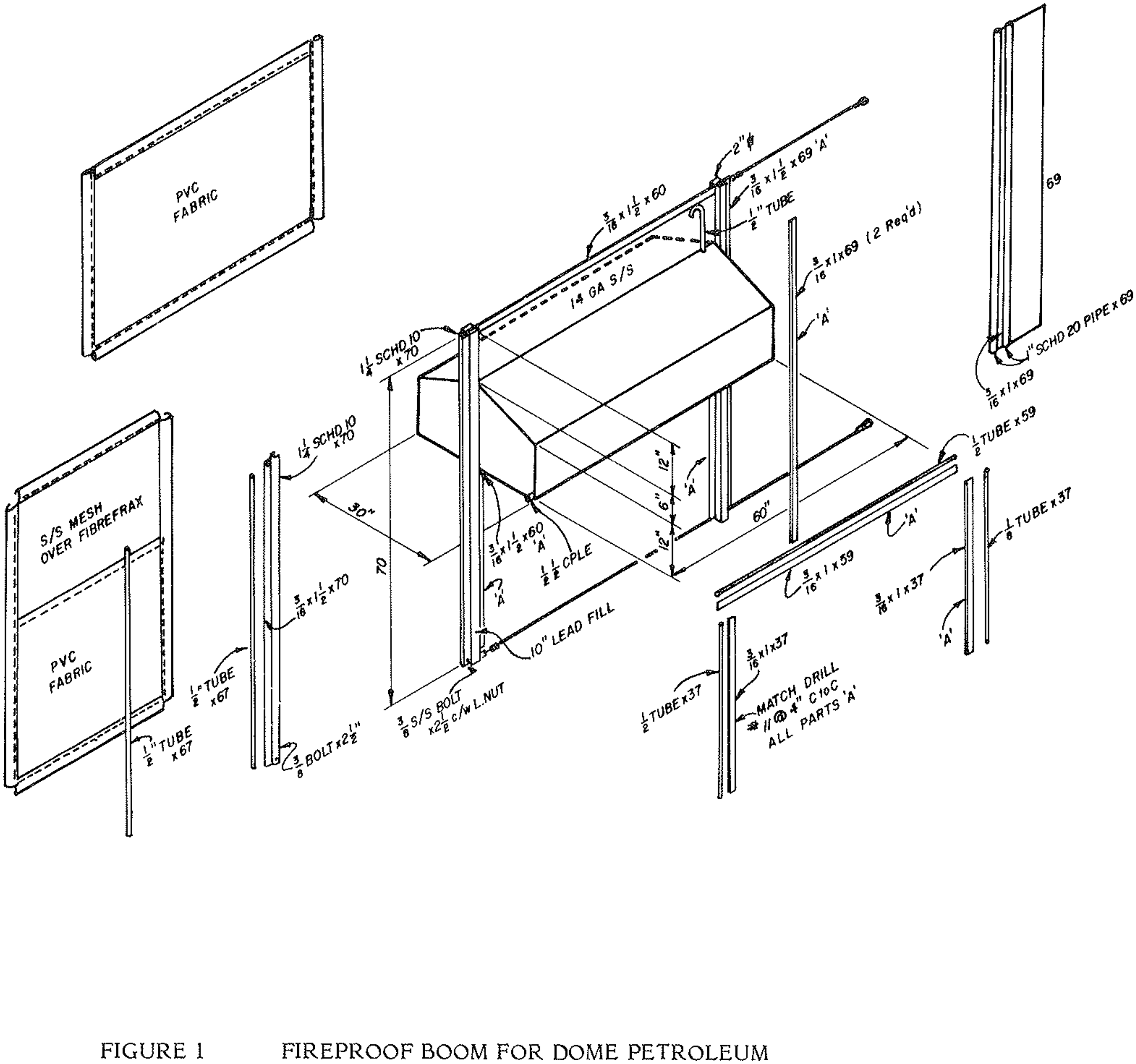


FIGURE 1 FIREPROOF BOOM FOR DOME PETROLEUM

Each section of the boom was connected by means of a sliding joiner. These joiners fit inside slotted pipes fastened to both the free end of a flexible panel and the end of the next flotation unit.

TOWING TRIALS

Following successful static flotation trials that confirmed the stability of the flotation units, the boom was tow-tested in both straight line and catenary configurations. The straight line tests revealed that the boom could be successfully towed at speeds up to 5 knots, but that at this speed the prop wash tended to deflect the first section of the boom. A significant bow wave was set up by the first section which resulted in a high drag force on the boom as well. It was concluded that for an operational model a towing paravane should be included.

The catenary towing trials were held in a short, choppy sea with wave heights of approximately 1 m and a wind speed of 30 km/h. The boom conformed well to the waves, demonstrated excellent stability and was only overtopped once by a small amout of spray from a breaking wave.

Following these trials it was discovered that the "Fibrefrax" material had been seriously eroded by the action of the waves and it was concluded that the flexible panels, as originally designed, would not contain oil.

FLEXIBLE PANEL REDESIGN

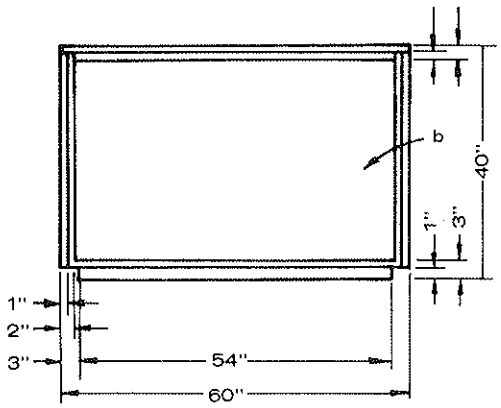
Following a further investigation of suitable construction materials, it was decided that the flexible panels should be built from a thin gauge (0.4 mm) type 321 stainless steel sheet that had been corrugated to provide the required flexibility (see Figure 2). These panels were fitted to the boom and a second towing trial confirmed that they did have the required flexibility and durability. Each boom section as redesigned, has a weight of approximately 125 kg, a gross buoyancy of approximately 440 kg and a buoyance to weight ratio of 3.5:1.

BURNING TRIALS

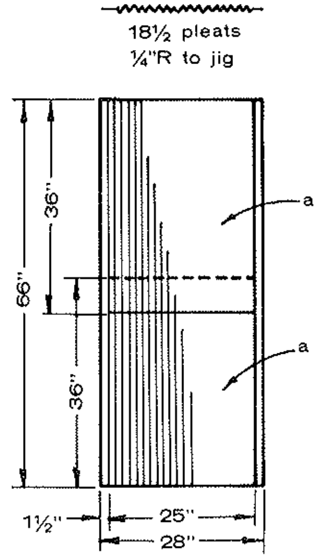
In order to confirm that the design of the boom and the materials selected would withstand the temperatures of a crude oil fire; that no corrosion problems would occur and to investigate the continuous combustion of crude oil on water, a burning trial was held December 12, 1980 near Port Mellon, B.C.

The boom, with the redesigned flexible panels, was connected in a circle and secured inside an area encircled by 0.9 m inshore boom and fender logs, as shown in Figure 3.

Thermocouples were mounted at various locations on one section of the boom and monitored from a barge, placed adjacent to the test site, for use as a logistics and observation platform. Nine drums of Redwater Crude Oil (specific gravity = 0.839 @ 26°C, viscosity = 8 mPa.s @ 21°C) supplied by Imperial Oil, were also placed on the barge and a pump and hose were provided to pump the oil continuously under the skirt of the fireproof boom as shown in Figure 3.



Part 'D' BOTTOM PANEL
1 Req'd



Part 'B' CONNECTION PANEL
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FIGURE 2 FIREPROOF BOOM PROTOTYPE - FLEXIBLE PANEL DETAILS

After a slick of 2-3 mm thickness had been pumped into the area enclosed by the fireproof boom it was ignited by a burning oil-soaked sorbent pad. Over a two hour burning period, 1 545 litres of crude were pumped into the boomed area. At the completion of the trial only 2 litres of oil residue remained within the boom resulting in a burn efficiency of 99.87% and a slick regression rate of 2.3 mm/min. Analysis of the burn residue revealed that it had a specific gravity of 0.933, and before and after analysis of water column and sediments did not detect conclusive differences in hydrocarbon concentrations. Both these results lead to the conclusion that no oil was lost to the water column during the burns.

The temperatures measured at various points on and around the boom are shown in Figure 4. The maximum temperature measured was 905°C (1 660°F) well within the design maximum exposure temperature of 980°C (1 800°F).

It is interesting to note that the inside boom skin temperature was consistently recorded as higher than the flame temperature. This may either be a calibration error or a reflection of the fact that, due to oxygen starvation the combustion process was taking place at the edges of the boom and in the air space above it, rather than immediately above the slick.

The thermocouples located in the water below the fire (No.'s 1 and 2 on Figure 4) indicated that although some heat was being transferred to the water it was not raising

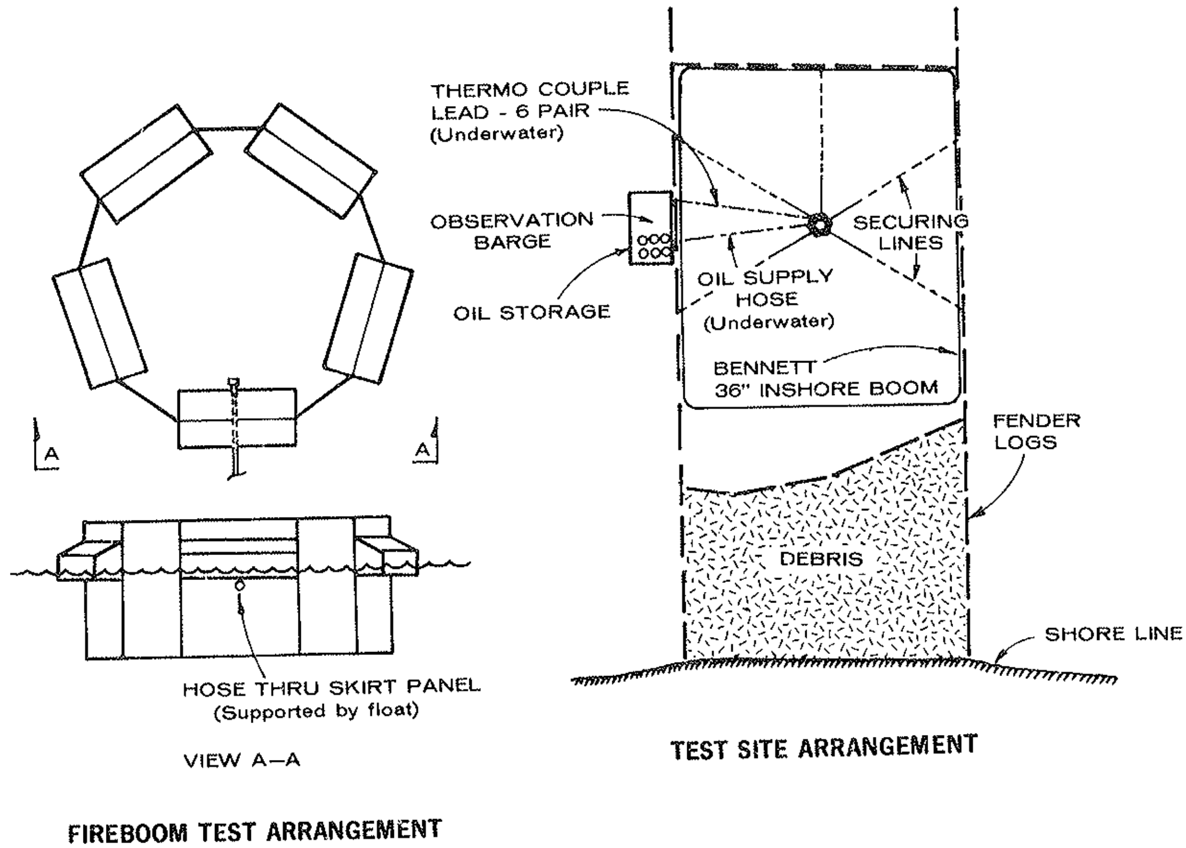

FIGURE 3 FIREPROOF BOOM PROTOTYPE - TEST ARRANGEMENT

the water temperature appreciably, even 4 cm below the burning slick. Presumably much of the heat transferred into the water column was being absorbed in boiling off a thin surface layer of water. This was evidenced by observations of some droplet carryover during the combustion, normally caused by boiling, and the fact that during gusts of wind that bent the flame over the side of the boom; the surface water in close proximity to the fame could be observed boiling.

During the trial, a small fire was observed burning outside of the boom. The source of this leak was later determined to be a gap at the waterline in the stitch welding and not a failure of the boom caused by the burning.

The smoke plume generated by the burn rose vertically to a height of approximately 300 m and then dispersed horizontally with visible smoke disappearing within 2-3 km downwind.

