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BEAUFORT SEA DISPERSANT TRIAL

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Finally, we would like to thank Dr. S.D. Gill and members of the Canadian Offshore Aerial Applications Task Force (COAATF) for the guidance and support given throughout the study.

RÉSUMÉ

En 1986, la société Dome Petroleum Limited, de concert avec le Canadian Offshore Aerial Applications Task Force (COAATF), a mis un dispersant à l'essai dans la mer de Beaufort. L'exercice avait pour triple but de déterminer l'efficacité des dispersants appliqués par voie aérienne dans des conditions septentrionales, d'évaluer l'efficacité de l'application de dispersants à plusieurs emplacements et de définir la logistique et les coûts d'une opération d'application de dispersants à grand déploiement dans la mer de Beaufort.

L'exercice a été effectué en août 1986 et tous les objectifs énoncés dans le projet de l'exercice ont été réalisés tel que prévu. De façon générale, les résultats indiquent qu'il est possible, au plan logistique, d'effectuer une opération d'applications de dispersants par voie aérienne dans l'Artique. En outre, il y a eu des indications (surtout visuelles et photographiques) que les dispersants fonctionnent tel que voulu.

En dépit de ces résultats, il n'y a aucune preuve nette que les dispersants sont aussi efficaces qu'ils doivent l'être aux fins de la protection de l'environnement. L'exercice a montré qu'un mécanisme qui produit un phénomène appelé "boules d'émulsion" perturbe le procédé de dispersion et réduit globalement l'efficacité du dispersant. Ces "boules" se forment à la surface de l'eau dans chacune des nappes pulvérisées et faussent l'interprétation des images infrarouges, principale méthode de détermination de l'efficacité des dispersants. Tant que l'incertitude créée par la présence de ces "boules" n'aura pas été apaisée, l'utilisation de la technique de télédétection pour déterminer l'efficacité des dispersants devra être assortie d'un programme de confirmation des observations au sol.

SUMMARY

In 1986, Dome Petroleum Limited, in conjunction with the Canadian Offshore Aerial Applications Task Force (COAATF), conducted an offshore dispersant trial in the Beaufort Sea. The purpose of this trial was to determine the effectiveness of aerially applied dispersants under arctic conditions; to evaluate the efficacy of multi-hit dispersant application and to define the logistic and cost considerations for conducting a full-scale dispersant operation in the Beaufort Sea.

The operation was carried out in August of 1986 and all of the objectives outlined in the trial protocol were achieved as planned. In general, the results indicated that it is logistically possible to conduct an aerial dispersant operation in the Arctic and that there is some indication (mostly visual and photographic) that dispersants produce the desired effect.

In spite of this, there is still no clear evidence that dispersants are as effective as they need to be for environmental protection purposes. The trial showed that some mechanism which creates a phenomenon known as 'emulsion balls' interferes with the dispersion process and results in an overall reduction in dispersant effectiveness. These 'balls' formed on the surface of the water in each of the sprayed slicks and tended to confuse the interpretation of the infrared imagery which was the prime method used in determining dispersant effectiveness. Until the uncertainties created by the presence of these 'balls' can be resolved, the use of remote sensing as a technique for determining dispersant effectiveness should be supported with an adequate ground truthing program.

1.0 INTRODUCTION

The 1986 Beaufort Sea Dispersant Trial was the culmination of a number of years of dispersant testing to determine the effectiveness of these chemicals under field conditions (Gill, 1981; Gill and Ross, 1982; Swiss and Gill, 1984). The Canadian Offshore Aerial Application Task Force (COAATF) has been conducting such trials since the early '70's and has demonstrated that results achieved routinely under laboratory and mesoscale conditions cannot be easily duplicated in the field. The 1983 Halifax field trial, for example, was able to achieve a maximum measured dispersant effectiveness of only 40% (Myers and Corry 1984), far lower than necessary to adequately protect the environment. Analysis of the 1984 results suggested that the low effectiveness values were a function of the nonhomogenous nature of the slicks and the manner in which the dispersant was applied (i.e., single pass to achieve a 1:10 dispersant:oil ratio). Based on that trial, it was concluded that during an actual spill response operation, dispersant effectiveness rates could be increased significantly by the judicious re-application of dispersant to the portions of the slick that were not dispersed during the initial application.

To test this hypothesis, the Beaufort Sea Dispersant Trial was designed. The intent was to develop a plan that would more realistically simulate an operational application of dispersants. It was also decided that the dispersants would again be applied by helicopter and that the trial would be conducted in the Arctic where conditions could be expected to be more strenuous (5°C water temperature, remote location) than those encountered in more southern latitudes. The main purpose of the trial was to determine the percentage of oil that could be removed from the water's surface by dispersants applied under actual operating conditions. In addition, it was intended that the trial would be the basis for the development of operational procedures for the most effective way of using dispersants during an actual spill response.

Overall responsibility for the planning and conduct of the trial rested with Dome Petroleum Limited under the auspices of COAATF. The planning process including specific details of the trial are documented in the "Revised Operational Protocol for the Beaufort Sea Dispersant Trial", (COAATF, 1986).

Funding for the trial was provided by: The Environmental Studies Revolving Fund (ESRF); the Panel on Energy Research and Development (PERD); the Arctic and Marine Oilspill Program (AMOP); and the Petroleum Association for the Conservation of the Canadian Environment (PACE). In addition, materials, equipment and logistic support was provided by EXXON; British Petroleum International; Esso Resources Canada Ltd.; Gulf Canada Resources; Dome Petroleum Limited; the Beaufort Sea Oil Spill Cooperative; and East Coast Spill Response Inc. (ESRI).

1.1 TRIAL OBJECTIVES

Primary and secondary objectives for the experiment were as follows:

Primary

1. to determine the field effectiveness of two aerially applied dispersants under Arctic conditions;

2. to determine and test the operating parameters of a multihit dispersant application and document a strategy for applying dispersants under operational conditions so that all or most of the oil in a slick (90-95%) is removed from the surface of the water;

3. to define the logistic and cost requirements to support a dispersant operation in which a large percentage (90-95%) of a slick is removed from the water's surface.

Secondary

1. to obtain a long term record of an oil slick at sea in order to determine its fate.

1.2 TRIAL SETTING

1.2.1 Site and Timing

The site selected for the trial was an offshore location northeast of Esso's Arnak artificial island located in the Beaufort Sea at approximately 70°05'N; 133°22'W (Figure 1). The depth of water at this site was approximately 20m and it was roughly 40km from the nearest shoreline. In addition, the location was well outside the influence of the Mackenzie River plume in an open ocean environment.

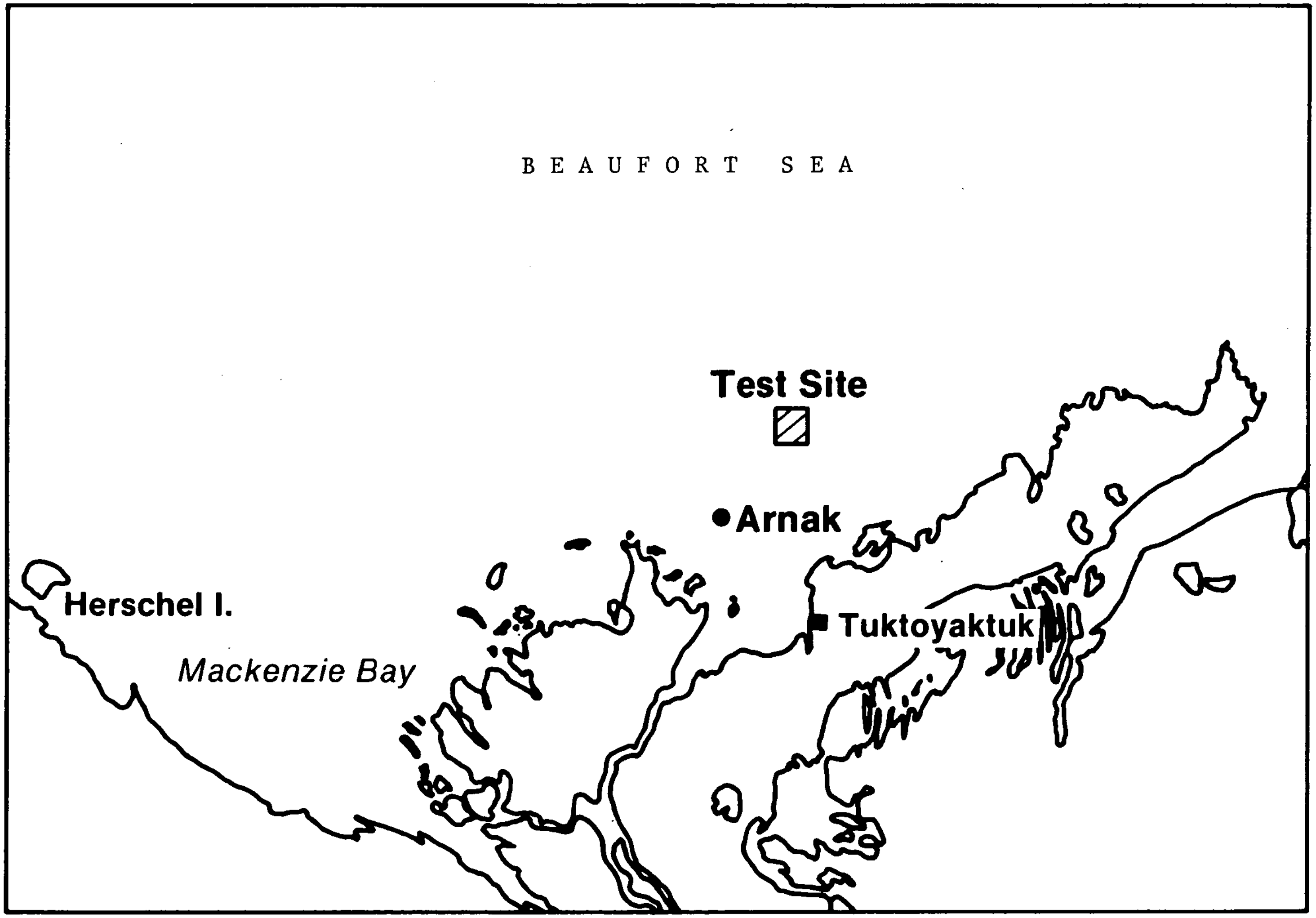
The time window selected for the trial was August 11-17, 1986 and operations were conducted on August 11 (aborted effort) and August 14 (successful attempt).