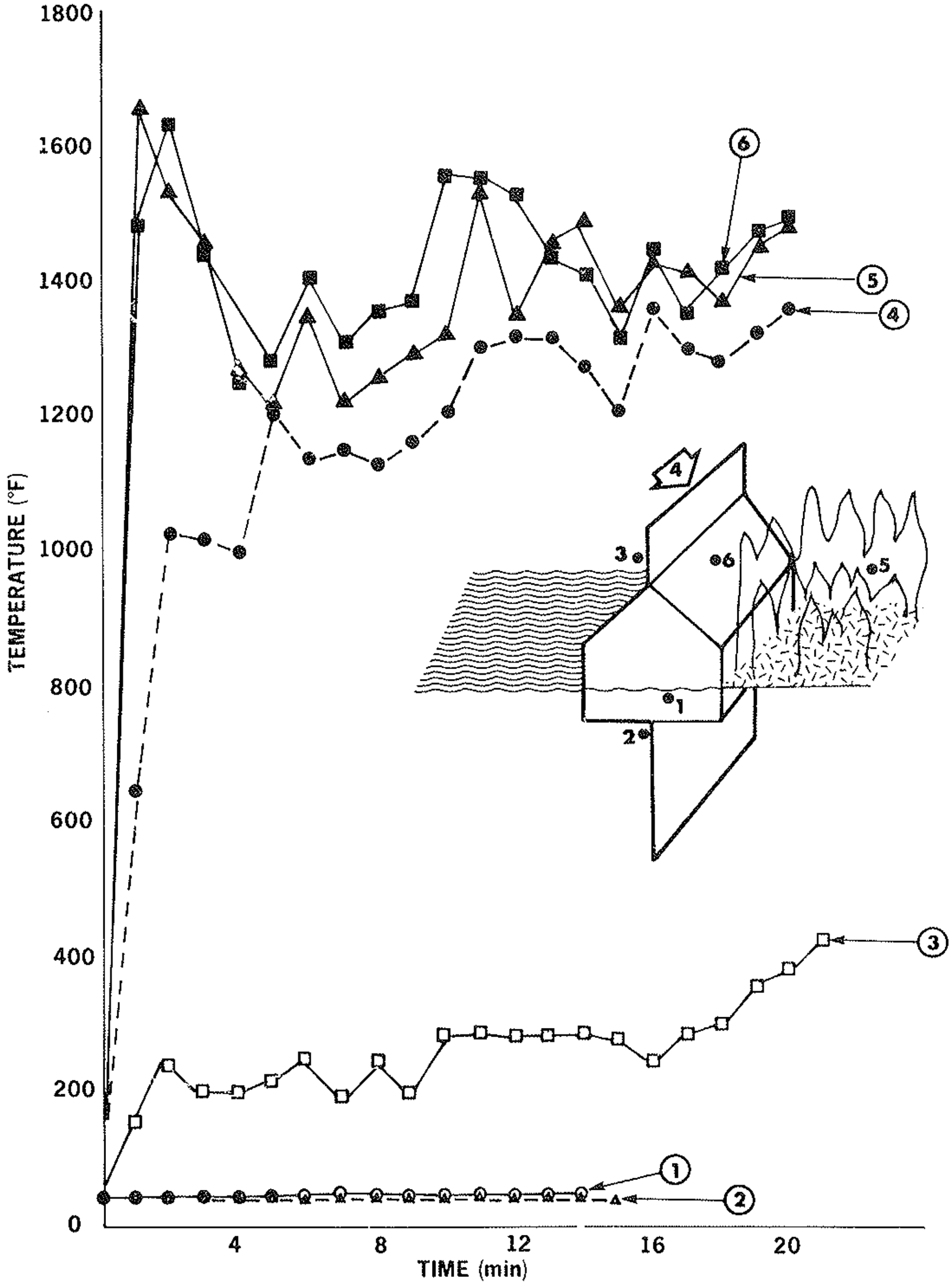

FIGURE 4 TEMPERATURE PROFILES

When the fire had extinguished itself the boom was examined and found to be in good structural condition. Some of the sheet metal was slightly warped and the exposed surfaces were covered with droplets of a hard asphaltic residue caused by the aforementioned droplet carryover. On removal from the water no further damage was observed and the boom was considered ready for immediate re-use.

OHMSETT TRIALS

Following the burn trails the prototype boom was tested at the U.S. Environmental Protection Agency Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) facility to further confirm its towing and stability characteristics, define its oil containment characteristics in controlled wave and current conditions, and investigate the effects of waves and currents on in situ combustion.

Two oils were utilized for the testing, a Circo 4X light oil (specific gravity = 0.9, viscosity = 11 mPa.s @ 22°C) for the containment trials and Murban crude oil (specific gravity = 0.85, viscosity = 9 mPa.s @ 14°C) for the in-situ combustion trials.

The test matrix and the preliminary results obtained from the program are summarized in Table 1.

As can be seen from Table 1 the boom exhibited excellent stability in all the wave conditions tested and was found to contain oil at speeds up to 0.4 m/s (0.75 knots). At this speed a vortex formed between adjacent flotation units that drew small quantities of oil beneath the skirts. The anomalous containment of oil by the boom at up to 1.25 m/s tow speeds observed in Runs 3R, 4 and 19 was presumably due to the small volumes of oil used in these runs.

Runs 8, 9, 10 and 19 showed that, in calm conditions the combustion was not adversely affected by increased tow speed up to 1 m/s. However, it is probable that had larger volumes of oil been used, at speeds exceeding 0.5 m/s the combustion efficiency would be reduced due to entrainment of the oil beneath the boom. A comparison of runs 8, 18, 14, 15 shows that increasing swell height did not affect the ability to ignite the slick or the intensity of the resulting in situ combustion. However it was observed that the amount of residue left increased with increasing swell height. This was a function of the relatively small volumes of oil used in these trials and is not expected to seriously affect overall combustion efficiencies on a large-scale.

The results of runs 15 and 16 illustrate that in the swell wave condition the intensity of the burn was not affected until the tow speed reached 0.5 m/s (1 knot) at which point it was drastically reduced, presumably by the turbulence set up inside the catenary by the small waves reflected off the boom at this speed.

Of the three runs done in harbour chop (11, 11R and 11R') ignition was only achieved once (11R') by increasing the oil volume and using two igniters. The flame spread was slow and the combustion poor. Before the entire surface area of the slick was ignited a breaking wave extinguished the flames.

TABLE 1 TEST MATRIX AND PRELIMINARY RESULTS

Test No.	Tow Speed (m/s)	Wave Type	Wave Height X Length (m)	Oil (Amount)	Remarks
1	0.25 - 1.0	calm	-	-	- stable in catenary, no rolling
2	0.25 - 1	swell	0.4 x 19	-	- stable, good wave confor-mance, no rolling
3	0.25 - 5.0	calm	-	Circo 75 l	- first loss at 0.4 m/s at vortex between floats
3R	0.25 - 1.25	calm	-	Circo 38 l	- required 1.25 m/s, to flush oil, at lower speeds oil not touching boom
4	0.25 - 1.0	swell	0.4 x 19	Circo 75 l	- first loss at 1 m/s, oil held out from boom by float backwash
7	0.25 - 1.0	harbour chop	0.2	Circo 75 l	- first loss at 0.4 m/s, oil dis-persed by tur-bulence in catenary
8	0.25	calm	-	Murban 38 l	- intense burn for 5 min, esti-mated greater than 90% effi-ciency
9	0.15	calm	-	Murban 38 l	- intense burn for 5 min 51 s, estimated same efficiency as 8

TABLE 1 TEST MATRIX AND PRELIMINARY RESULTS (cont'd)

Test No.	Tow Speed (m/s)	Wave Type	Wave Height X Length (m)	Oil (Amount)	Remarks
10	0.35	calm	-	Murban 38 1	- flames had some difficulty spreading up-wind, intense burn after for 4 min, 43 s
11	0.25	harbour chop	0.2	Murban 38 1	- no ignition of oil, igniter pushing oil away by bobbing
11R	0.25	harbour chop	0.2	Murban 38 1	- no ignition of oil
18	0.25	swell	0.2 x 19	Murban 38 1	- ignited in calm condition, in-tense burn for 3 min, 39 s, more residue than 7, 8 and 9
14	0.25	swell	0.4 x 19	Murban 38 1	- ignited in calm, intense burn for 2 min, 29 s, more residue than 18
15	0.25	swell	0.4 x 19	Murban 38 1	- ignited in waves, intense burn for 2 min, 54 s ,approx. same residue as 14
16	0.36 x 0.5	swell	0.4 x 19	Murban 38 1	- ignited in waves, intense burn for 2 min at 0.35 m/s, poor burn for 1

TABLE 1 TEST MATRIX AND PRELIMINARY RESULTS (cont'd)

Test No.	Tow Speed (m/s)	Wave Type	Wave Height X Length (m)	Oil (Amount)	Remarks
					min, 59 s, at 0.5 m/s
19	0.35 - 1	calm	-	Murban 38 l	- intense burn for 3 min, 10 s, no difference in burning with increased speed
11R'	0.25	harbour chop	0.2	Murban 38 l	- successful ignition, poor flame spread, poor combustion, extinguished by break wave
20	0.25	calm	-	Murban 38 l	- emulsified oil from 11R successfully burned for 7 min, 10 s
21	0.25 - 0.75	calm	-	Circo 3800 l	- first loss at 0.4 m/s through vortex, extensive loss by entrainment at 0.5 m/s
21L	0.25 - 1	harbour chop	0.6 m	-	- durability trial - survived well, excellent stability - minor damage to skirt observed on removal

Upon removal of the boom the only damage observed to have occurred was the loss of six rivets which resulted in the slight bending of one of the skirt holding rods, and some wear on the upper flexible panel tension cable securing points.

FUTURE TESTING

At the time of writing it was proposed that an additional 60 m of boom be constructed, with some minor design changes (principally reinforcing the tension cable securing points and using larger rivets) and tested offshore. The purpose of this testing would be to fully evaluate the boom's performance with respect to towing, stability, structural integrity and containment in Sea States 1 to 5 and evaluate ignition and in situ combustion of crude oil in Sea States 4 to 5. Operational guidelines with respect to deployment, recovery, maintenance and storage will also be developed.

CONCLUSIONS

1. The boom as now constructed has met the design criteria. It has a total height of approximately 1.8 m and each 2.25 m long section, consisting of a stainless steel flotation unit and stainless steel flexible panel, weighs 125 kg, has a gross buoyance of 440 kg and a buoyance to weight ratio of 3.5:1.

2. The boom has demonstrated excellent stability in both straight line and catenary configuration tow tests at speeds up to 5 knots in Sea States up to 3.

3. A successful calm water stationary burn trial was held during which time approximately 1543 of 1545 litres of crude oil pumped were burned off over a 2 hour period resulting in a 99.87% efficiency. Although the boom was exposed to flame temperatures in excess of 900°C during these trials it suffered no structural damage.

4. The boom can contain oil in swell and harbour chop at current speeds of up to 0.4 m/s.

5. The boom can thicken and contain burning oil in calm water and in swells of 0.4 m height x 19 m length at current speeds of up to 0.4 m/s.

6. In-situ burning of crude oil, in the harbour chop conditions and with the oil volumes tested, was not very successful; however, with larger quantities of oil it maybe possible.

RECOMMENDATIONS

1. The boom should be tested offshore to fully evaluate the boom's performance with respect to towing, stability, structural integrity and containment in Sea States 1 to 5 and to evaluate the feasibility of in situ combustion of oil in Sea States 4 to 5.

2. The flexible panel tension cable securing points should be reinforced.

3. Larger rivets should be used to secure the skirt material.

4. A paravane should be utilized to reduce drag during straight line tows.

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SPILL TECHNOLOGY NEWSLETTER

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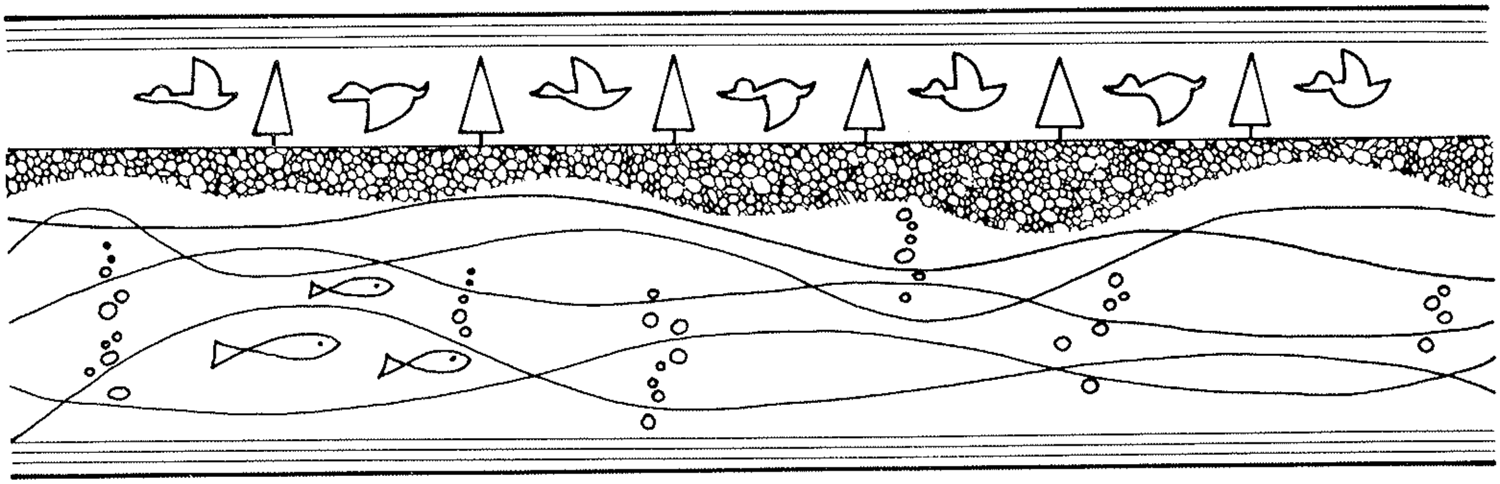


Table of Contents

Spill Technology Newsletter

EDITORS

Mr. M.F. Fingas and Dr. D.E. Thornton

Research and Development Division
Environmental Emergency Branch
Environmental Impact Control Directorate
Environmental Protection Service
Department of the Environment
Ottawa, Ontario
K1A 1C8

Phone: (819) 997-3921

The Spill Technology Newsletter was started with modest intentions in 1976 to provide a forum in Canada for the exchange of information on oil spill countermeasures and other related matters. The interest in it was such that we now have over 2,500 subscribers in Canada and around the world.

To broaden the scope of this newsletter, and to provide more information on industry and foreign activities in the field of oil spill control and prevention, readers are encouraged to submit articles on their work and views in this area.

INTRODUCTION

The first article of this issue by Mssrs. Rosen and Reinson describes a shoreline classification of Groswater Bay, Labrador. This type of classification can then be used as a basis for the development of a contingency plan for the area. The second article was submitted by members of the Faculty of Chemical Engineering at the University of Palma de Mallorca. The article describes a dispersant efficiency test of the product, Renex 697. The finding in this study was that a maximum of 48% of the oil (Kirkuk crude) could be dispersed with the optimal application rate of 1:20 (dispersant:oil). The third article of this issue by Mark Reed describes an Oil Spill - Fisheries impact model which has been developed.

REPORTS AND PUBLICATIONS

- Concawe (The Oil Companies' International Study Group for Conservation of Clean Air and Water - Europe) has released the publication, "A Field Guide to Coastal Oil Spill Control and Clean-Up Techniques". For further information contact: Concawe, Babylon - Kantoren a, Koningin Julianaplein 30-9, 2595 AA, Den Haag, Netherlands.

- The Environmental Emergency Branch has recently released a contractor's report, the title of which appears below. Reports in this series are unedited and have not undergone rigourous technical review but will be distributed on a limited basis to transfer the results to people working in related fields. For copies of these reports contact: Publications Coordinator, Environmental Impact Control Directorate, Environmental Protection Service, Ottawa, Ontario, K1A 1C8.

  "Laboratory Experiments in the Detection of Oil Under Ice." (EE-26).

- The Baffin Island Oil Spill (BIOS) project has recently released three working reports, the citations of which appear below. These reports have not undergone rigorous technical review but will be distributed on a limited basis to provide the results to those working in related topics. For copies of these reports contact: Publications Coordinator, Environmental Impact Control Directorate, Environmental Protection Service, Ottawa, Ontario, K1A 1C8.