1.2.2 Operating Constraints

The following weather/seastate/logistic conditions were used to make a GO/NO GO decision on a daily basis. If any of these factors prevailed, the trial was delayed until acceptable conditions returned:

1. Unacceptable flying conditions
2. Less than five miles visibility at sea
3. Rain
4. Snow
5. Waves less than 0.5m
6. Greater than 1/10 ice cover
7. Presence of wildlife in the vicinity of the trial
8. Onshore winds
9. Canadian Marine Drilling Company Limited (Canmar) operating constraints

Figure 1
Trial Location



1.3 WEATHER AND SEASTATE

The following table provides a summary of the weather and seastate conditions that existed on the two days of the trial.

	August 11	August 14
Wind Direction	NE	ENE
Wind Speed	10-15 knots	10-15 knots
Visibility	16 km(prior to fog)	24km
Ceiling	unlimited(prior to fog)	unlimited
Significant Wave Height	1.0-2.0m	1.0-1.5m
Water Temperature	6°C	6°C
Air Temperature	8°C	10°C
Ice	None	None

2.0 LOGISTIC SUPPORT

Successful conduct of the trial would have been impossible without logistic support from Canadian Marine Drilling (Canmar), Gulf and Esso. Support was provided in the way of ships, aircraft and personnel. The details of this support are outlined in the following sections and depicted in Figure 2.

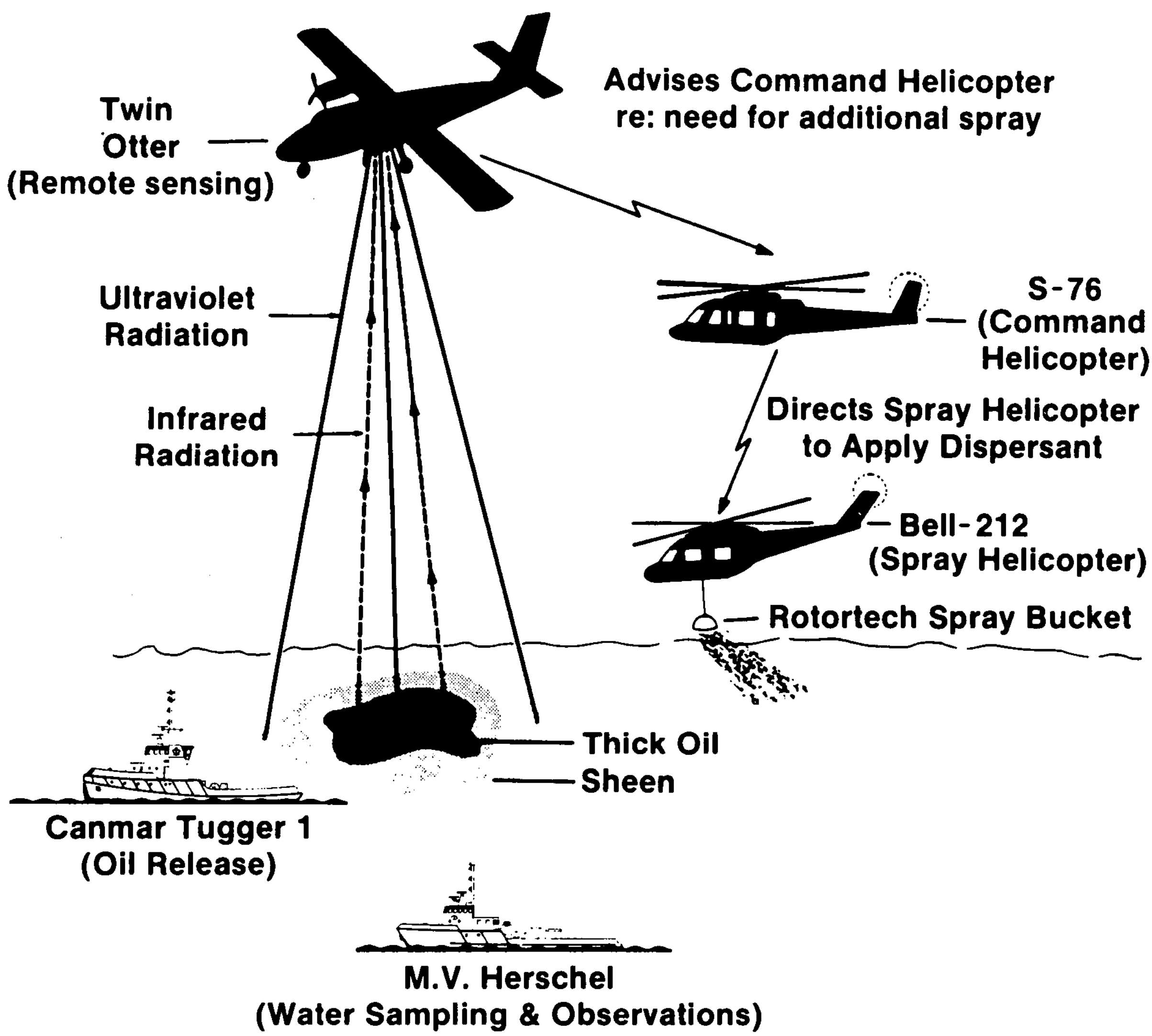
2.1 SHIP SUPPORT

2.1.1 Offshore Supply Vessel (Plate 1)

The major marine support for the trial was provided by Canmar's Tugger 1. This ship is an ice-strengthened seagoing tug 35.86m in length and 10.36m wide. It has a displacement of 805 tons and is rated at 3050 BHP. Tugger 1 was used during the trial to release the oil, collect oceanographic data,

Figure 2

Equipment and Technique Used to Release Oil, Apply Dispersant & Monitor Results.



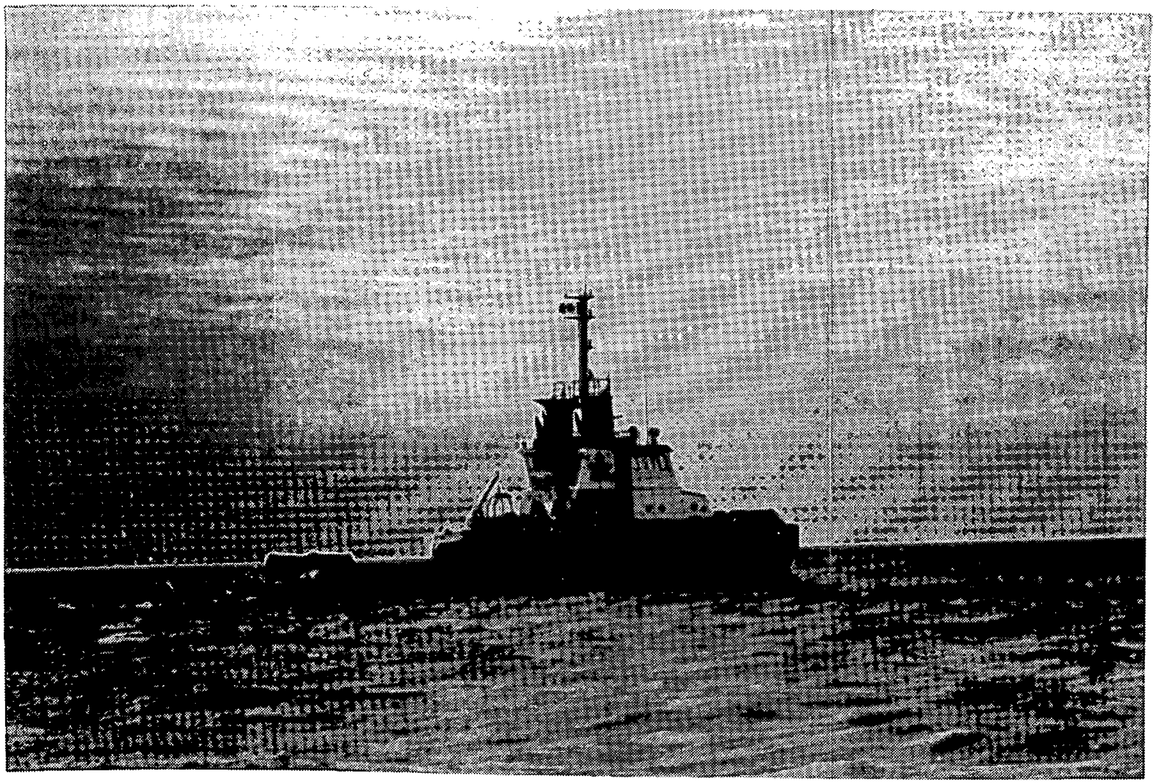


PLATE 1: CANMAR TUGGER 1 - Oil Release

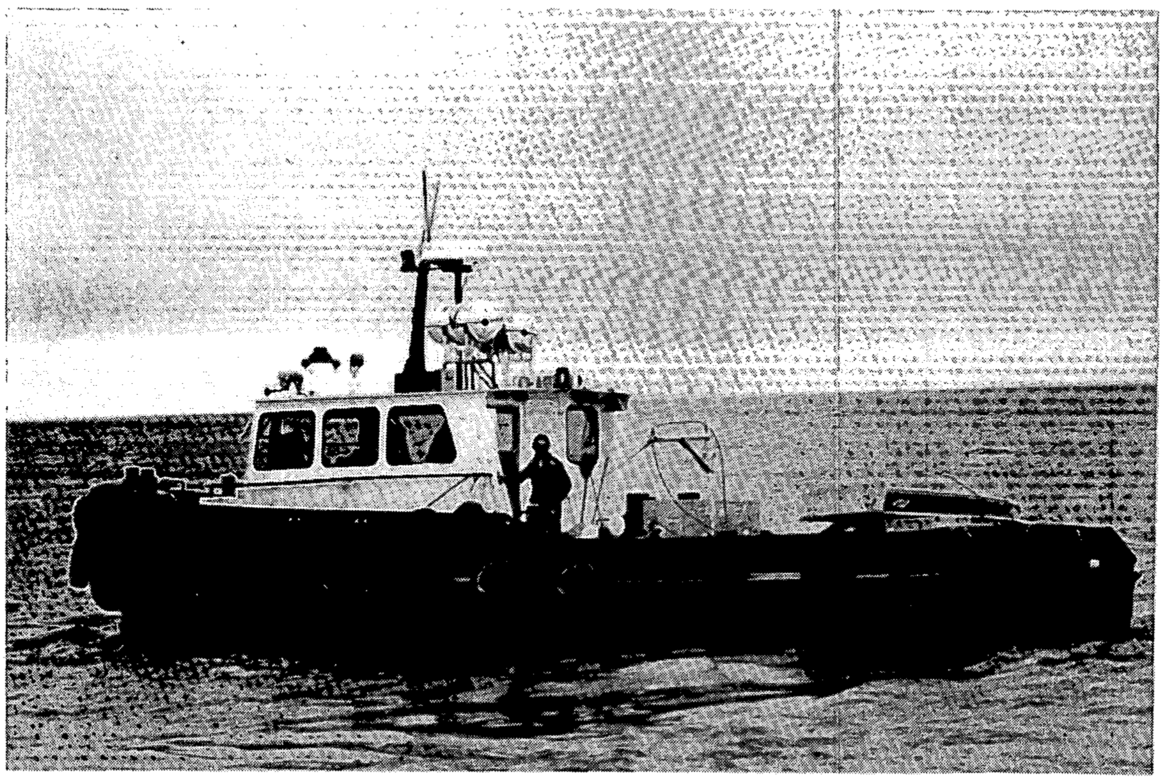


PLATE 2: M.V. HERSCHEL - Sea Level Observations

provide a spill response capability if required and to act as a safety vessel and escort for the M.V. Herschel. A summary of the activities of the Tugger 1 and copies of her daily log sheets are provided in Appendix I.