  Bunch, J.N., Harland, R.C. and Laliberté, J., 1981, Microbiology: 1. Effects of Oil on Bacterial Activity - 1980 Study Results. (BIOS) Baffin Island Oil Spill Project Working Report 80-5: 68 p.

  McLaren, P., Barrie, W.B. and Sempels, J.M., 1981, Geomorphology - 1980 Study Results. (BIOS) Baffin Island Oil Spill Project Working Report 80-7: 200 p.

  Dickens, D.F. and Brown, R., 1981, Ice Conditions - 1980 Study Results. (BIOS) Baffin Island Oil Spill Project Working Report 80-8: 86 p.

- The following reports are available from the U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia, 22161, Telephone (703) 487-4650. Most reports are also available on Microfiche at $3.35 each (U.S.A. Price). Canadian buyers add $2.50 to each paper copy and $1.50 for each microfiche report. Prices are quoted in U.S. dollars.

  <u>Oil and Petroleum</u>

  "Assessment of Treated vs Untreated Oil Slicks. Final Report". M.P. Wilson. Rhode Island University, Kingston. February, 1981. 1048 p. DOE/EV/24047-03 $66.50.

"The Biological Effects of Oil Spills. 1978-May, 1981 (Citations from the NTIS Data Base)". National Technical Information Service, Springfield, Virginia. May, 1981. 253 p. PB81-806200 $28.00.

"Research Needs to Reduce Maritime Collisions, Rammings and Groundings". National Research Council, Washington, D.C. May, 1981. 142 p. AD-A100 09216 $12.50.

Other Hazardous Materials

"The effects of Toxic Substances on Fish. January, 1970-June, 1981 (Citations from Pollution Abstracts)". National Technical Information Service, Springfield, Virginia. June, 1981. 80 p. PB81-869083 $28.00.

"Development of a System to Protect Groundwater Threatened by Hazardous Spills on Land". K.R. Huibregtse and K.H. Kastman. Rexnord, Inc., Milwaukee, Wisconsin. May, 1981. 143 p. PB81-209587 $12.50.

"Program to Compute Downwind Concentrations from a Toxic Spill". J. Zimmerman. National Weather Service, Salt Lake City, Utah. February, 1981. 18 p. PB81-205296 $5.00.

"Bibliography on Hazardous Materials Analysis Methods". J.R. Simons. Aerospace Corp., Germantown, Maryland. June, 1981 88 p. PB81-213258 $9.50.

- The Environmental Emergency Branch has released a new publication; the title and abstract of which appears below. This publication may be obtained upon request from:

Publications Coordinator
Environmental Impact Control Directorate
Environmental Protection Service
Ottawa, Ontario
K1A 1C8

Microwave Systems for Detecting Oil Slicks in Ice - Infested Waters: Phase I - Literature Review and Feasibility Study (EPS-3-EC-81-3).

A study was undertaken to ascertain the possibilities and problems associated with the use of microwave techniques in detecting oil pollution in the ice environment. A comprehensive investigation into the microwave emission and scattering properties of sea ice, oil on water, and the ocean surface was made and the results of analyses are presented. Available information on the electrical properties of oil and the behaviour of oil in the ice environment is included. A selected, annotated bibliography of the published literature on microwave scattering and emission from sea ice, water and oil on the water surface is attached as Appendix 6. The design and data requirements of an experiment have been outlined. Possible radar data processing and analyses methods are given. In recommending required future efforts, it is suggested that theoretical and laboratory studies, as well as experiments under controlled conditions, are likely to produce quantitative information on the microwave emission and scattering from oil in the ice environment.

The results show that only a qualitative assessment of a limited nature can be made on the performance of active and passive microwave systems in detecting oil slicks in the ice environment from the limited information available on microwave emission and scattering from sea ice, oil on water, and the ocean.

It appears that either Ku-orX-band active measurements, along with L-band measurements, are suitable for detecting oil when it is present on and in the top surface of the ice. Both VV and HH polarizations seem equally likely to succeed, with cross-polarization providing additional useful information.

The passive systems operating at frequencies of around 37 GHz with horizontal polarization and at angles of incidence of 30° to 45° from nadir seem appropriate. The use of a lower frequency in the range from 8 to 14 GHz may provide additional information.

Active and passive systems operating in the frequency range from 100 to 300 MHz may be able to detect oil when it is present under ice, or is contained within the lower regions of sea ice.

The presence of oil in the ice environment is likely to be detected through indirect subtle clues (i.e., changes in texture and tone such as those produced by increased melting of oil covered areas in comparison with oil free areas).

UPCOMING CONFERENCES

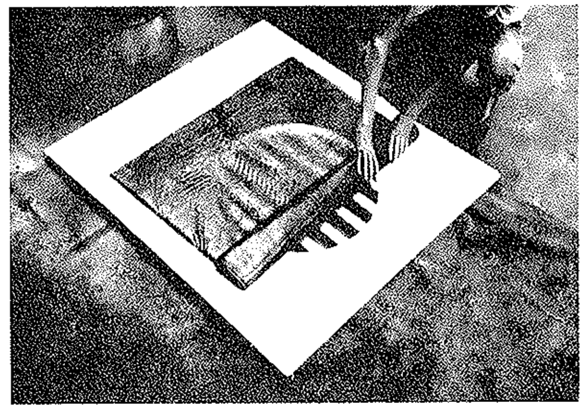
- The Sixteenth International Symposium on Remote Sensing of Environment will be held 2 - 9 June, 1982, in Buenos Aires, Argentina. Further information on this conference can be obtained from; Dorothy M. Humphrey, Environmental Research Institute of Michigan, P.O. Box 8618, Ann Arbor, Michigan, 48107, Telephone: (313) 994-1200.

- The 65th Chemical Conference and Exhibition of the Chemical Institute of Canada will be held in Toronto, Ontario, May 30 - June 2, 1982. For further details contact; the Chemical Institute of Canada, 151 Slater Street, Suite 906, Ottawa, Ontario, K1P 5H3, Telephone: (613) 233-5623.

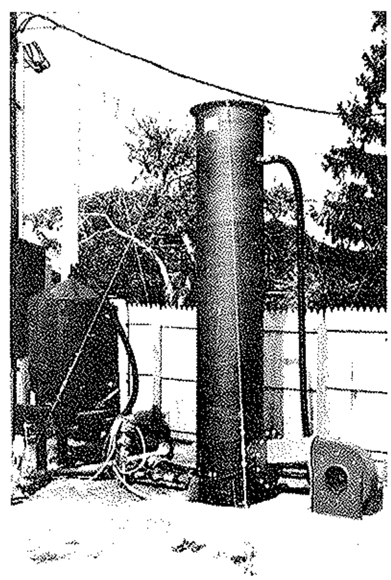
- A one week introductory course on "Groundwater Pollution and Hydrology" will be offered at The Nassau Inn in Princeton, New Jersey. Registration is $675 (U.S.). For further information contact: Mrs. Iva Barros, Princeton Associates, P.O. Box 2010, Princeton, New Jersey, 08540, Telephone: (609) 924-4163.

NEW PRODUCTS

●SPILSTOPPER is a flexible elastomeric mat designed to seal surface-mounted drains, manholes and grates from spills of petroleum or other products. The device is claimed to be easily cleaned, portable and inert to caustic materials. For further information contact: Clark Products Co., Inc., 916 W 25th Street, Norfolk, Virginia, 23517, Telephone: (804) 625-5917.



●Oil Recovery Systems Inc. has recently designed a water purification system consisting of an air-stripping tower and carbon absorption tank, to remove dissolved organics from groundwater recovery wells. The tower is 2 feet in diameter and 14 feet high. The carbon tank has a 200 gallon capacity. Tests have been conducted at 6.5 gallons per minute yielding efficiencies greater than 99%. Additional tests at 12 g.p.m, 28-30 g.p.m, and 48-50 g.p.m yielded efficiencies greater than 90%. For further information contact; Oil Recovery Systems Inc., Greenville, New Hampshire, 03048, Telepone (603) 878-2500.



AN OIL-SPILL CONTINGENCY PLAN FOR GROSWATER BAY, LABRADOR: SHORELINE CLASSIFICATION

Submitted by:

P.S. Rosen, Department of Earth Sciences,
Northeastern University
Boston, Massachusetts 02115

G.E. Reinson, Consulting Geologist,
180 Cornwallis Dr., N.W.,
Calgary, Alberta, Canada T2K 1V2

INTRODUCTION

The purpose of this investigation was to define shoreline characteristics of the Groswater Bay region, Labrador, as a means to assess the susceptibility of the coast to oil-spill impact. The study area extends from Ship Harbour (north) to Sandy Point (south) (Fig. 1). Groswater Bay is an 80-km long embayment which is the entrance to Lake Melville. The Lake Melville-Groswater Bay system is the largest embayment and the primary shipping and port area on the Labrador Coast.

METHODS

The study area was divided into eight segments. Data was compiled for each segment to characterize differing regions in Groswater Bay (Table 1).

The shore classification system was initially utilized by Rosen (1980) to define the morphology of the Makkovik region, Labrador. It is based on morphologic parameters (cobble, sand beaches; salt marsh; fractured, smooth rock) which can readily be identified with aerial overflight. A measure of wave energy along the shoreline is described by the height of the wave-wash zone above HWL (high water line) along rocky shorelines: 0-2 m, low energy; 2-6 m, moderate energy; 6 m, high energy.

A shoreline density index was devised to describe the amount of shoreline per given length of coast. This index is the ratio between the total shoreline length and the coastal length, measured by straight lines between major headlands. A higher index defines shore regions with highly indented shorelines or complex island-and-tickle morphology (Table 1). A given oil spill will contaminate more shoreline length in these areas.

With the exception of one community (Rigolet), the region is sparsely populated. The vulnerability of shorelines in this area is based on the ability of the coast to restore itself by natural physical processes. Any cleanup or containment activities can be concentrated on the most vulnerable regions, as defined herein.

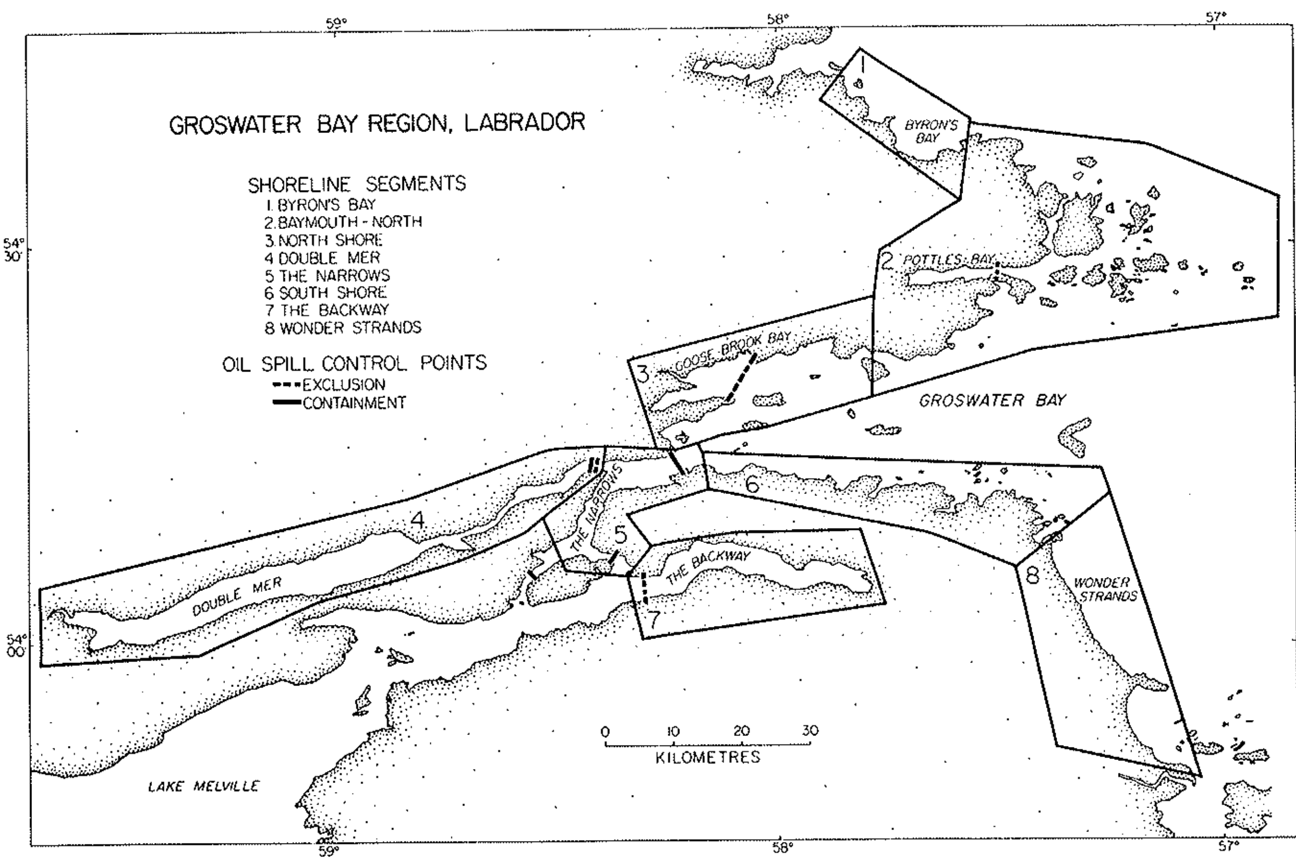


FIGURE 1 MAP OF THE GROSWATER BAY REGION SHOWING THE EIGHT SHORELINE SEGMENTS AND PROPOSED OIL SPILL CONTROL POINTS

TABLE 1 COASTAL ENVIRONMENTS OF THE GROSWATER BAY REGION, LABRADOR (The data has not yet been compiled for Double Mer)

	Marsh		Sand Beach		Cobble Beach		Low Energy		Smooth Rock Moderate Energy		Smooth Rock High Energy		Fractured Rock Low Energy		Fractured Rock Moderate Energy		Fractured Rock High Energy		Total Segment Length	Shoreline Density Index
	%	km	%	km	%	km	%	km	%	km	%	km	%	km	%	km	%	km		
1 Byron's Bay	5	2	37	15	10	4	0	0	20	8	0	0	0	0	13	5	15	6	40	1.25
2 Baymouth North	16	67	2	9	23	99	10	45	17	74	6	24	15	66	6	23	5	21	428	5.48
3 North Shore	60	62	8	8	15	16	8	8	0	0	0	0	7	7	2	3	0	0	104	1.29
4 Double Mer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5 The Narrows	11	7	9	6	36	24	29	19	0	0	0	0	15	10	0	0	0	0	66	1.46
6 South Shore	37	44	10	12	16	19	20	24	1	1	3	3	10	13	3	4	0	0	120	2.15
7 The Backway	28	31	41	45	16	18	10	11	0	0	0	0	5	5	0	0	0	0	110	1.20
8 Wonder Strands	0	0	81	46	2	1	0	0	3	2	9	5	0	0	2	1	3	2	57	1.08
Total	23	213	15	141	20	181	12	107	9	85	3	32	11	101	4	36	3	29	915	2.16

Total Rock Shore: 42%/390 km

A more extensive geomorphic analysis of the central Labrador coast (Reinson *et al.*, in prep.) will be used to extend and refine the plan.