2.1.2 M.V. Herschel (Plate 2)

The M.V. Herschel was provided through contract with Gulf Canada Resources. This vessel was to be used as the means of deploying the Environmental Protection Service (EPS) towed fluorometer and as a platform from which sea level observations could be made.

Unfortunately, wave conditions on site and the design of the fluorometer combined to damage the instrument and no subsurface fluorometric data were collected. In spite of this, the vessel proved very useful as an observation platform, and valuable information on dispersant/oil interactions and processes were collected by those on board.

2.2 AIRCRAFT SUPPORT

2.2.1 Bell 212 (Plate 3)

The Bell 212 helicopter was supplied under contract by Gulf Canada Resources as the spray aircraft. A similar arrangement was also in place with Esso Resources Inc. and had the trial taken place on another day, the spray helicopter would have been provided by Esso.

The job of the spray aircraft was to pick up a full spray bucket from Arnak Island, transport it to the experimental site and, under the direction of the trial coordinator in the command helicopter, apply dispersant to the slicks.

PLATE 3: BELL 212 - Spray Helicopter

PLATE 4: SIKORSKY S-76 - Command Helicopter

2.2.2 Sikorsky S-76 (Plate 4)

The command helicopter supplied under contract by Dome was a Sikorsky S-76. Although originally viewed as being larger than necessary for the job, it proved to be a very suitable aircraft. Not only did it act as the command platform from which operational direction was provided, but it also provided a vantage point for the Ocean Dumping Inspector, the Hunter's and Trapper's Association (HTA) representative and two additional observers.

The function of the aircraft was to provide a location from which direction could be given for discharging the slicks, applying the dispersant and sampling the subsurface water column with the towed fluorometer.

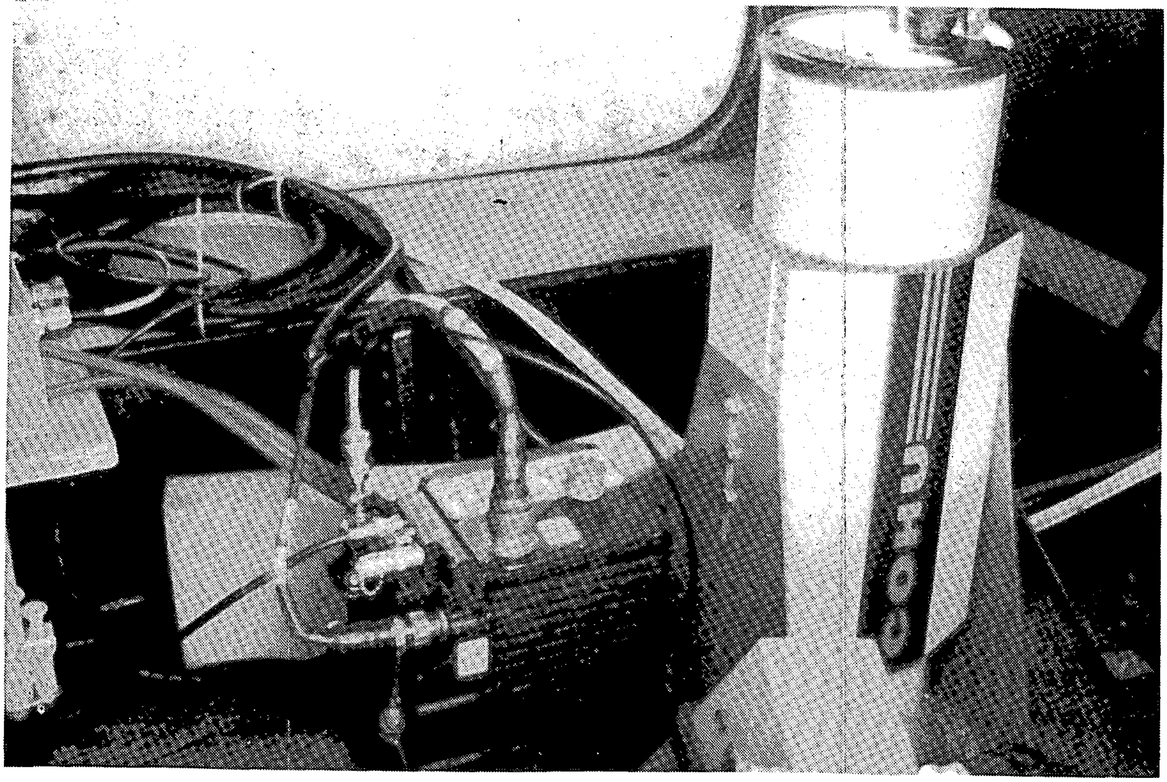
2.2.3 Twin Otter (Plate 5)

The Twin Otter used in the trial was contracted from Ken Borek Airlines Ltd. It's main function was to act as a platform for remote sensing activities (these will be described in Section 3.4), but it was also used to do a wildlife survey prior to the trial and as an advance aircraft to check weather and seastate conditions at the site prior to mobilizing the entire fleet of aircraft. This aircraft was outfitted with the remote sensing gear (Plate 6) in Inuvik prior to the trial. It spent the week of the trial on standby in Tuk.

2.2.4 Falcon (Plate 7)

The fourth aircraft involved in the trial was the Canada Centre for Remote Sensing Falcon 20. It also provided infrared and ultraviolet remote sensing support (Appendix II).

PLATE 5: TWIN OTTER - Remote Sensing Aircraft



Infrared and Ultraviolet Detectors

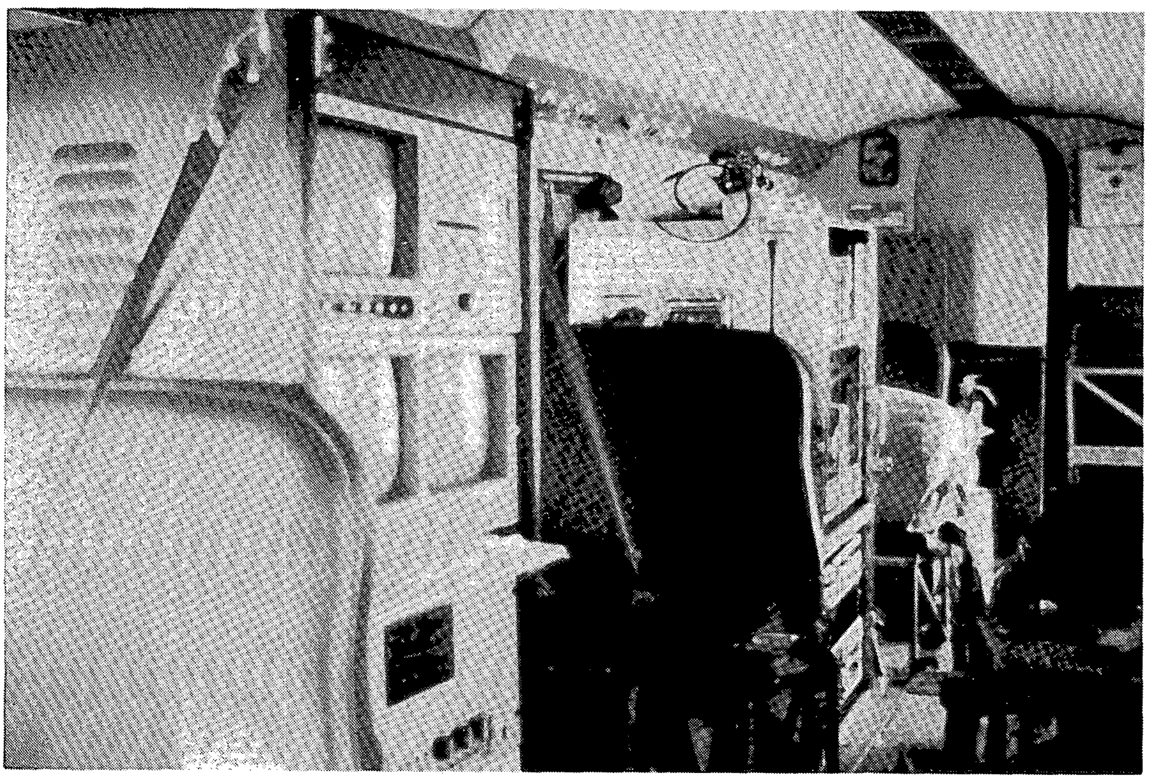


Image Analysis Equipment

PLATE 6: Remote Sensing Equipment Mounted in Twin Otter

2.3 SPRAY SYSTEM

The spray system used during the trial was the Rotortech Limited TC-3 underslung spray bucket. It consists of a 680 litre fibreglass bucket, a gasoline engine, centrifugal pump, fuel and spray booms (Plate 8). Dispersant was carried in the bucket and then pumped to the spray booms when required. Switches for starting the engine and turning the spray booms on and off were located on a small control box situated in the cockpit of the helicopter. The bucket was attached to the aircraft hook and a simple plug-in arrangement was used for the electrical connections.

Two spray buckets were used for this trial. This was done to provide back-up in case of mechanical failure. They were on loan from East Coast Spill Response Incorporated in St. John's Newfoundland.

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL DESIGN

The original experimental design for the trial is described in detail in the 'Revised Operational Protocol for a Beaufort Sea Dispersant Trial' (COAATF, 1986).

The trial was conducted from three locations: 1) Esso's Arnak artificial island (Figure 1 and Plate 9) where the dispersants were stored and loaded; 2) the test site approximately 10km northeast of Arnak; and 3) Tuk Base/Airport which was the operational centre for aircraft support.

On August 11, a decision was made to proceed with the trial. Equipment and material's were assembled on site and procedures were initiated as described in the 'Revised Protocol'. Unfortunately, equipment and weather problems preempted completion of the trial on that day (See Section 4.1).

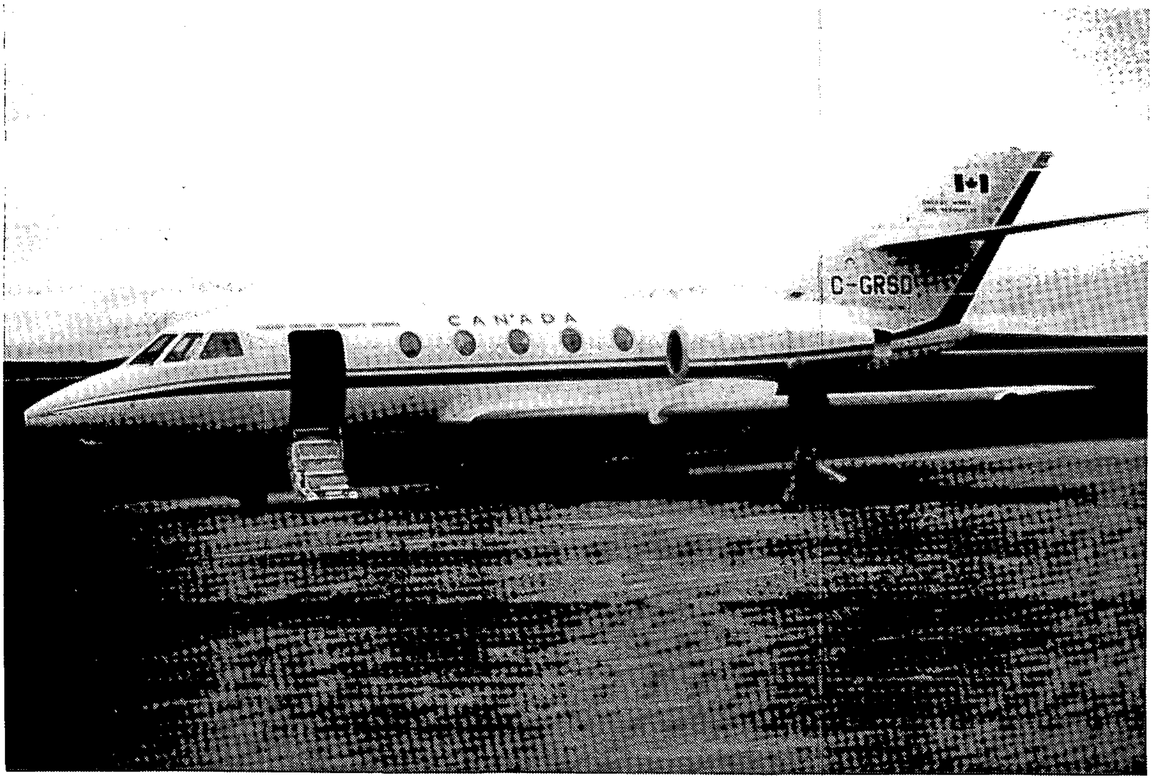


PLATE 7: CCRS Desault Falcon - Remote Sensing Aircraft

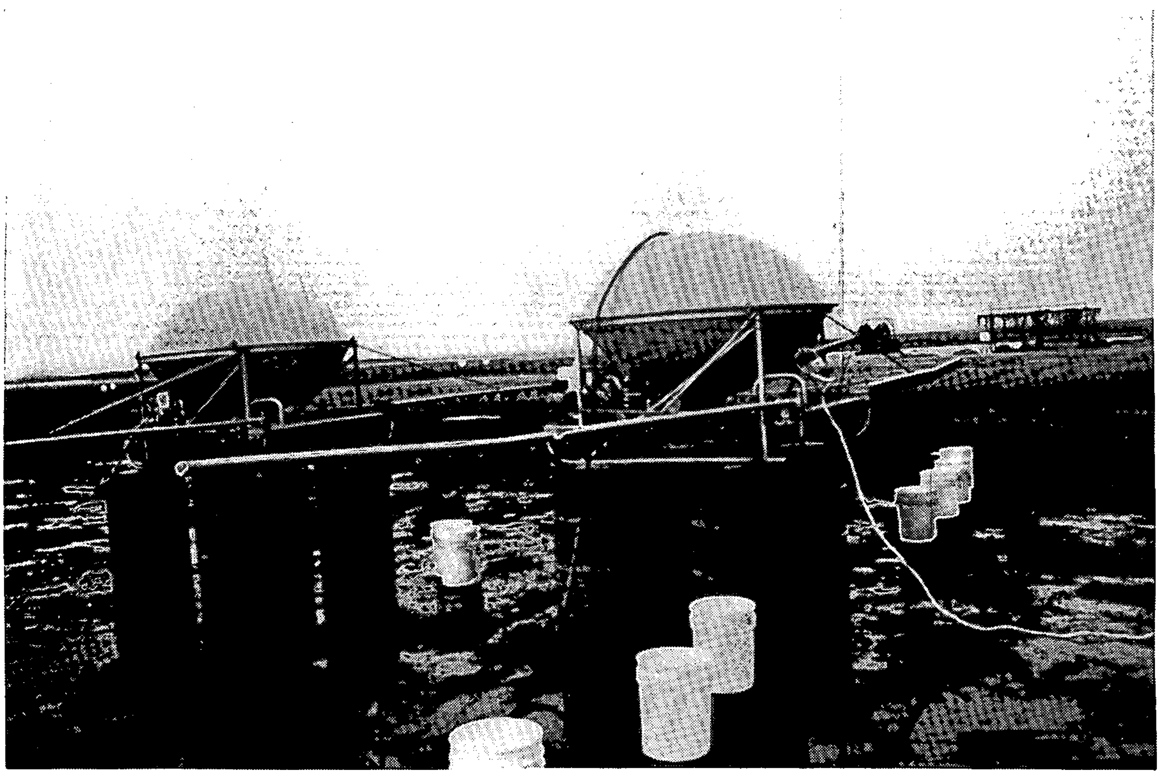


PLATE 8: ROTORTECH Spray Buckets - Being Calibrated with Water

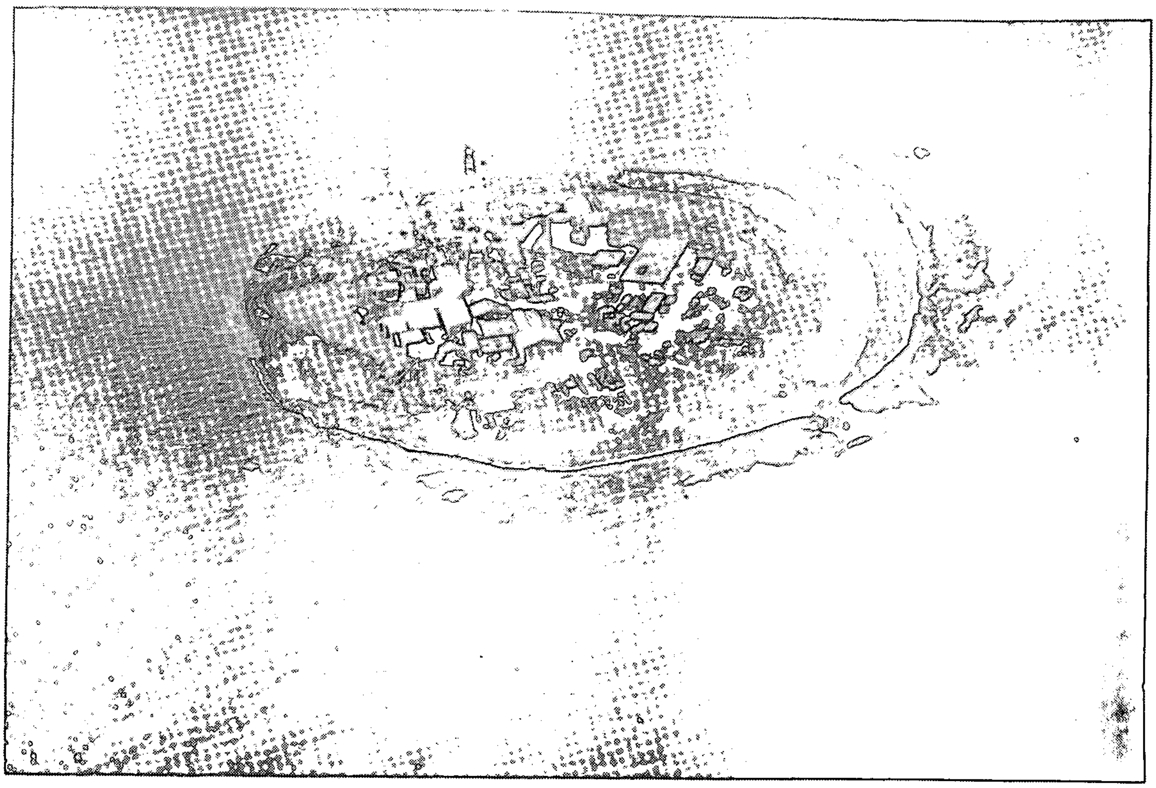


PLATE 9: ARNAK - Esso Artificial Island

Because $5m^3$ of the available $15m^3$ of oil was released on August 11, it was not possible to complete the remainder of the trial as originally planned. In order to make maximum use of the remaining $10m^3$ of oil and to come as close as possible to achieving the original objectives of the trial, the experimental design was modified.

The basic components of the modified trial are outlined as follows:

- The experiment took place during the week of August 11-15, 1986. The actual day of the trial was Thursday, August 14.

- Two dispersants (Exxon's CRX-8LT and British Petroleum's Enersperse 700) were tested.

- The test oil was Alberta Sweet Mixed Blend weathered to remove 15-20% of its volume.

- Four slicks were released ($2.5m^3$/slick) about two kilometres apart.