SEGMENT DESCRIPTIONS

1. Byron's Bay

This segment, extending from Cape Rouge to Ship Harbour, faces the Labrador Sea. It consists of rock shorelines (45 percent) with numerous embayed accretional sandy beaches. The largest are at Byron's Bay and Michael's River. The vegetation on the barrier dunes is a unique habitat composed of tundra and coastal species (personal communication, Paul Godfrey, 1978). An oil spill should not affect this habitat directly. The high wave energy exposure and low shore density index (1.25) should facilitate natural cleansing. However, any shore cleanup should be focused on the two major beach systems to prevent possible burial and long-term preservation of the contaminant.

2. Baymouth-North

This region, extending from Black Island to Cape Rouge, encompasses the peninsula that forms the northern bay entrance. This segment contains the largest amount of shoreline, resulting in a density index of 5.48. Most of this distance is composed of numerous islands separated by narrow straits (tickles). Although much of this segment is exposed to the full wave energy of the Labrador Sea, much of the coastal length lies in leeward settings, providing areas conducive to the collection of oil. However, there is minimal development of sedimentary intertidal zones; 59 percent of the area is rocky shores and 23 percent consists of cobble beaches. There are two major embayments. Abliuk Bight is 8 km long and virtually devoid of sediment and salt marsh. Pottles Bay is 15 km long and morphologically similar to "Goose Brook Bay" (q.v.), containing most of the marsh habitats in the segment. The narrow (1 km) entrace to Pottles Bay is the most efficient exclusion point, as most marsh is inside this point. The remainder of this segment can restore itself by natural processes in time, with minimal long-term damage.

3. North Shore

This segment, extending from Ticoralak Head to Black Island, is the most environmentally sensitive area in Groswater Bay. Although this is a relatively straight coast (density index = 1.29), over 60 percent of the shore has marsh development (62 km). A large bay, referred to as "Goose Brook Bay", encompasses most of the segment. This bay contains extensive boulder/mud flats, but no boulder barricades. The mud flats result from the input of two large rivers which transport fine-grained material into the system. The most extensive salt marsh in the Groswater region occurs at the mouth of Goose Brook (about 12 km^2). Fringe marsh lines the shore, at least intermittently, throughout the segment. The isolated sand beaches usually occur associated with the numerous creeks draining into the bay.

Cleanup of oil would be difficult, due to the boulder flats, extensive shoal areas and abundant marsh. However, containment of the pollutant outside the 5.5 km wide mouth of "Goose Brook Bay" would protect the most valuable marsh community in the region.

4. Double Mer

This shoreline is morphologically similar to the Backway. This 73-km long embayment is connected to the Narrows by an 0.7-km wide channel, which would make an efficient exclusion point for protecting over 150 km of marsh and beach-dominant shoreline.

5. The Narrows

The Narrows ranges from one to three km in width and is the only tidewater access to Lake Melville. High tidal currents keep the channel ice-free for most of the year. This low wave energy segment has a low shoreline density index (1.46) and is composed primarily of cobble beaches and rock. With less than 20 km of marsh and sand beaches, this segment should have a low priority for any cleanup procedures and may serve as a suitable containment area.

6. South Shore

The southern shore of Groswater Bay contains a complex shore morphology. The region is composed of numerous small embayments resulting in a high shoreline density index (2.15). Small salt marsh areas, confined to the heads of embayments, comprise 37 percent of this shoreline. This marsh is primarily fringe marsh, but more extensive marshes are developed at the heads of larger bays. Broad boulder/mud flats are prevalent in the intertidal zone and boulder barricades are common, while much of the outer shore is rock.

As this region is exposed to the full fetch of Groswater Bay to the north, contaminants will readily collect in the embayments and marsh areas. However, cleanup on this coast would be extremely inefficient and there are no natural features to facilitate containment.

7. The Backway

The Backway is a 35-km long bay with a mean width of 3.6 km. The segment contains highly sensitive shore environments. 28 percent of the shoreline is fringe marsh and 41 percent sand beaches. The marsh density increases toward the bay head. The Backway is characterized by a straight shore from (shore density index = 1.20), and boulder barricades are present intermittently. This is a low wave energy setting, which minimizes any natural cleaning potential. Because the 110-km long shoreline system is connected to Groswater Bay by a 3.5 km wide mouth at the Narrows, maximum protection is afforded by exclusion of contaminants at the mouth. Cleanup along this shoreline is feasible, but shipping should be excluded from this sensitive area.

8. Wonder Strands

This segment, flanking Groswater Bay to the south, is the longest sand beach (46 km) in Labrador, interrupted only by Cape Porcupine. The beach is straight and continuous, with numerous streams flowing over the beach. This area is exposed to high wave energy which should be an effective natural cleansing agent on this simple platform.

DISCUSSION

An oil spill in Groswater Bay is inevitable if development continues in that area. Cleanup or containment should initially be limited to the most sensitive environments. Cleanup of most shore areas would be difficult due to the poor accessibility, which in most areas is possible only by helicopters or small boats. Many sedimentary intertidal zones inside Groswater Bay have boulder barricades or boulder flats. Therefore, initial response to an oil spill should be based on a philisophy of containment and exclusion rather than shore cleanup.

Four locations (Pottles Bay, "Goose Brook Bay", Double Mer and The Backway, Fig. 1) contain the greatest length of sensitive shorelines relative to the expense of spill control. Essential protection of the coast will be attained if field preparations are designed to prevent oil from passing the exclusion points marked in Figure 1. These preparations include shore anchoring points, helicopter landing sites and a predetermined spill control regimen for each site. As well, consideration should be given to excluding all commercial shipping from these areas.

The Narrows is an area of high probability for oil spill due to the narrow passage on high tidal currents. The shore within this area is not very sensitive to spill, so the region should be viewed as a containment area. Preventing the passage of oil at four narrow straits, seals the area from both the Lake Melville and Groswater systems.

If preparations are made to control oil movements at the eight sites shown on Figure 1, of which probably no more than four will be utilized for any given spill, Groswater Bay will attain the maximum essential protection of environmentally sensitive areas.

ACKNOWLEDGEMENTS

This work was supported by the Geological Survey of Canada, Atlantic Geoscience Centre, Project 780041.

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Rosen, P.S., 1980. Coastal environments of the Makkovik region, Labrador, p. 267-280, in McCann, S.B. (ed.), The Coastline of Canada: Geological Survey of Canada, Paper 80-10, 439 p.

MEASURING OIL DISPERSING EFFICIENCY: RENEX 697

Submitted by: J.R. Bergueiro; M. Estrades and F. Dominguez
Department of Chemical Engineering
Faculty of Sciences. University of Palma de Mallorca
Carretera de Valldemossa km, 7.5
Palma de Mallorca. SPAIN

INTRODUCTION

The purpose of this work is to determine the dispersing efficiency of Renex 697, a polyoxyethylene alkyl aryl ether to a crude oil of the Kirkuk type, completing a previous study (1) on the relationship between: dispersant/crude oil ratio, speed of stirring, agitator power (P), Reynolds Number (N_{Re}) and stability of emulsion as a function of time.

Of all the procedures used for the in-situ elimination of oil spills, the treatment with dispersants is one of the most generally used. In order to facilitate microbial degradation it is necessary that the crude oil disperses in the sea water, thereby creating a greater contact surface and an increased potential for bacterial contact. The role of the dispersant is to break down the crude oil into small drops, so that they will not have a tendency to recoalesce. This is done, in practice, by spraying the dispersant over the spilled oil and supplying mixing energy. The mixing energy is related to interfacial area and interfacial tension through the following equation (2):

$$W_k = A_{o/w} \cdot \gamma_{o/w}$$

where:

W_k = mixing energy, ergs
$A_{o/w}$ = interfacial area, cm^2
$\gamma_{o/w}$ = interfacial tension of oil/water, dynes/cm or $ergs/cm^2$

EXPERIMENTAL

The experiments consisted of dispersing one liquid (crude oil) in another immiscible with it (sea water) by means of a dispersing agent to form an emulsion. The apparatus used consisted of a beaker with two spiggots that enabled sampling at different depths.

Of the many methods described in the literature for the determination of dispersed crude oil we have used one based on UV-VIS (3,4) and IR spectrometry (5). In essence the analytical procedure consists of the following steps:

i. Extraction of dispersed crude oil with CCl_4

ii. Spectrometric determination of extracted crude oil in CCl_4 solution.

Further information about the analytical procedure followed may be obtained from an earlier paper by M. Estrades and J.R. Bergueiro (1).

The apparatus used consisted of a 5-litre beaker with two spiggots that enabled sampling at different depths, thermostatized at 20.0 ± 0.1°C. Samples were mixed using a Heidolph RGL 55-1 stirrer fitted with an S-289 (type 5) shaft. Different batches were held under stirring for 5 minutes after which a 100 ml sample from each was withdrawn at 1;2;8 and 24 hours. After 24 h. dispersions appeared to be completely stable. Table I provides details of the experimental apparatus and parameters.

TABLE I VARIABLES IN THE STUDY

Experimental Device	
Rotor type: three bladed propeller	
Rotor speed	2 000 - 4 000 r.p.m.
Diameter of rotor	5.8 cm.
Width of blades	1.5 cm.
Height of mixing device above bottom	4.0 cm.
Level of liquid	13.25 cm.
Diameter of tank	17.00 cm.
Characteristics of Crude Oil and Sea Water	
Type of crude oil	Kirkuk
Origin	Iraq
Average paraffin wax content	5%
% Sulphur	1.95
Density	.85 gm/cm^3
Viscosity	10 kg/m.s
Residue at 200°C:	
% volume	64
viscosity	120 kg/m.s
Residue at 350°C:	
% volume	40
density	.950 gm/cm^3
Density of sea water	1.03 gm/cm^3
Viscosity of sea water	1.09 kg/m.s

Samples were successively extracted with five 5 ml. portions of CCl_4 that were pooled for each sample. The next step was the determination of the absorption maxima in the spectrum of the crude-oil under observation. The wavelengths chosen were: 3.37 µm; 3.41 µm; 3.48 µm; 263 nm; 400 nm and 510 nm.

Table II shows the percentages of dispersion obtained. This table also illustrates the effect of oil/dispersant ratio and the speed of stirring. Table III shows the relationship among Reynolds Number (N_{Re}), speed of stirring and agitator power P(W).

TABLE II DISPERSION AS A FUNCTION OF DISPERSANT/CRUDE OIL RATIOS AND STIRRING SPEED

Dispersant:Crude Oil Ratio	Stirring Speed Rev/min	% Dispersion at time (t) standing unstirred			
		1 (h)	2 (h)	8 (h)	24 (h)
1:5	2 000	40.17	31.36	8.38	7.15
	2 500	46.13	40.53	11.36	7.86
	3 000	50.86	49.43	15.72	8.19
	4 000	69.58	52.36	21.60	10.85
1:10	2 000	40.60	34.60	26.90	22.80
	2 500	44.50	37.22	28.21	25.38
	3 000	54.26	56.25	32.60	25.63
	4 000	66.62	56.25	32.60	29.30
1:15	2 000	54.90	46.10	36.28	35.90
	2 500	63.40	54.50	43.60	42.60
	3 000	65.72	58.90	44.60	42.72
	4 000	67.87	58.38	46.27	45.66
1:20	2 000	58.00	47.76	36.61	31.81
	2 500	62.87	47.97	45.71	35.91
	3 000	70.46	60.93	52.00	44.23
	4 000	69.60	69.88	50.73	48.07
1:25	2 000	66.01	55.90	35.20	34.86
	2 500	67.28	56.83	50.06	38.71
	3 000	57.71	50.62	45.21	36.13
	4 000	69.58	64.96	41.86	37.96

TABLE III RELATIONSHIP BETWEEN STIRRING SPEED, REYNOLDS NUMBER AND AGITATOR POWER

Stirring Speed (Rev/min)	Reynolds Number $N_{Re} \cdot 10^{-5}$	Agitator Power P (W)
2 000	1.0671	3.92
2 500	1.3333	6.86
3 000	1.6006	10.48
4 000	2.1342	22.19

DATA ANALYSIS

The following statistical techniques were used for the analysis of data obtained in this work:

i. Inverse linear regression analysis for calibration lines for each wavelength.
ii. Determination and tabulation of data obtained from modified calibration curves (1).
iii. Fitting of calibration curves. An inverse linear least squares regression line, applied to the region where the ratio absorbance/concentration gives a straight line and disregarding any non-linear zones.

CORRELATION PARAMETERS

By using the results obtained in this work, we have been able to relate the percent dispersion with the amount of dispersant and Reynolds Number. First, we plotted the Ln of % dispersion against the ratio of dispersant/crude oil. This yields the following set of equations:

r.p.m.	$R_e \cdot 10^{-5}$	Ln % of dispersion = $a_1 + b_1 \cdot x_1 - c_1 \cdot x_1{}^2$			
		a_1	b_1	c_1	r
2 000	1.0671	2.1524	33.4100	183.9250	0.9763
2 500	1.3333	2.3918	35.9200	235.8925	0.9897
3 000	1.6006	2.3634	43.5800	282.5000	0.9989
4 000	2.1342	2.5624	39.8820	240.8931	0.9978

x_1 = ratio dispersant:crude oil

Second, coefficients b and c were plotted against Reynolds Number, giving the following correlations:

$$b = 4.8497 + 13.3983\, N_{Re} - 4.4018\, N_{Re}^2;\ r = 0.9669$$

$$c = 16.8497 - 32.5693\, N_{Re} + 9.4951\, N_{Re}^2;\ r = 0.9987$$

where:

r	=	correlation coefficient
N_{Re}	=	Reynolds Number = $\frac{D_a^2 . N . \rho}{\mu}$
D_a	=	agitator or impeller diameter (m)
ρ	=	density (Kg/m^3)
μ	=	viscosity (Kg/m•s)
N	=	agitator speed (rev/min)

CONCLUSIONS

1. From the data in the Table II, we concluded that the dispersing efficiency was found to increase with increasing dispersant:crude oil ratios. A maximum value was reached at the dispersant:oil ratio of 1:20.

2. The optimum dispersion was obtained by stirring at 4 000 rev/min ($N_{Re} = 2.1342.10^{-5}$; p = 22.19 W).

3. A relative increase of dispersant:oil ratio beyond 1:20 did not give any increase in the dispersant efficiency.

4. All errors detected were mainly attributable to calibration errors (1). Errors due to the degradation of the samples were not detected.

5. Under optimum conditions 48% of the crude oil was dispersed.

6. The dispersant:oil ratio required to reach this optimum is less than given by other authors (6).

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AN OIL SPILL - FISHERIES IMPACT MODEL

Submitted by: Mark Reed
Applied Science Associates
West Kingston, Rhode Island
Phone (401) 789-6224

The consulting firm Applied Science Associates (ASA) has developed a system of computer models designed to simulate the evolution and fate of an oil spill, and the impact of the spill on commercially fished species in the area. In a current study funded by the Department of Interior, Bureau of Land Management, New York Office, researchers from ASA have joined forces with modelers from the University of Rhode Island Graduate School of Oceanography and Department of Ocean Engineering to assess the impacts of potential spills on Georges Bank cod, haddock, herring, and yellowtail.

The oil spill-fishery interaction model is composed of an oil spill fates model, a continental shelf hydrodynamics/constituent transport model, and a fish population and yield model. The model components are illustrated in Figure 1. The oil spill fates sector is fully three dimensional, maintains a continuous mass balance of hydrocarbons in the water, in the air, and at the interface, can simulate instantaneous and continuous spill scenarios, spreading, drifting, entrainment, sinking, evaporation, subsurface transport, and effects resulting from treatment alternatives including booming, skimming, and the addition of dispersants. The fish population model, unusual in its inclusion of ocean scale spatial dimensions, uses output from the oil spill fates model, in the form of hydrocarbon concentrations and distributions in and on the water to infer first order direct impacts of oil on a commercial fishery through hydrocarbon induced egg and larval mortality. Thus surface and subsurface oil concentrations are mapped in space and time and tested for intersection with simular maps of ichthyoplankton, under selected assumptions concerning threshold toxicities. The reduced cohort of young-of-the-year enters the adult population model, final output being measured in terms of the ensuing catch differential between natural and impacted populations. Typical model outputs are illustrated in Figures 2, 3, 4.

Most scientists agree that the wide annual variability in egg and larval distribution and survival combined with sampling problems results in such large confidence limits on field survey estimates that mortality below an order of magnitude greater than normal would be virtually impossible to detect. In addition, the continuous collection of such data is extremely expensive and time consuming. ASA researchers therefore believe that a sophisticated modeling approach is by far the best solution strategy available. Although the model system has been constructed to operate in situations for which data is extremely sparse, the stronger the data base, the better the final impact etimates.

Results of the present study on Georges Bank indicate maximum impacts for cod on the order of 20% of one year's catch lost due to a major 30 day spring blowout releasing 5 thousand tons of petroleum per day. Because of growth dynamics within the adult population, this loss will be distributed over the 5 years following the spill, with a

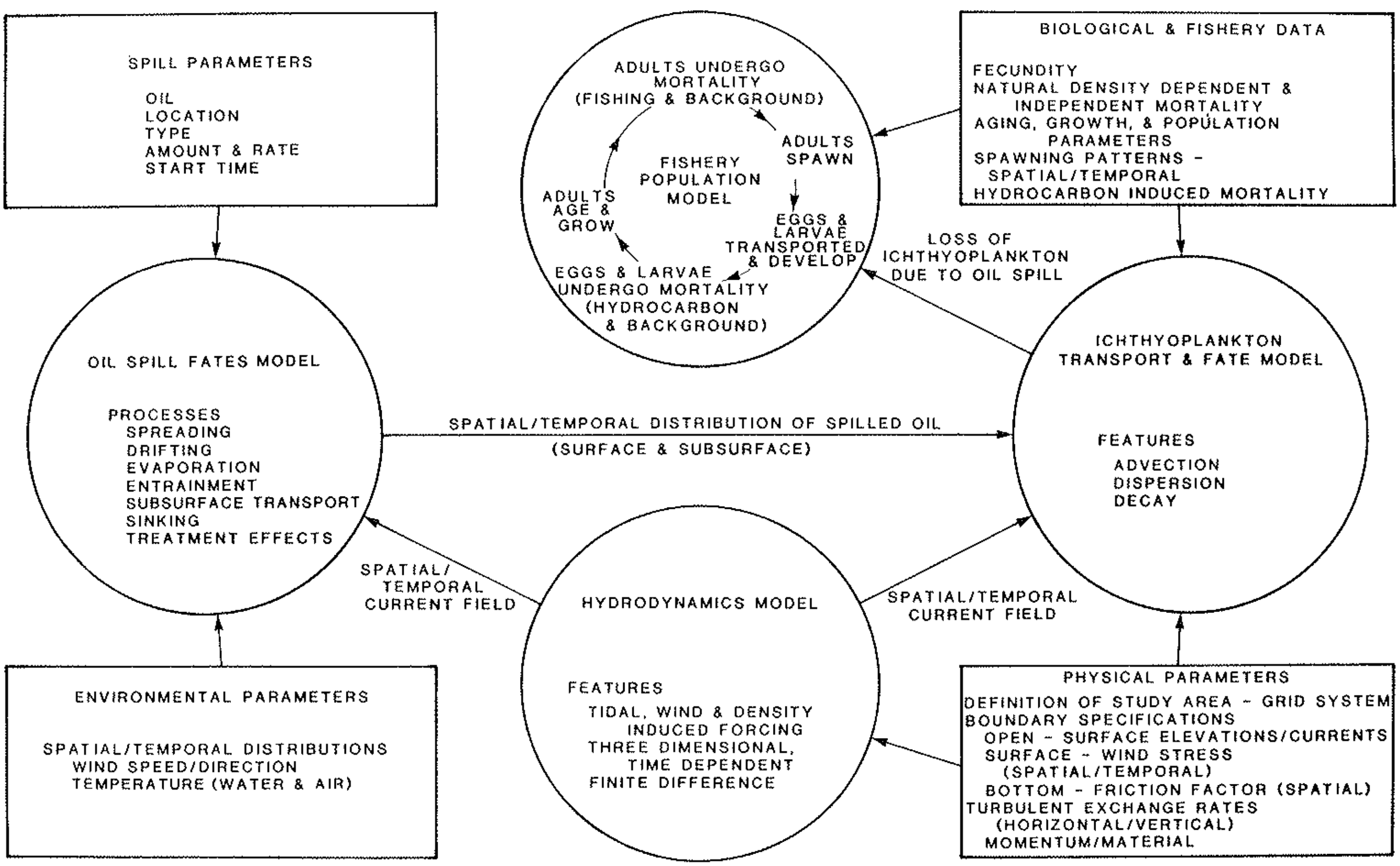
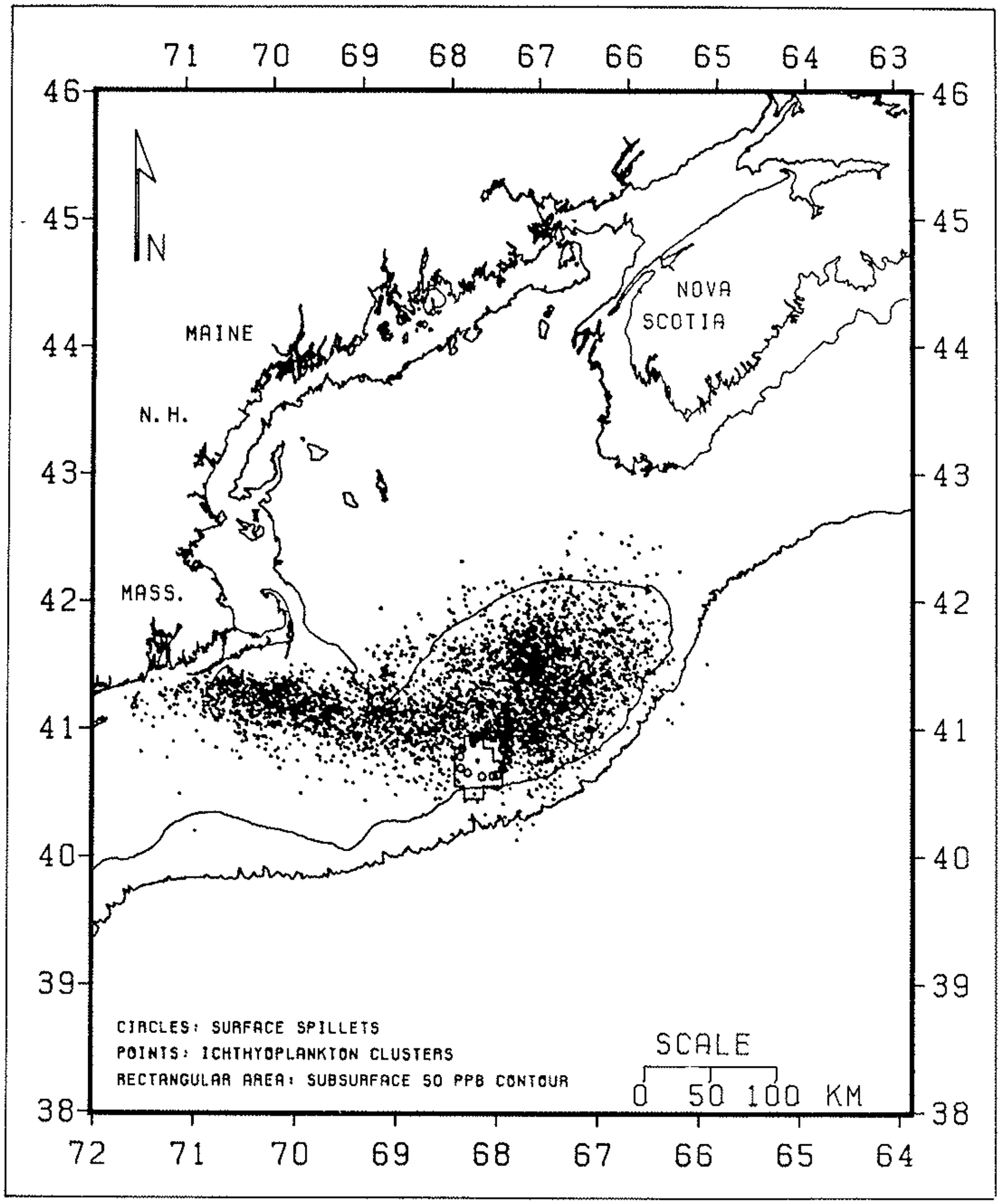


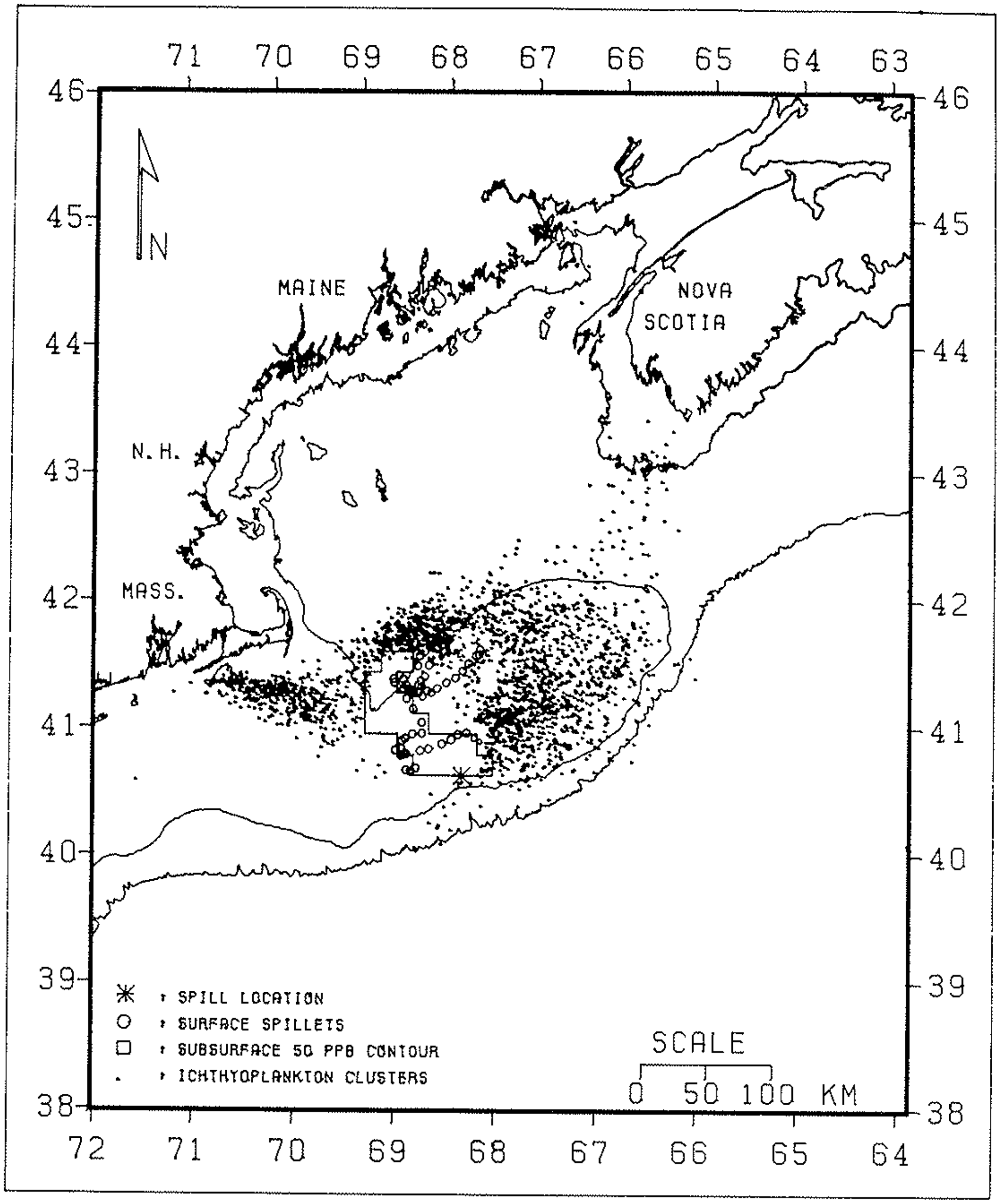
FIGURE 1 MODEL SYSTEM COMPONENT RELATIONS