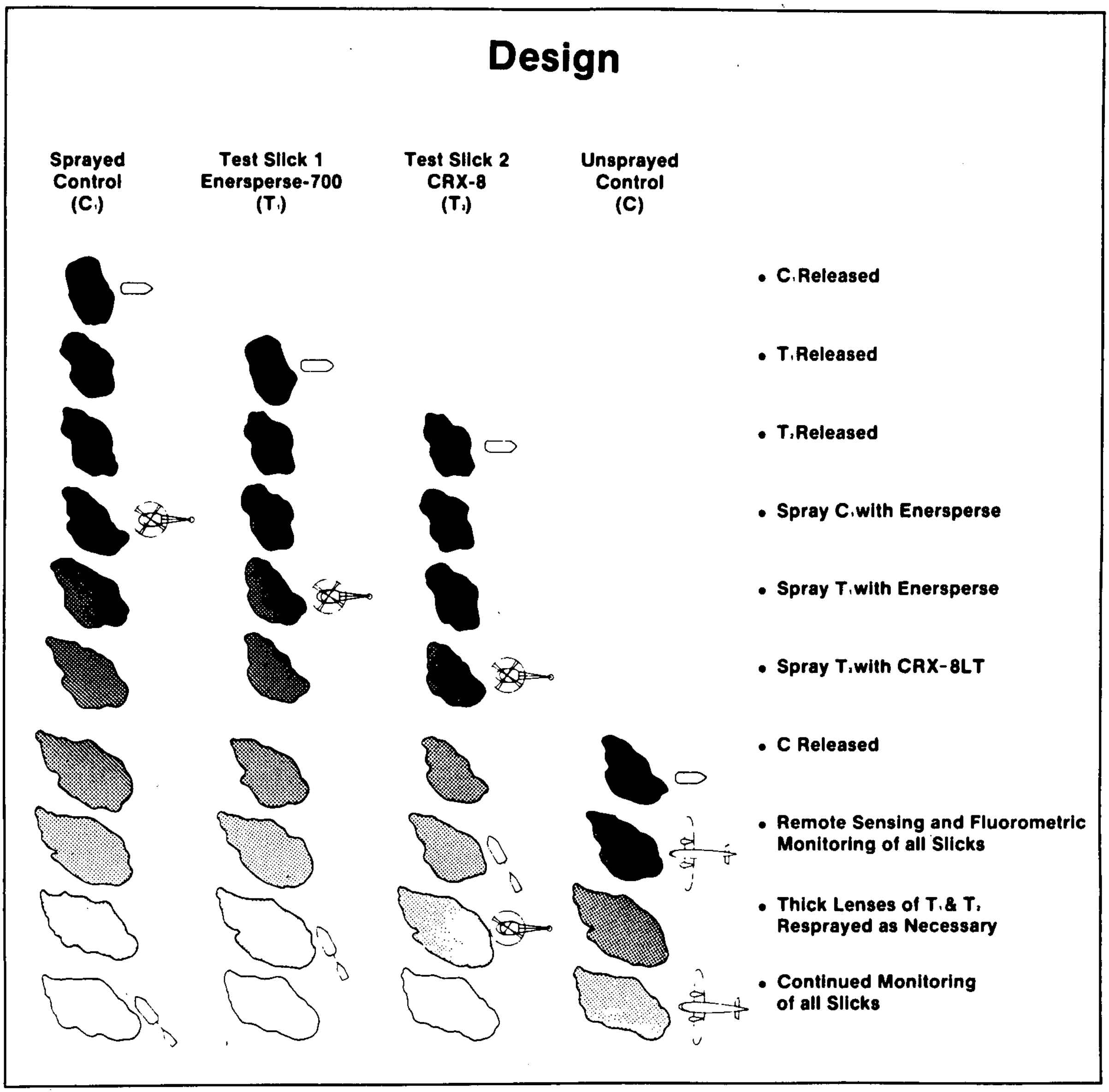
- One slick (C) was an unsprayed control with no dispersant applied. The second slick (C_1) was a control sprayed once with Enersperse 700 applied at the ratio of 1:10 dispersant to oil. The third slick (T_1) was a test slick sprayed three times with Enersperse 700. The fourth slick (T_2) was also a test slick and was sprayed three times with CRX-8LT.

- During the first spray passes of the test slicks (T_1 and T_2), the entire slicks were sprayed. They were then monitored by the remote sensing aircraft and after a period of time (0.5 to 1 hr) any remaining thicker lenses of oil were resprayed. This procedure was repeated until most of the oil had been dispersed (as determined by infrared imagery). A diagrammatic representation of this procedure is shown in Figure 3.

- Effectiveness was monitored by remote sensing aircraft and judged on the basis of disappearance of "thick" ($>$100 um) lenses of oil.

A more detailed breakdown of the experimental components is shown in Table 1.

Figure 3
Modified Experimental Design Used In Trial



3.2 OIL DISCHARGE

The discharge of the oil were one of the most crucial aspects to the success of the trial. The slick size had to be optimized for sampling, remote sensing and, most importantly, dispersant application by the careful release of the oil. The discharge system was designed to incorporate the following characteristics:

1. simplicity of operation;
2. reliability and field repairability
3. control of slick geometry
4. high volume of oil discharge rate;
5. known and predictable discharge rates; and
6. minimum disturbance of oil on water during and after discharge.

Release of the oil took place while the vessel (Tugger 1) was moving at the slowest possible speed upwind. Discharging while steaming upwind eliminated the possibility of the vessel being oiled and improved the chances of controlling slick geometry.

TABLE 1: EXPERIMENTAL COMPONENTS

1.	Location	- Arnak Artificial Island: 69°45'40"N; 133°46'20"W
2.	Timing	- August 14, 1986
3.	Oil	- Alberta Sweet Mixed Blend - Total 10.0 m^3 - 2.5 m^3/slick - 4 slicks per test
4.	Dispersant	- CRX-8LT (Exxon) - Enersperse 700 (BP)
5.	Spray System	- Rotortech TC-3
6.	Aircraft Support	- Bell 212 (Spray Plane) - Twin Otter (Remote Sensing) - Sikorsky-76 (Command, photography, regulatory)
7.	Ship Support	- Canmar *Tugger 1* (oil release, oceanography, safety) - *M.V. Herschel* (subsurface water sampling, sea level observation
8.	Operations Centre	- Tuk Base/Airport

Ten cubic metres of oil was carried on the aft deck of Tugger 1. Three pressurized tanks had been constructed prior to the trial to form three separate 2.7 m^3 storage sections. Schematic diagrams of these tanks and their arrangement on the supply vessel are shown in Figures 4 and 5 respectively. Once the oil was placed into these tanks, the tanks were pressurized (less than 240 Pa) using compressed air. This pressurization aided in discharging the oil from the tanks through the floating hoses and onto the sea surface. In addition, a small pump was placed in-line between the tank and the hose to augment the release of the oil. Since there were only three tanks and four slicks were required in the modified design, one of the tanks was filled and emptied twice.

In order to minimize propwash effects and discharge vessel oiling, the hose was deployed from the side of the aft deck of Tugger 1 through the scuppers. The use of a 10m length of hose permitted the end of the hose to trail slightly astern of the vessel. Once released, the oil was allowed to spread for approximately 20 minutes prior to initiation of dispersant spraying. A summary of the oil release procedure is shown in Appendix I.

3.3 DISPERSANT APPLICATION

Based on a series of trials undertaken by COAATF in 1981, a S-76 helicopter flying a Rotortech TC-3 bucket at a height of approximately 8m creates a dispersant swath some 15m wide. It was assumed that a similar swath width and droplet density would be achieved using the Bell 212 aircraft and the Rotortech bucket.

Using the design dispersant-to-oil ratio (1:10), 250L of dispersant are required to make one complete spray pass; however, considering the possible dimensions of the slick to be dispersed (approximately 150m X 150m) and the appropriate flying speeds for the dispersant helicopter (80 knots or 40 m/s), it was assumed that 20 to 35% of the dispersant would not hit the desired

Figure 4

Design Of Oil Release Tanks

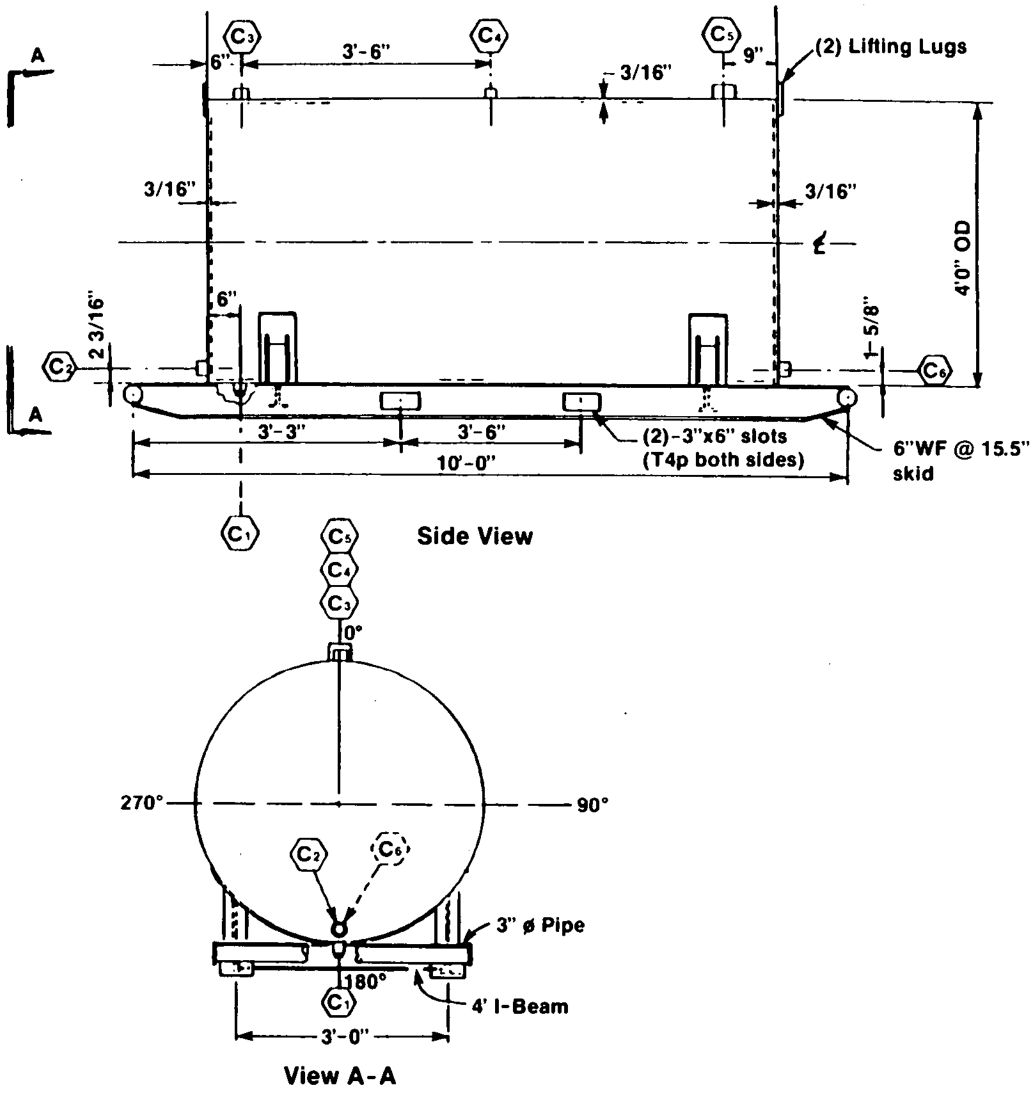
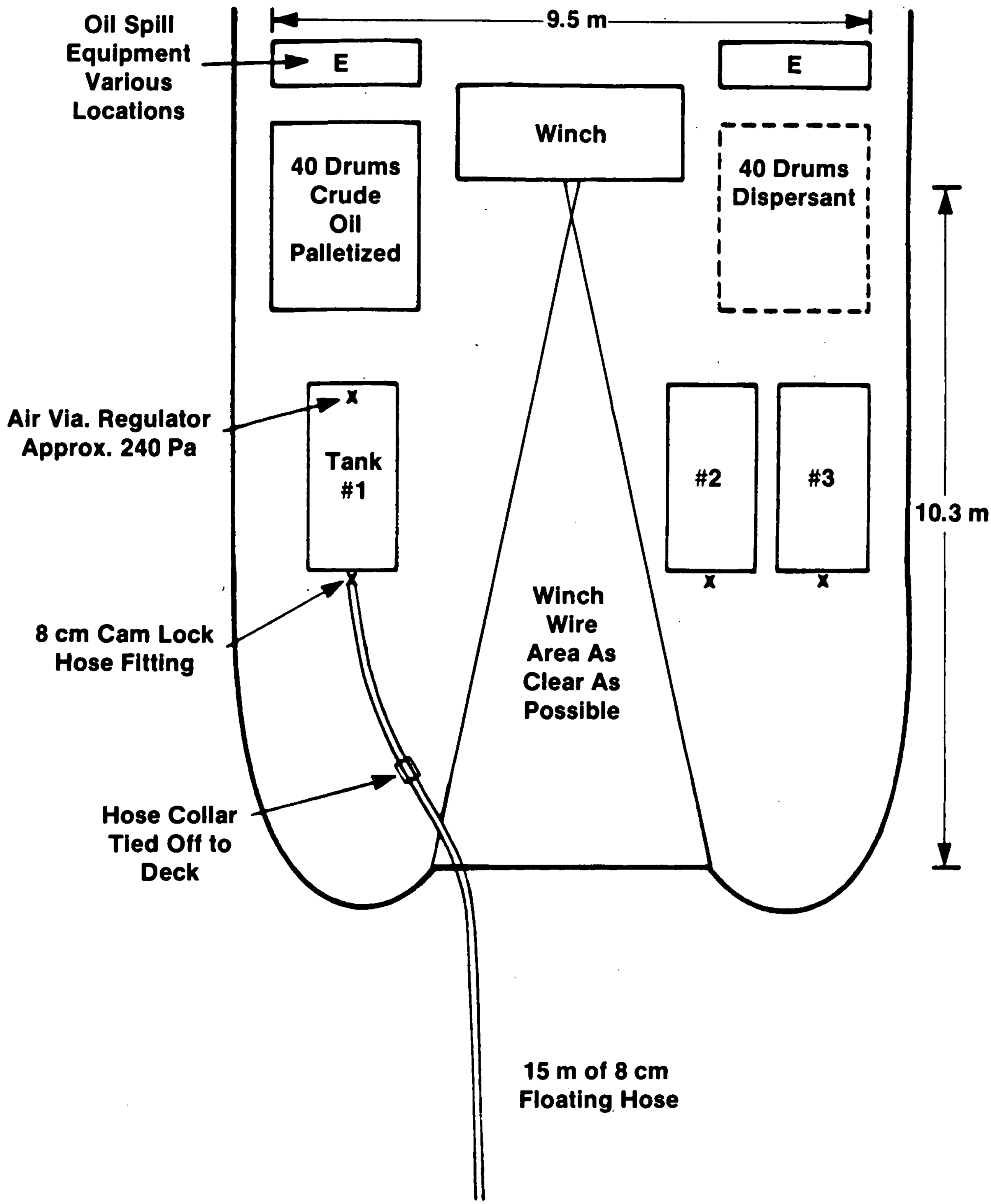


Figure 5

Supply Vessel Deck Arrangement



target (the thick portions of the slick). Therefore, to more accurately simulate an operational application of dispersants, a full load of dispersant (416L) was carried in the bucket.

Both spray buckets were calibrated at Tuk airport prior to beginning the trial. This involved pumping water through the spray nozzles and adjusting the nozzles until they all delivered approximately the same amount of fluid. During the trial, the helicopter picked up full spray buckets from Arnak when additional dispersant was required. Since two buckets were available, there was always a full one awaiting pick-up. The total quantity of dispersant (in litres) remaining in each bucket after each bucket exchange, was measured and recorded. No dye was added to the dispersant. A summary of the dispersant application procedure is shown in Table 2 and a detailed description of the bucket loading procedure and measurement of remaining dispersant is outlined in Appendix III.

The helicopter was advised to fly with the bucket at an altitude between 7 and 11m and a forward speed of approximately 150km/hr. The dispersant was applied via the 10m spray bar with the pump at full speed. During the initial dispersant application the helicopter made parallel passes upwind over the slick commencing at one side of the slick. Spray overlap was avoided as much as possible. During subsequent applications, the helicopter was directed to spray only the thicker lenses of oil remaining in the test slick. Each pass of the dispersant helicopter was directed by the command helicopter. By using a coloured smoke flare, which was deployed at the upwind edge of the slicks, the spray helicopter was able to align itself accurately both in relation to the prevailing wind and the edge of the previous swath.

TABLE 2: DISPERSANT APPLICATION SUMMARY

Helicopter	- Bell 212
Spray Bucket	- Rotortech TC3 - 10m spray bar
Altitude	- 10-15m (helicopter) 7-11m (bucket)
Speed	- 150 km/hr (80 knots)
Application Rate	- 125 L/ha (Max. pump rate)
Timing	- initial application 20-25 min. after oil discharge, subsequent applications as needed
Flight Path	- parallel upwind paths 15m apart
Flight Control	- command helicopter

3.4 REMOTE SENSING TECHNIQUES

Unlike previous trials, which relied heavily on water column sampling, this experiment used a remote sensing aircraft as the prime method for determining dispersant effectiveness. This approach had the following advantages:

1. It reduced the need for people in small boats, and therefore relaxed the restriction on upper wave heights allowing the trial to be conducted under more realistic conditions;

2. It eliminated the requirement for a large chemical analysis component which is both time consuming and costly;

3. It focused attention on removal of oil from the water's surface (the prime concern) and deemphasized the need for measuring extremely patchy concentrations of oil in the three dimensional water column; and

4. Remote sensing provided almost immediate feedback to the command helicopter which was essential for determining the need for additional application of dispersant and for determining when the desired level of dispersants was achieved.

The remote sensing program had three functions: 1) to provide coverage of the slicks during the spray period; 2) to determine the percentage of oil removed from the water surface and provide the information to the command aircraft; and 3) to locate and evaluate the slicks after they had drifted for 12 to 48 hours.

The program involved use of an imaging infrared/ultraviolet (IR/UV) system mounted in the Twin Otter (Goodman and Morrison, 1985). The UV channel was used to define the entire extent of the slicks (mostly sheen), while the IR channel defined the areas of thick oil (i.e.$>$ 100 um).

The flight altitudes ranged from 300 to 2000m above sea level. As the slicks increased in size, it was necessary to increase the altitude to cover the total slick in one image. The output of the IR camera was fed into an airborne image analyzer (Compuheat VIPS 300C: see Appendix IV), which calculated the area of the thick part of the slick. This area, and the location of the thicker lenses within the slicks, were transmitted to the command helicopter, which used the information to guide the spray helicopter.

In addition to the real time analysis, the oil slick images and navigational information from the aircraft were recorded on a 3/4" recorder. The 3/4" tapes were analyzed after the trial using a Spectral Data image analyzer. The unit provided for image enhancement and subsequent measurement of the areas of both the thick lenses and the sheens as a function of time.

On the day after the trial, the aircraft was used to find any remnants of the slicks. The probable locations of the slick remnants were determined through trajectory modelling.