10 DAYS AFTER THE RELEASE (JULIAN DAY 131)

SPILL PARAMETERS
OIL- STATJFORD NORWAY CRUDE
SITE- 68 DEG 12 MIN W. 40 DEG 37 MIN N
TYPE- WELL BLOWOUT
AMOUNT- 50 MILLION GAL OVER 30 DAYS
START- SPRING, JULIAN DAY 121
SPECIES- COD

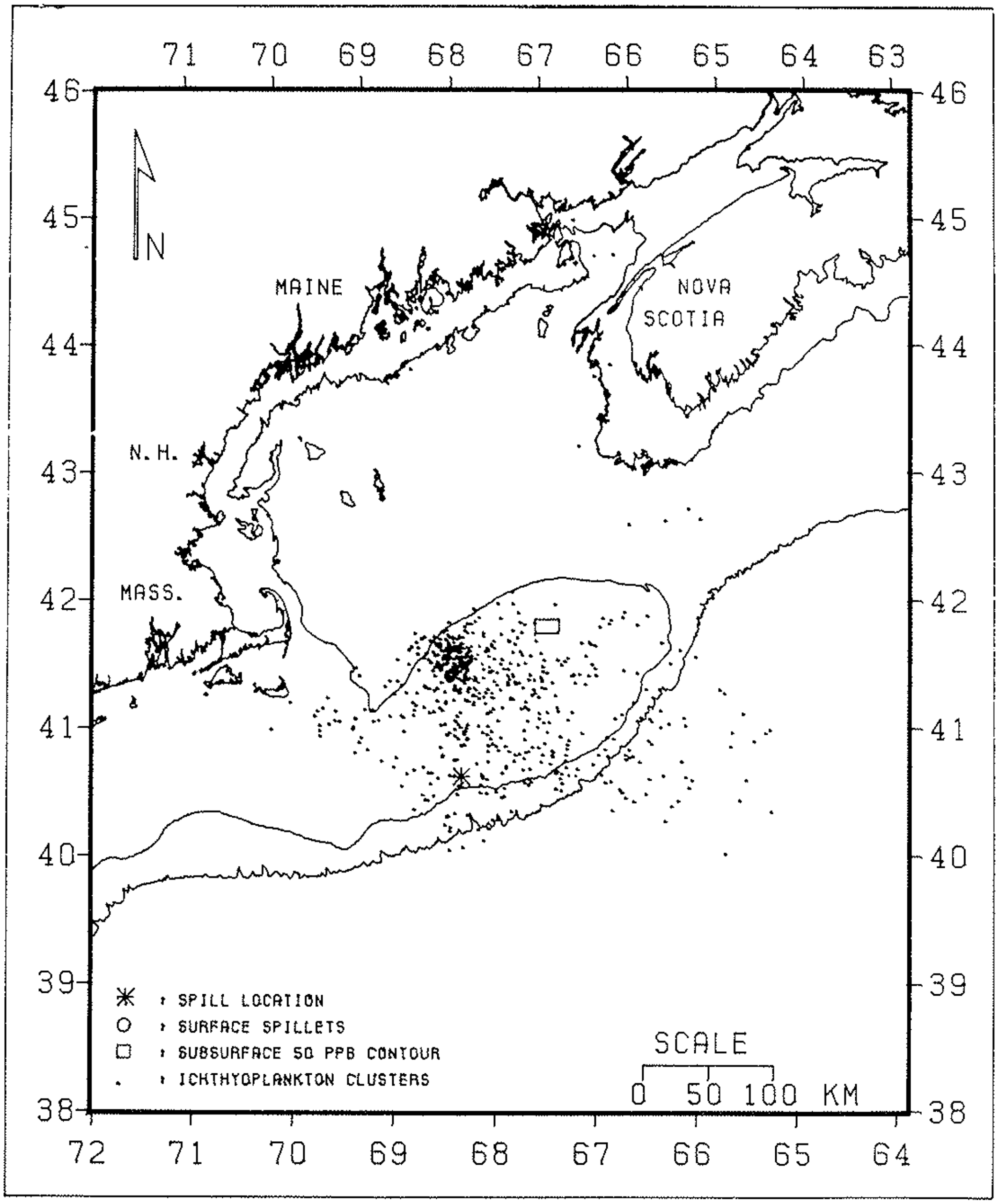
FIGURE 2 TYPICAL MODEL OUTPUT



29 DAYS AFTER THE RELEASE (JULIAN DAY 150)

SPILL PARAMETERS
OIL- STATFJORD NORWAY CRUDE
SITE- 68 DEG 12 MIN W. 40 DEG 37 MIN N
TYPE- WELL BLOWOUT
AMOUNT- 50 MILLION GAL OVER 30 DAYS
START- SPRING. JULIAN DAY 121
SPECIES- COD

FIGURE 3 TYPICAL MODEL OUTPUT



89 DAYS AFTER THE RELEASE (JULIAN DAY 210)

SPILL PARAMETERS
OIL- STATFJORD NORWAY CRUDE
SITE- 68 DEG 12 MIN W, 40 DEG 37 MIN N
TYPE- WELL BLOWOUT
AMOUNT- 50 MILLION GAL OVER 30 DAYS
START- SPRING, JULIAN DAY 121
SPECIES- COD

FIGURE 4 TYPICAL MODEL OUTPUT

	OIL SPILLS SIMULATED			
	NORTH BLOWOUT SPRING	NORTH BLOWOUT WINTER	SOUTH BLOWOUT SPRING	NORTH BLOWOUT SPRING
FISHERIES	COD	COD	HADDOCK	HADDOCK
(*) Predicted percent LARVAL Mortality	36.9 %	34.5 %	29.7 %	28.4 %
FIRST Catch Loss (A) in graph below	0.9 % in 2nd YR.	0.6 % in 2nd YR.	2.0 % in 2nd YR.	1.9 % in 2nd YR.
MAX. Annual Loss (B) in graph below	6.4 % in 4th YR.	6.0 % in 4th YR.	4.7 % in 4th YR.	4.5 % in 4th YR.
MAX. Cumulative Loss (C) in graph below	23.9 % in 7th YR.	22.3 % in 7th YR.	20.5 % in 8th YR.	19.6 % in 8th YR.

(*): Mortality estimates from the ichthyoplankton transport and fate model.

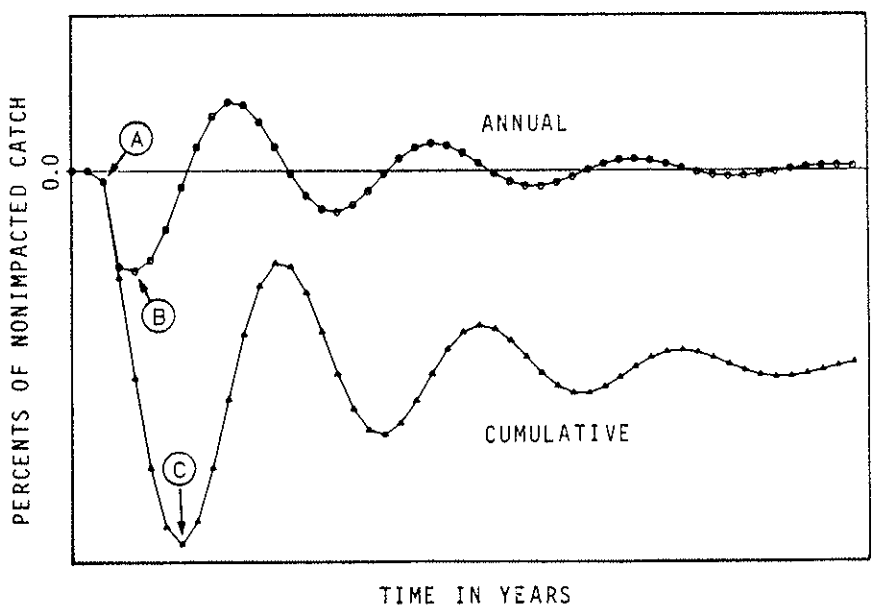


FIGURE 5 SUMMARY OF FISHERY MODEL APPLICATION RESULTS.

maximum reduction on the order of 6%, or 1.4 thousand metric tons of cod. The magnitude of the impacts depends on a complex interaction between spill location and timing, the spatial and temporal spawning distribution, and the hydrodynamics of the area. On Georges Bank, largest impacts are associated with winter and spring spills. A typical model output is illustrated in Figure 5.

For further information on the oil spill - fishery interaction system, contact Dr. Mark Reed or Dr. Malcolm L. Spaulding, Applied Science Associates, Inc., 529 Main Street, Wakefield, RI 02879.

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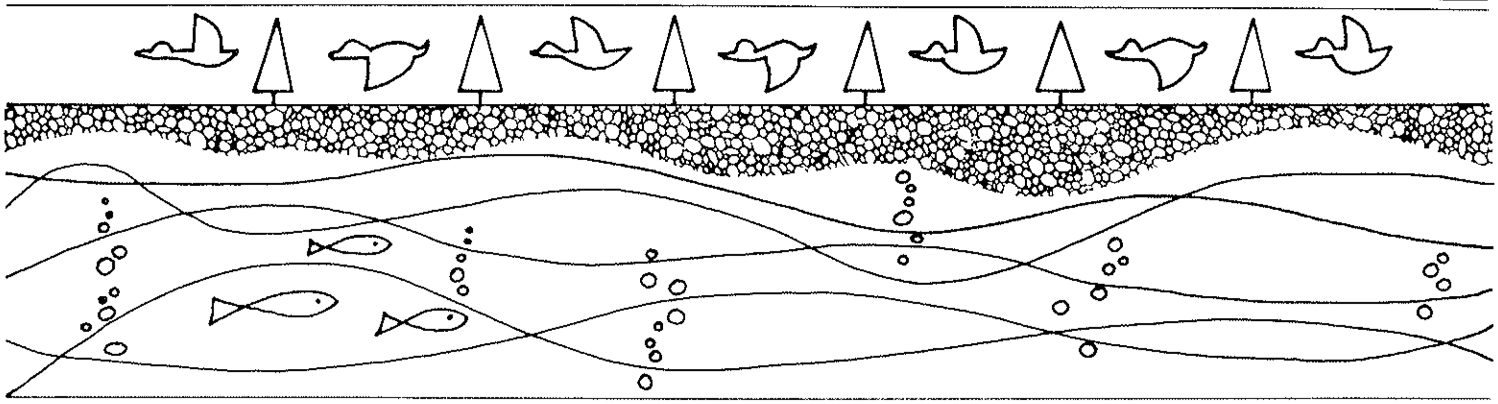


Table of Contents

Spill Technology Newsletter

EDITORS

Mr. M.F. Fingas and Dr. D.E. Thornton

Research and Development Division
Environmental Emergency Branch
Environmental Impact Control Directorate
Environmental Protection Service
Department of the Environment
Ottawa, Ontario
K1A 1C8

Phone: (819) 997-3921

The Spill Technology Newsletter was started with modest intentions in 1976 to provide a forum in Canada for the exchange of information on oil spill countermeasures and other related matters. The interest in it was such that we now have over 2,500 subscribers in Canada and around the world.

To broaden the scope of this newsletter, and to provide more information on industry and foreign activities in the field of oil spill control and prevention, readers are encouraged to submit articles on their work and views in this area.

INTRODUCTION

The first article of this issue is by Shawn Gill who describes the development and testing of the "Oil Harvester". This device which uses a hay bale elevator as a starting component, is promising for heavy oil recovery and can be built cheaply. The second article by Steve Pond describes the development of a Shoreline protection and cleanup manual. The use of videocassettes of the shoreline allows a flexible approach to decisions during a spill event. The third article by Merv Fingas and Brian Lea describes a test of oil spill tracking buoys. Two of those tested (Orion 2100 and Novatech RF 200), were found to be useful for simulating slick movement.

REPORTS AND PUBLICATIONS

- The New Zealand Government has released the "New Zealand Atlas of Coastal Resources". This Atlas contains a variety of information including coastal geomorphology, oceanography, coastal vegetation and biota, behaviour of oil, and sensitivities. The Atlas is available at $29.50 N.Z. (plus handling and postage) from the New Zealand Government Printer, Private Bag, Wellington.

- The following reports are available from the U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia, 22161, Telephone (703) 487-4650. Most reports are also available on Microfiche at $3.35 each (U.S.A. Price). Canadian buyers add $2.50 to each paper copy and $1.50 for each microfiche report. Prices are quoted in U.S. dollars.

Oil and Petroleum

"Crude Oil Effects to Developmental Stages of the American Lobster". J.M. Capuzzo. Woods Hole Oceanographic Institution, Maryland. September, 1981. 108 p. PB82-117656 $11.00

"Dispersant Application System for the U.S. Coast Guard 32-foot WPB (Waterways Patrol Boat)". M. Borst and G.F. Smith. Mason and Hanger-Silas Mason Co., Inc., Leonardo, New Jersey. September, 1981. 32 p. PB82-101684 $6.50

"Oil Slick Dispersal Mechanics". C.A. Osamor and R.C. Ahlert. Rutgers University, New Brunswick, New Jersey. September, 1981. 238 p. PB82-105560 $18.50

"Deployment Configurations for Improved Oil Containment with Selected Sorbent Booms". G.F. Smith. Mason and Hanger-Silas Mason Co., Inc., Leonardo, New Jersey. September, 1981. 32 p. PB82-101650 $6.50

"Performance Testing of the Diperna Sweeper". M.K. Breslin. Mason and Hanger-Silas Mason Co., Inc., Leonardo, New Jersey. September, 1981. 44 p. PB82-109174 $6.50

"Performance Testing of Four Skimming Systems". H.W. Lichte, M.K, Breslin, G.F. Smith, D.J. Graham and R.W. Urban. Mason and Hanger-Silas Mason Co., Inc., September, 1981. 92 p. PB82-101353 $9.50

Other Hazardous Materials

"Hazardous Materials Management System. A. Guide for Local Emergency Managers". M.T. Lee and P.G. Roe. Multnomah County, Portland, Oregon. July, 1981. 137 p. AD-A104 437/9 $12.50

"Development of an Identification Kit for Spilled Hazardous Materials". A Silvestri, M. Razulis, A. Goodman, A. Vasquez and A.R. Jones. Aberdeen Proving Ground, Maryland. September, 1981. 88 p. PB82-110727 $9.50

"Restoring Hazardous Spill-Damaged Areas: Technique Identification/Assessment". R.S. Wentsel, R.H. Foutch, W.E. Harwood, W.E. Jones and J.F. Kitchens. Atlantic Research Corp., Alexandria, Virginia. September, 1981. 374 p. PB82-103870 $32.00

"Modification of Spill Factor Affecting Air Pollution. Volume 1. An Evaluation of Cooling as a Vapor Mitigation procedure for Spilled Volatile Chemicals". J.S. Greer, S.S. Gross, R.H. Hiltz and M.J. McGoff. MSA Research Corp., Evans City, Pennsylvania. September, 1981. 86 p. PB82-108382 $9.50

"Guidelines for the Use of Chemicals in Removing Hazardous Substance Discharges". C.K. Akers, R.J. Pilie and J.G. Michalovic. Calspan Corp., Buffalo, New York. September, 1981. 82 p. PB82-107483 $9.50

"Techniques for Handling Landborne Spills of Volatile Hazardous Substances". D. Brown, R. Craig, M. Edwards, N. Henderson, and T.J. Thomas. Battelle Columbus Labs, Ohio. September, 1981. 101 p. PB82-105230 $11.00

"Use of Selected Sorbents and an Aqueous Film Forming Foam on Floating Hazardous Materials". M.K. Breslin and M.D. Royer. Mason and Hanger-Silas Mason Co., Inc., Leonardo, New Jersey. September, 1981. 58 p. PB82-108895 $8.00

"A Hazardous Materials Spill Warning System". M. Kirsch, R. Melvold and J. Vrolyk. Rockwell International, Newbury Park, California. September, 1981. 69 p. PB82-108424 $8.00

"Removing Water-Soluble Hazardous Material Spills from Waterways with Carbon". G.R. Schneider. Rockwell International, Newbury Park, California. September 1981. 67 p. PB82-103813 $8.00

UPCOMING CONFERENCES

- The Products Storage and Handling Committee of P.A.C.E. (Petroleum Association for Conservation of the Canadian Environment) is planning a 2-day Symposium on the technology of underground tank testing devices, their theory, practicality and methodology. Detection of leakage of Refined Petroleum products from underground tanks is of grave concern to the oil industry, and to those regulatory bodies and others associated with the problem. Potential hazards of environmental contamination, and the loss of a valuable commodity are only too well known.