3.5 WATER COLUMN SAMPLING

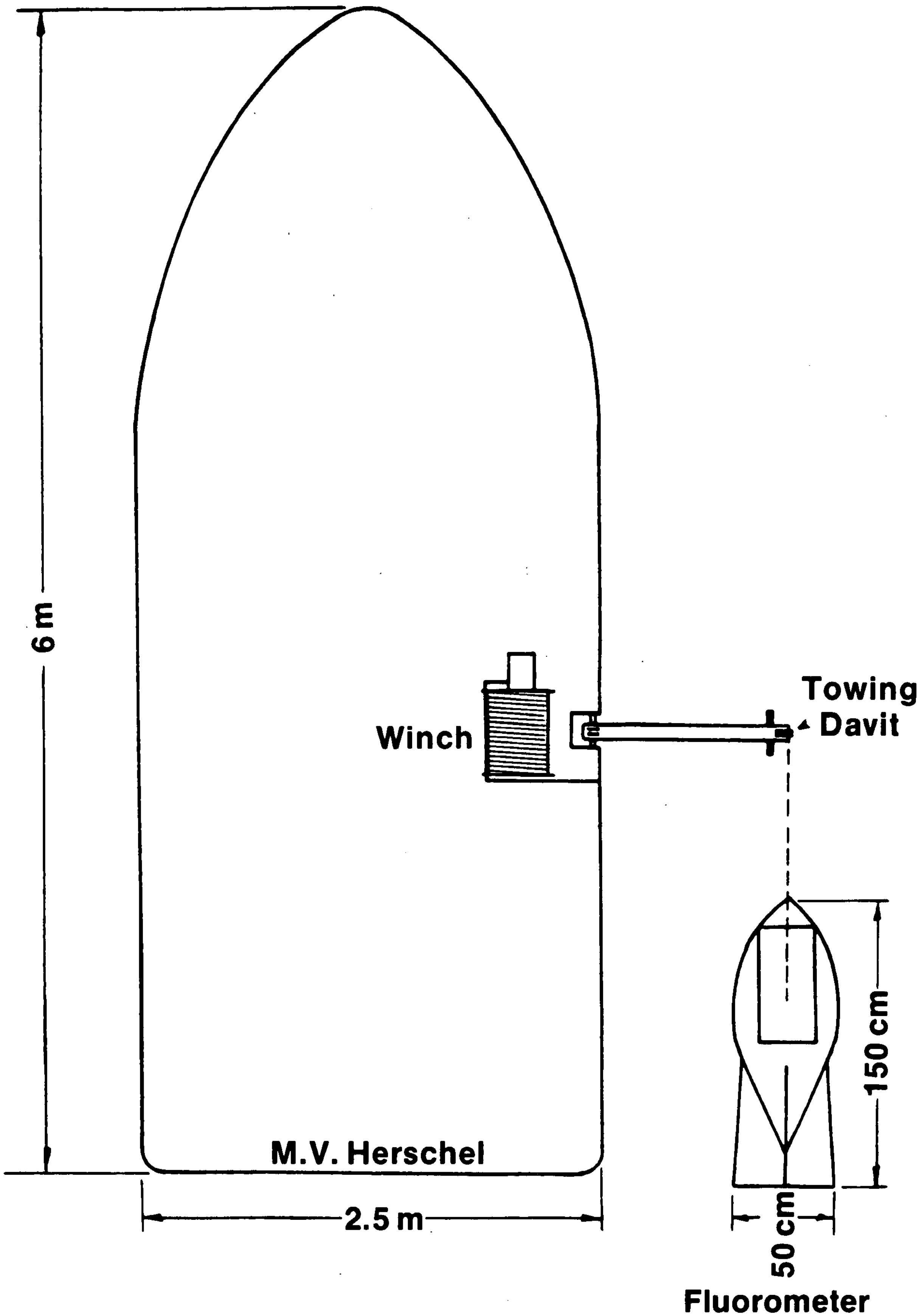
As mentioned previously, the sampling of hydrocarbons in the water column was to be done at a much reduced scale compared to previous studies. Only one sampling vessel was deployed (M.V. Herschel) and plans were made to sample both test and control slicks with this vessel.

The sampling system was Environment Canada's towed fluorometer. This system consists of a modified TURNER flo-through fluorometer which was pulled behind the Herschel. The in-water components of this sampling system are streamlined to facilitate manoeuvring of the vessel (Figure 6).

The fluorometer was to be towed at a depth of 1-3m beneath each slick to produce a continuous record of subsurface oil concentrations. The initial pass through each slick was to be along the longitudinal axis with a second pass perpendicular to the first at the centroid of the slick. Passes were to

Figure 6

Schematic of Towed Fluorometer and Boat (M.V. Herschel)



be made beneath the two control slicks (C and C_1), once near the start of the operation and once near the end. The test slicks (T_1 and T_2) were to be sampled as many times as possible during the operation.

Data was to be recorded on a Compaq computer system to provide a continuous record of the concentration of oil (in ppb) along the sampling path. These data were to be analyzed after the trial and a data report produced for incorporation into the overall project report.

Unfortunately, the fluorometer was damaged just as the trial got underway and no data were collected.

3.6 OCEANOGRAPHIC DATA

Background information describing the oceanography of the test site was provided by operators working in the vicinity. This information was supplemented by measurements taken on-site by the crew of Tugger 1. The data produced by these two sources were used for making daily decisions on the conduct of the trial and to analyze the dispersant effectiveness information collected during the trial.

3.7 WEATHER FORECASTING AND TRAJECTORY MODELLING

Weather and seastate forecasting for the trial was provided by the Beaufort weather office. Forecasts were initiated three days prior to commencement of the trial and provided every six hours. They included 12, 24, 36 and 48 hour forecasts with outlooks to 96 hours. A weather briefing was held at the Operations Base at 0700 and 1900 daily. An oilspill trajectory model (Esso/AES) was used to predict the slick size and oil centroid location at 6, 12, 18, 24, 36 and 48 hours after an assumed release time. This information was used to predict the movement of the slicks for the purposes of the go/no go decision, assist the remote sensing aircraft in monitoring the remnants of the slicks and verify the accuracy of the Esso/AES model.

4.0 RESULTS

This section includes a description of the initial release and spreading of the oil; application of dispersant; visual observations of dispersant effectiveness; real time analysis of dispersant effectiveness using infrared imagery; and post operational analysis of effectiveness using infrared and ultra violet imagery.

4.1 OIL DISCHARGE AND SPREADING

August 11

Oil discharge was generally achieved as described in the materials and methods section. On August 11, two slicks were created. The first was released at 1518 local time (LT) and took two minutes and 27 seconds to be completed. Location of this slick was at 70°04'42"N; 133°22'00"W, as determined by the navigational system on Tugger 1. This slick spread to a maximum area of $900m^2$ (thick oil) before beginning to dissipate.

The second slick released on August 11 was started at 1545 LT and took two minutes and 18 seconds to be completed. This slick was located at 70°07'42"N; 133°22'00"W. This slick spread to a maximum area of $2000m^2$ of thicker oil.

Shortly after laying these slicks down, an operational problem with the spray bucket was discovered and it became inoperable. Attempts to use the second bucket failed when a fog bank moved into the area and operations had to be terminated for the day.

In spite of this, some useful information was obtained from the slicks by the remote sensing aircraft which collected data from the slicks until the fog prevented further flying.

August 12 & 13

All crew and equipment were on standby waiting for the weather to improve. Tugger 1 remained on-site monitoring conditions throughout the two days. The Herschel stayed on-site during the day and spent the nights either at Tuk or Arnak.

August 14

The decision to again proceed with the trial was made at approximately 1000 hr LT (Local Time) on August 14th. All personnel were notified and advised to congregate at the offshore test site. By 1200 hr (LT), all equipment and personnel were in position, and the slicks were released and sprayed in the manner described in section 3.1. Table 3 summarizes the location, timing, and spreading of the four slicks.

TABLE 3: SUMMARY OF DATA FOR RELEASE OF FOUR SLICKS ON AUGUST 14

Slick	Code	Time of Release (LT)	Location	Pumping Time	Orion Buoy #	Thick Oil Area after Spreading
Unsprayed* Control Slick	C	1804	70°08'30"N 133°23'00"W	2 min 50 sec	2	790M^2
Sprayed Once Control Slick	C1	1216	70°02'24"N 133°22'00"W	2 min 45 sec	4	1600m^2
Enersperse Test Slick	T1	1242	70°04'00"N 133°22'00"W	2 min 15 sec	5	1870m^2
CRX-8LT Test Slick	T2	1427	70°06'06"N 133°23'12"W	2 min 45 sec	6	750m^2

* It should be noted that control slick C was released in a manner dissimilar from the other slicks. In this case, the oil was poured onto the water from a height of approximately 1 metre rather than being laid on the surface as was the case for the other slicks. In addition, the sea state at the time of release was higher than for the other slicks (1.5m vs 1.0m).

4.2 DISPERSANT APPLICATION

The number of spray applications made for each slick varied and was dependent on the size and shape of the thick oil lenses (as determined by the remote sensing equipment) and the decisions of those in the command helicopter regarding the need for additional spray. Since there was no attempt to collect spray droplets at sea level, the dispersant to oil (D:O) ratio was calculated based on the amount of dispersant used for each spray sortie (ie. the initial bucket load minus the amount remaining after spraying.) Although this approach lacked the precision of a rigorous scientific protocal for determining dispersant to oil ratio's, it was compatible with the prime objective of the trial which was to evaluate the effectiveness of an operational application of dispersant.

The type and amount of dispersant sprayed on each slick and the cumulative D:O ratio after each spray pass are shown in Table 4. Actual movements of the amount of dispersant remaining in the spray buckets after each sortie are presented in Appendix III. Calculations of the D:O ratios were based on the assumption that the total amount of oil available for spraying was 2,500 L (2.5 m^3) and that all of the sprayed dispersant contacted oil.

TABLE 4: AMOUNT OF DISPERSANT SPRAYED ON EACH SLICK AND CUMULATIVE DISPERSANT:OIL RATIO

Slick	Number of Applications	Dispersant	Amount Sprayed	Approximate Cumulative Dispersant to Oil Ratio
C_1	1	Enersperse 700	261 L*	1:10
T_1	1	Enersperse 700	261 L*	1:10
	2	Enersperse 700	409 L	1:3.5
	3	Enersperse 700	364 L	1:2.5
T_2	1	CRX-8LT	273 L	1:9
	2	CRX-8LT	559 L	1:3
	3	CRX-8LT	409 L	1:2

* These applications were made during the same spraying sortie. Based upon comparable total spraying times, it is assumed that the amount of dispersant applied to C_1 and T_1 (during the first application) was the same (261L).

These values are, of course, over-estimates of the actual dispersant to oil ratios. Some of the dispersant would evaporate en route to the slick, some would miss the slick entirely, and some would probably pass through the oil into the water. Therefore, the actual D:O ratios would be somewhat less than those calculated above.

4.3 VISUAL OBSERVATIONS

Visual observations of the trial were made both from the air and from the surface of the sea. These observations provide insight into the effectiveness of the two dispersants and to the mechanisms operating during the post spray periods.

In all cases, the oil spread after initial release to form large 'tear drop' shaped slicks that became aligned with the prevailing wind (ENE). This took approximately 20 minutes and allowed the slicks to stabilize prior to spraying.

The initial spray passes for all three treatments produced similar visual effects. After these first applications, an obvious coffee coloured cloud of dispersed oil developed just under the water's surface and remained at the upwind end of the slicks as time passed. This "dispersed oil cloud" remained visible for up to 3 hours after its appearance. In addition, definite lenses of thick oil remained on the surface of the water and moved down wind from the clouds of dispersed oil. This effect was observed in both previous COAATF Trials (Gill and Ross, 1982; Gill et al, 1985).

When the thick oil lens of the T_1 slick was sprayed a second time with Enersperse 700 there was a very dramatic increase in the quantity of dispersed oil. In this case, the size and intensity of the cloud was much greater than that observed in the initial spray application. (Plate 10). This effect was not noticed for the third Enersperse 700 application nor for either of the second or third CRX-8LT spray treatments. In these cases, there was additional dispersed oil present (i.e. more than was observed after the initial applications), but the increase was far less dramatic than for the second T_1 spray and was similar to the results observed for the initial spray applications of Enersperse. As with the initially observed dispersed oil, the submerged clouds gradually became less intense and were not influenced by the wind, tending to remain upwind of the surface oil. A dispersed oil cloud was not observed in the unsprayed control slick (C).