  Considerable research has been undertaken in recent years to develop tank testing devices that will accurately detect leaks. This Symposium will take the form of a series of technical papers covering some of this research and its application to various devices studied over the past few years, together with demonstrations of such devices. Oil Company personnel, Government Agencies, equipment suppliers, contractors and others concerned with this problem will find this a very timely seminar.

  The fee for this Symposium is $125.00 per participant which will include attendance at the seminar, preprinted papers, luncheons and refreshments, and due to limited accommodation early enrollement is advised.

  The date for this seminar is May 25-26, 1982 at the Park Plaza Hotel, 4 Avenue Road, Toronto, Ont. (M5R 2E8) telephone number (416) 924-5471, and further details including enrollment forms, etc., are available from the P.A.C.E. Office, 275 Slater Street, Suite 1202, Ottawa, Ontario, K1P 5H9, telephone number (613) 236-9122.

- The American Society for Testing and Materials (ASTM) in Philadelphia, Pennsylvania, is soliciting papers for its symposium entitled "Oil Spill Dispersants: Five Years of Research," to be held on 12 and 13 October 1982 in Hilton Head, South Carolina. Authors are encouraged to submit papers on the following topics: dispersant application, techniques, case histories, toxicological effects, effectiveness testing, criteria and guidelines, and contingency planning. The symposium, sponsored by ASTM Committee F-20 on Hazardous Substances and Oil Spill Response, and its Subcommittee F20.13 on Chemical Treatment of Oil Spills, is a followup to the 1977 Conference on Chemical Dispersants for Control of Oil Spills. A poster session has been introduced to provide an opportunity for more detailed presentations of data and methods, including graphics and other visual aids. For further information, contact: Tom E. Allen, Halliburton Services, Box 1431, Duncan, OK 73536; Tel: 405-251-3619; TWX: 910-830-6902.

- The 7th Inland Spills Conference will be held in Columbus, Ohio, September 27 - 29, 1982, Marriott Motor Hotel/North. For further details contact Sara E. Garnes, Coordinator, The Ohio EPA, 361 E. Broad Street, Room 219, Columbus, Ohio, 43216-1049, Telephone: (614) 466-8820.

DEVELOPMENT OF THE CANADIAN COAST GUARD OIL HARVESTER

Submitted by: S.D. Gill and E. Gauthier
Canadian Coast Guard Emergencies
Place de Ville, Tower A
Ottawa, Ontario K1A 0N7

(The Oil Harvester development project is under the general stewardship of Victor Bennett, Regional Coast Guard Marine Emergency Officer, Central Region, and receives financial support from EPS and functional direction from the above office.)

The Canadian Coast Guard Oil Harvester is the development of an idea born during the Nepco 140 spill in the St. Lawrence River in June of 1976. The sight of pools of heavy No. 6 fuel oil in the backwaters of the Thousand Islands, mixed with floating debris, together with the repeated failures of the Slicklicker belt system, prompted the suggestion to use a hay bale elevator to lift the mess from the water's surface. (Over the last 10 years the majority of oil spills in Canadian waters have been bunker fuel spills).

At the time there was no opportunity to develop the idea further. In fact, it made more sense to improve the belting system of the 32 Slicklickers maintained in the Canadian Coast Guard inventory, and indeed, this has since been done. Nevertheless, Ron Powers, Pollution Equipment Maintenance Supervisor for the CCG Base Prescott, proceeded on his own to exploit the concept in his spare time.

Starting with a Little Giant hay bale elevator fabricated by the Portable Elevator Division of Dynamics Corporation of America, Bloomington, Illinois, distributed in Canada by Allied Farm Equipment of St. Mary's, Ontario, Ron divided the 30' unit in half and mounted one piece on an A frame to serve as a deck support (Figure 1). The track consisted of standard agricultural flat steel (rectangular) links with galvanized steel cross members (flights). He doubled the number of flights and reversed the direction of rotation i.e. dorsal track has a downward motion. (Figure 2) In this mode the Oil Harvester - as we are wont to call the device, rotates in a direction opposite to the Slicklicker, the flights touching the surface of the oil slick, pulling it down under the water, and thence up the lower deck of the elevator. Unlike the Slicklicker, oil cannot drip onto the deck of the workboat because the bottom of the elevator is completely sealed with a layer of galvanized sheet metal. Furthermore, the large link chain drive does not cause the tracking problems often experienced with a belt system. With the Slicklicker, the belt is scraped and/or squeezed by upper tension rollers, an action that extrudes the oil from the belt's surface. The Oil Harvester, however, must reply on the material falling off the blades, or flights, as they pass over the upper-most sprocket for their return trip to the water (Figure 3). To enhance recovery, then, Ron attached steam coils enclosed in heat retention trays beneath the sheet metal deck of the elevator. As oil travels up the lower deck its viscosity is reduced by the heat, increasing the tendency for it to fall off the flights into the collection chute. Any oil that still adheres to the flights during the downward travel can drip off onto the ascending track on the lower deck.

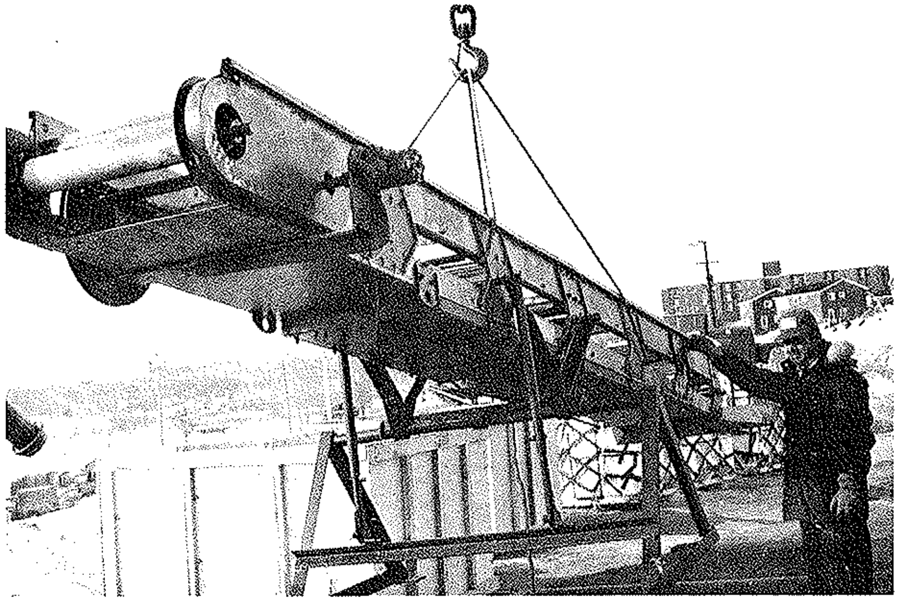


FIGURE 1 OIL HARVESTOR WITH A-FRAME DECK-MOUNTING BRACKET

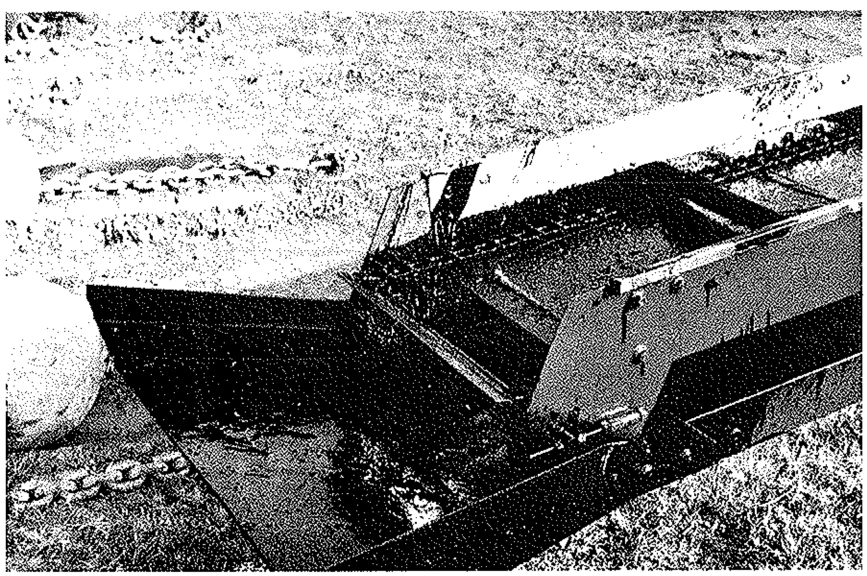


FIGURE 2 ILLUSTRATION OF THE CHAIN AND FLIGHT ASSEMBLY. MOST OF THE INTERMEDIATE DECK HAS BEEN REMOVED TO ALLOW OIL TO DRIP FROM THE DORSAL, DOWNWARD FLIGHTS, TO THE LOWER DECK.

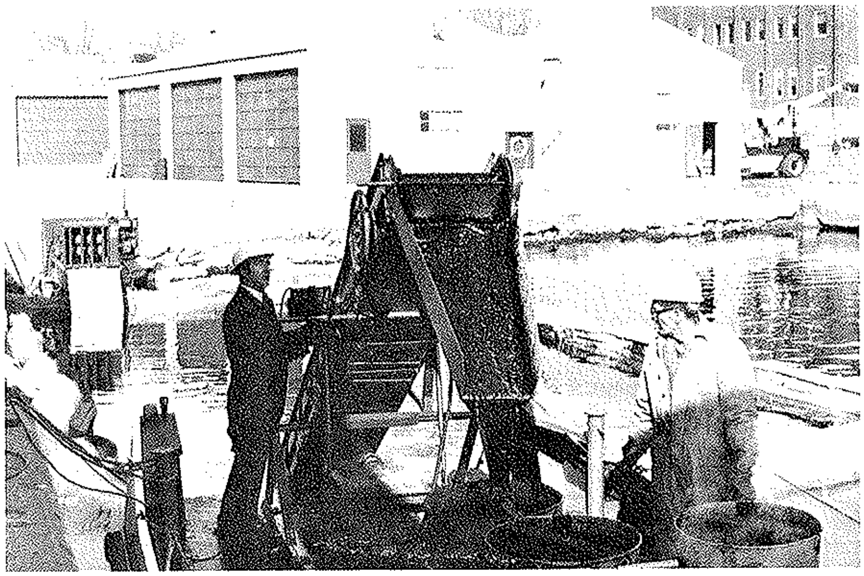


FIGURE 3 HEAVY OIL FALLS FROM FLIGHTS INTO COLLECTION CHUTE. ELECTRICAL MOTOR AND BELT ASSEMBLY HAS BEEN REPLACED BY HYDRAULIC DRIVE AS DEPICTED IN FIGURE 1.

The initial test of the unit was conducted at Prescott in November 1979. Both the Oil Harvester and the original Slicklicker were mounted on a Canadian Coast Guard SP barge in a calm water enclosure. Performance of the harvester was most encouraging. Initial observations indicated an optimal speed of operation, in excess of which free water began to be recovered. Ron has used the original one horsepower electrical motor to power the unit. Following the initial trial in 1979, it was proposed to drive the device with a small hydraulic motor fed by the Spate-Komara or MI-30 power-pack (units already maintained in the Canadian Coast Guard national inventory).

The application of steam, as supplied by a CCG Steam Jenny, improved the rate of recovery by some 50-75%. While this represents an added logistical encumbrance during tidewater operations, fresh water can be carried aboard an SP barge or is often available when working in the vicinity of a berth. The main advantage of the harvester resides in its price compared to the replacement cost of a Slicklicker. Part of this saving is realized by not having to purchase a power-pack. Secondly, since the hay bale elevator is a standard agricultural product that is mass produced, there is a further saving at the retail price level. One elevator ($CDN. 2 000.00) supplies the basic parts for two "oil harvesters". (It is also possible to buy the chain, flights and sprockets independently from most agricultural equipment dealers.)

In November of 1981, a second set of trials were conducted at the Prescott base. This exercise consisted of recovering heavy oil and emulsion at below pour point temperatures from a port-a-tank to which oil was repeatedly added. This work was undertaken to again compare the two units; the Slicklicker, fitted with the nylon reinforced neoprene industrial conveyor belting, and the harvester now powered by the Spate-Komara hydraulic drive. The harvester functioned quite satisfactorily under heavy loads for a period of 6 hours. Admittedly, the Slicklicker exhibited a better recovery rate as a result of its wider 36" track vs. the 20" track of the harvester. Too, the harvester showed some sensitivity to debris, with smaller bits of wood becoming jammed between the flights and the lower pan. However, since machinery of this kind is never operated unattended, this problem can be overcome by either removing the offending debris before it enters the recovery unit or by installing a hydraulic reverse valve on the drive unit to free any article from beneath the blades. A trash screen only serves to restrict the entry of viscous oil to the unit.

For the present, the Canadian Coast Guard views the Oil Harvester as a potential inexpensive replacement for the Slicklicker. It is currently planned to fabricate a second unit, this time with a 36" track and steam trays that are sealed to enable recycling of steam condensate. The project, to include a set of shop drawings and a cost analysis, should substantiate the contention that the unit is cost effective once allowances are made for the labor involved in effecting the modifications of the Little Giant.

The Nepco 140 demonstrated the obvious; once you have a requirement for a piece of oil spill hardware, you usually require several such units. This program affords an opportunity to augment the national inventory with an inexpensive device that can be integrated with existing hardware.

THE CASE FOR DEVISING A SHORELINE PROTECTION AND CLEANUP MANUAL

Submitted by: Steve Pond
Environmental Protection Service
West Vancouver, B.C.

Beginning in 1978 we have conducted a series of studies aimed at clarifying the things that EPS could do to make the best use of our time and talent to improve the environmental emergency problem in B.C. In the "West Coast Countermeasure Study" we looked at the potential for large coastal oil spills during year one and in year two studied how well the existing spill response system could cope with large spills in particularly "sensitive" areas. While we still cannot say how well the system would cope (the subject was too difficult to resolve) we did learn that one of the bottlenecks in the system was the transfer of environmental, scientific information and opinion to the persons arranging for shoreline protection and cleanup. This was most critical in the first 4-5 days of a spill and less important later as the "system" for a particular spill matured.

The problem was not in identifying "sensitive areas". There is perhaps a surprising amount of agreement among environmental scientists concerning which areas are most or least sensitive and in B.C. there are several map sets and other information sources available which present good information.

There were two problems.

First, there was a serious time problem. Much useful helpful scientific information was lost or not used because of lack of adequate time. Typically environmental advice is decided at a meeting. Notwithstanding the high level of competence for each individual, the reasonable level of familiarity with oil spill countermeasures techniques and a strong motivation to solve the problem, there was not and never would be sufficient time or sufficient numbers of "experts" for a meeting or series of meetings to do justice to the information needs of an on-scene-commander.

Second, there was a terrible problem in "priorization" of sensitive areas. Although priorization is one of the inputs customarily asked of the environmental crowd, and a number of numerical schemes have evolved for this, there was much disagreement and much time spent in attempting to discriminate between areas which were more-or-less similarly sensitive.

Perhaps due to the nature of protected southern coastline off B.C., no numerical system for ranking priority areas which, to a biologist's eye, were of equal priority, made sense. These schemes did a fair job at discriminating sensitive from relatively insensitive areas, but were unconvincing when treating areas of comparable sensitivity.

We thought this problem was capable of solution, and began a project whose objective was to reduce "argumentation" time as much as possible, by pre-identifying priority areas and by prescribing scientifically and practically sound strategy and tactics for shoreline protection and cleanup, reviewing each with the appropriate cleanup/scientific advice personnel in advance.

This sounds like reinventing the wheel but the product evolved is different from other apparently similar works (e.g. Barry Worbet's manual; the Connecticut manual) in several aspects.

Essentials of the Shoreline Protection and Cleanup Manual System

First, there is a simple, intuitively-correct priorization scheme. A particular geographic unit is either of primary concern all year (if contaminated at any time of the year, serious effects would last a year or more); primary concern on a seasonal basis (if contaminated during a key season, serious effects would last a year or more); secondary concern (areas of considerable concern but where serious effects last less than a year) or none of the above.

This priorization scheme depends on a consensus being reached between those who have something to contribute. This is really what occurs during a spill anyway; the advantages of doing it beforehand are obvious. A great deal depends on the skill of the convener who must make available the best possible information on shoreline type, biology, geomorphology, oceanography and past history of oil persistence and effects on similar areas.

The second essential is a set of "nesting" maps; large, intermediate and small scale, on which is placed different information appropriate to the use of the particular map. The name and purpose of each map type is:

The Regional Response Map:	- large scale - gives an overview of how serious the problem is - contains biological, physical and population information
The Operational Map	- intermediate scale - suitable for devising a spill-response strategy - contains symbolic and narrative advice on shoreline protection/cleanup strategy
The Tactical Map	- small scale - suitable for very site-specific activities; could be given to a foreman to use - contains very detailed shoreline protection and cleanup advice - usually prepared only for key areas

The third essential is a series of videocassettes of the shoreline in question. This is potentially the most "catchy" part of the system; it is also the lowest-cost part. Videotapes show a continuous oblique aerial view of the shoreline (a helicopter ride) at an extreme low tide on a sunny day (both of these are rare events on the Pacific coast).

Videotapes are a necessity for the manual author (to see shoreline types; access etc.) and can easily be converted to a useful item for the on-scene-commander by adding a voice-over and a visual "locater" on the screen. Videotapes do not replace charts, vertical or oblique aerial photographs, or maps for certain information needs, but for personnel who for various reasons cannot take a surveillance flight during a spill provide a unique "feeling" or orientation to the geography in question that these other sources do not. The videotapes are the next best thing to being there. They are also more compact, transportable, viewable by a group than the alternatives. Ed Owens (Spill Technology Newsletter 5 (5)) has made the case better than I can.

Experience with the System

Without exception people who have seen the system think it is good. This includes government environmental scientists, government oil spill response personnel, government civil emergency program people, and both managerial and spill cleanup personnel in the oil industry. But does the promise hold up in a real spill?

In October, 1981 a very extensive "black oil" slick, source unknown, was reported on the Canadian side of Juan de Fuca Strait, an area for which a Shoreline Protection and Cleanup manual exists. Surveillance was difficult because of extensive, thick fog; no aircraft could view the problem; cleanup at sea was impossible. Even the Coast Guard and Department of Fisheries patrol craft had difficulty staying with the slick because of the terrible visibility.

A slick movement model predicted the slick would come close to shore but then be carried seaward. The Government agencies (EPS and Coast Guard) planned shoreline protection measures on the basis of the manual; the single "primary concern" identified, and the protection scheme (which involved a "sacrificial beach") thought out, and equipment (booms) was sent to the area in readiness. The videotape was viewed to get an appreciation of the shoreline. The sacrificial beach identified on the manual was changed for a nearby site; this was a compromise made after consulting with local residents to avoid oiling a beach in close proximity to a settlement. In the end the slick dissipated at sea.

This experience demonstrated the workability of the concept. Perhaps of most interest was the change of "sacrificial beaches". Although the beach chosen was technically less optimal, it was possible to identify one. We believe that unless we had pre-planned to the extent we did, we would have encountered great local resistance to the concept of sacrificial beaches. It is axiomatic that most plans will go awry in some respects; the manual allows one to have a game plan which can accomodate many changes in specifics because the consequent change "downstream" in the process can be recognized.

WHERE TO GO FROM HERE

We have completed a manual for Juan de Fuca Strait, and completed a guide to the preparation of these manuals. Because of money and personal limitation it is clearly impossible for the government alone to extend coverage to all the areas desirable which, we believe, ultimately should include all of Canada's coast. However, we think it is likely that others will see the manual as a useful way of portraying the results of environmental assessment data gathering and contingency planning studies.

The B.C. Petroleum Association daringly saw the advantages of the manual system and, in cooperation with EPS, are devising a manual for the Port of Vancouver. EPS will undertake to "clear" the protection and cleanup recommendations with the usual regulatory agencies, which is perhaps the only item which only government can supply.

We hope this will be the first of many industry-led efforts. The products can be made available at cost to anyone who wants them, and EPS is willing to serve as a clearing house putting users in touch with problems.

Acknowledgements

The manual is the product of a number of people. Besides Fred Beech, who wrote the manual, the greatest contributions were made by Ed Owens (Woodward-Clyde Limited) and Wishart Robson (then EPS, now Petro-Can).

EVALUATION OF THREE OIL SPILL TRACKING BUOYS

Submitted by: M.F. Fingas
Environmental Protection Service
Hull, Quebec

B. Lea
Dobrocky Seatech (Nfld.) Limited
St. John's, Newfoundland

Three oil spill tracking buoys were evaluated during the dipersant-application field trials conducted at St. John's, Newfoundland, in October 1981. This arcticle is a brief summary of those tests; the full report is available from the editors of this Newsletter (Lea, 1981).

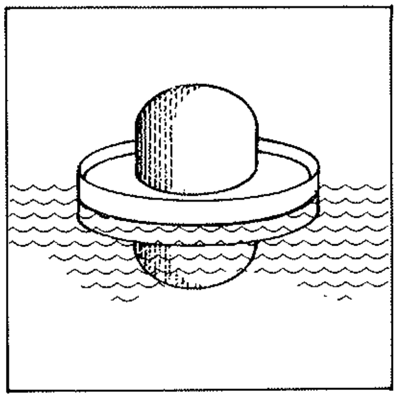
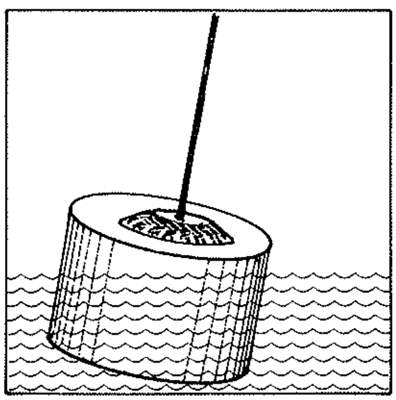
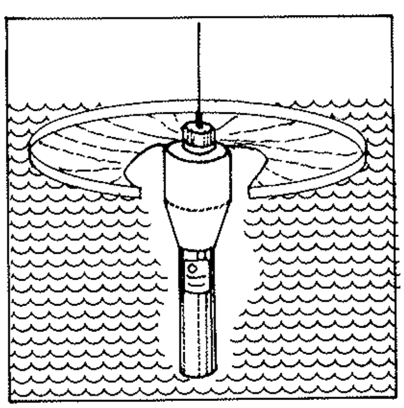
The first commercially-available oil spill tracking buoy was an Orion Electronics Ltd. device similar to their current model 2100. This device was evaluated in tests conducted in Halifax harbour and in the Bay of Fundy. The latter tests involved the use of two test oils (a light Arabian Crude and an aged/emulsified Arabian Crude) to verify the ability of the tracking device to move as an oil slick (Fingas, 1977). This trial showed that the Orion device had negligible deviation from the centroid of the two slicks. Two weights of the same device were used, the heavier one in the emulsified crude and the lighter one in the fresh crude. In this test, a passive device (4' x 4' plywood sheets coated with epoxy) that had been used for oil spill simulation, was also tested. These panels deviated significantly from the centroids of the test slicks. The deviations were as large as 0.11/hour (a relative deviation used to express movement of the buoy from the centroid of the slick versus the total movement of the slick). It was concluded that the plywood sheets were not suitable for simulating the movement of oil slicks, whereas the Orion device was judged to be excellent for the purpose.

Recently two new devices (Orion 4800 and Novatech RF200) were placed on the market and, in addition, the Orion 2100 had undergone a number of changes. Details of these devices appear in Table 1. It was therefore appropriate to evaluate all three of these devices for their ability to simulate the movement of an oil slick.

The tests were conducted near St. John's, Newfoundland using four slicks laid down to evaluate the effectiveness of dispersant application and the subsequent fate of this oil. Permission was obtained from the controlling Industry-Government Committee to use the slicks for testing the buoys. Extensive monitoring or other activity which interferred with the dispersant trials could not be done. Thus it was not possible to test passive devices (spill tracking cards, etc.) in the test.

The methods employed in this, and previous tests, was to place buoys in the slick and monitor their movement with respect to the centroid of the slick. The positions of the buoys were noted at regular intervals during the experiment and also at the end of the experiment. Positions of the buoys were then plotted on aerial photographs. This

TABLE 1 DESCRIPTION OF OIL SPILL TRACKING BUOYS

Buoy Model	Drawing	Manufacturer	Description
Orion 2100		Orion Electronics Ltd. Box 58 Saulnierville, Nova Scotia BOW 2XO Phone (902) 769-3059	A radio-frequency trackable buoy available in twelve frequencies from 150.800 MHz to 150.965 MHz in 15 khz steps.
Orion 4800		Orion Electronics Ltd. Box 58 Saulnierville, Nova Scotia BOW 2XO Phone (902) 769-3059	A transponder specially designed to provide automatic position and bearing using a special base station.
Novatech RF200		Novatech Designs Ltd. 822 Cormorant Street Victoria, British Columbia V8W 1R1 Phone (604) 381-1121	A radio-frequency trackable buoy available in a number of frequencies from 150.815 MHz in 30 khz steps.

double-verification system provided an accuracy of the buoy positions of less than 10 metres. Radio tracking was used during the experiment to provide relative position only since range cannot be determined by this method.

The results of this evaluation are summarized in Table 2. These results show that the Novatech RF200 and Orion 2100 had little deviation in oil of this type (Venezuelan Lagomedio Crude) and thus would be useful as oil simulation devices. The Orion 4800 could not be located on the photographs and during the experiment was observed to deviate widely from the slick.

During the experiment it was noted that two of the devices were difficult to track visually. The Novatech RF200 has a fluorescent-orange skirt which quickly becomes fouled with oil and thus difficult to see. The Orion 4800 is a metal cannister and floats low in the water and thus is not easily seen. By contrast the Orion 2100 is a fluorescent-orange plastic device which does not readily become fouled with oil and thus is easy to find by visual means.

References

B. Lea, "Field Evaluation of Oil Spill Tracking Devices". Environmental Emergency Branch Report, EE28. February, 1982.

M. Fingas. "The Evaluation of an Oil Spill Tracking Buoy". Spill Technology Newsletter, January-February, 1977.

TABLE 2 SUMMARY OF TEST RESULTS AT ST. JOHN'S, NEWFOUNDLAND

Buoy	Test Date and Number	Movement from Centroid/Slick Movement (Metres)	Deviation	Test Time (Hours)	Deviation/ Hour	Total Average Deviation/ Hour	Comments
Novatech RF200	Oct. 21-1	98/6,300	0.02	4.0	0.04	0.009	Buoy suitable for spill tracking.
	Oct. 22-1	28/1,700	0.02	3.4	0.005		
	Oct. 22-2	24/2,200	0.06	3.4	0.017		
Orion 2100	Oct. 21-1	98/6,300	0.15	4.0	0.038	0.04	Buoy suitable for spill tracking.
	Oct. 21-1	161/5,400	0.03	3.4	0.009		
	Oct. 22-1	454/1,700	0.27	3.4	0.079		
	Oct. 22-2	270/2,200	0.12	3.4	0.036		
Orion 4800	Oct. 21-1	-	-	-			Buoys not located, presumed to have deviated widely.
	Oct. 22-2	-	-	-			