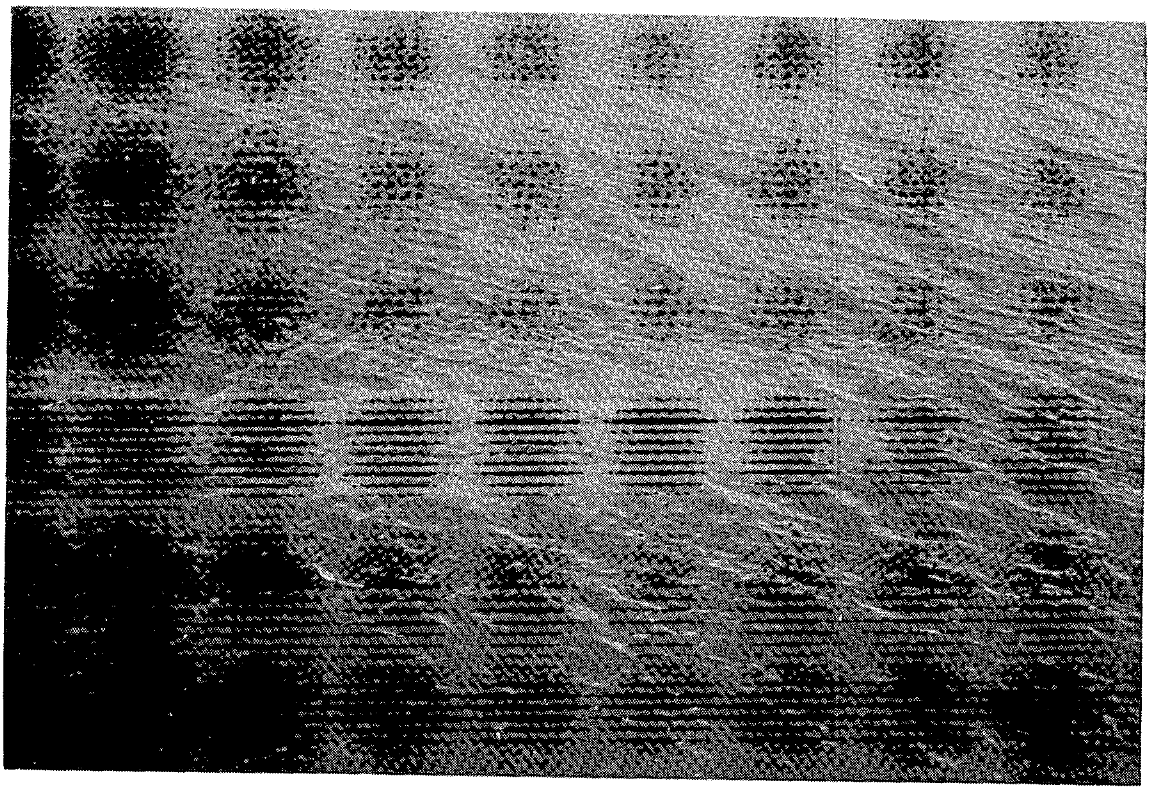


PLATE 10: Dispersed Cloud After Second Treatment with Enersperse 700

On the water's surface, another phenomenon was observed. In addition to the clouds of dispersed oil that were seen from the air, the sea surface observers also reported a large number of 'grape-sized' balls of oil which covered the surfaces of the sprayed slicks (Plate 11). These 'balls' have been variously referred to as 'herdy balls' 'pea floc' and 'emulsion balls' and have been observed in previous offshore trials (Fingas, Personal Communication and Bocard, Personal Communication). The term 'emulsion balls' will be used throughout the rest of this report when referring to this phenomenon. Sea surface observations of slick C were made by those on board the M.V. Herschel. No emulsion balls were observed in this slick (Fingas, personal communication).

Although attempts were made to collect samples of these emulsion balls, it was found that upon being touched, they burst apart and dissipated leaving no remnants of the original structure.

4.4 REMOTE SENSING IMAGERY

4.4.1 Real Time Analysis

The real time analysis of the infrared images produced by each slick provided an indication of the areas of thick oil within each of the four slicks. Post trial analysis of the data collected in the field was carried out to minimize any possible error in field calculations. An example of the real time and post operational images that were produced by the remote sensing system for the multi-spray test slick T_1 is shown in plate 12. It should be noted that the images shown in these plates were taken at various altitudes (2000-3500ft). Because of this, it is not possible to visually compare image areas from frame to frame. The areas calculated by the computer took into account the altitude at which the image was taken. A summary of the areas calculated for each slick (in real time) are shown in Table 5. The decrease in area of thick oil in each slick was calculated as a percentage reduction over time. These values were plotted against time after initial release and are shown in Figure 7. The points at which dispersant was applied are also shown in this figure.

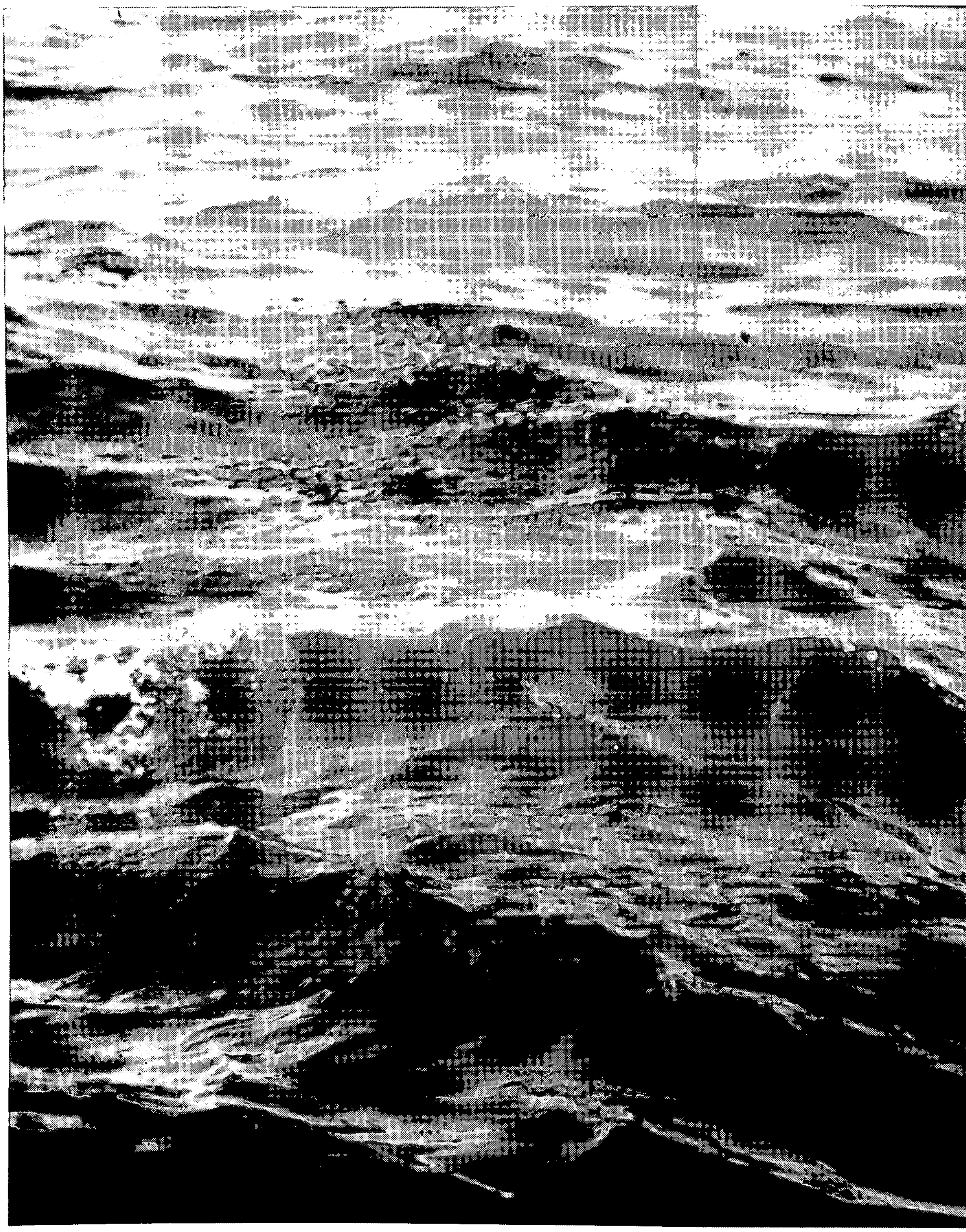
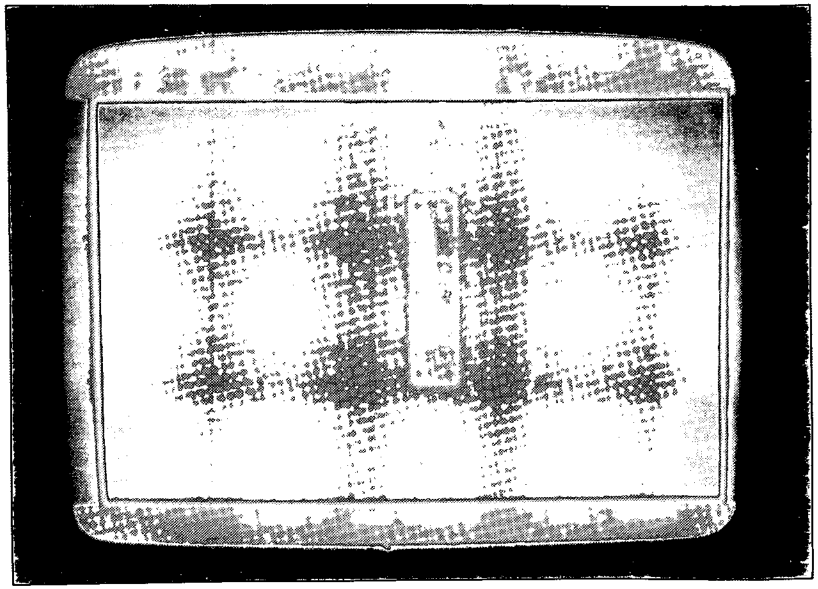


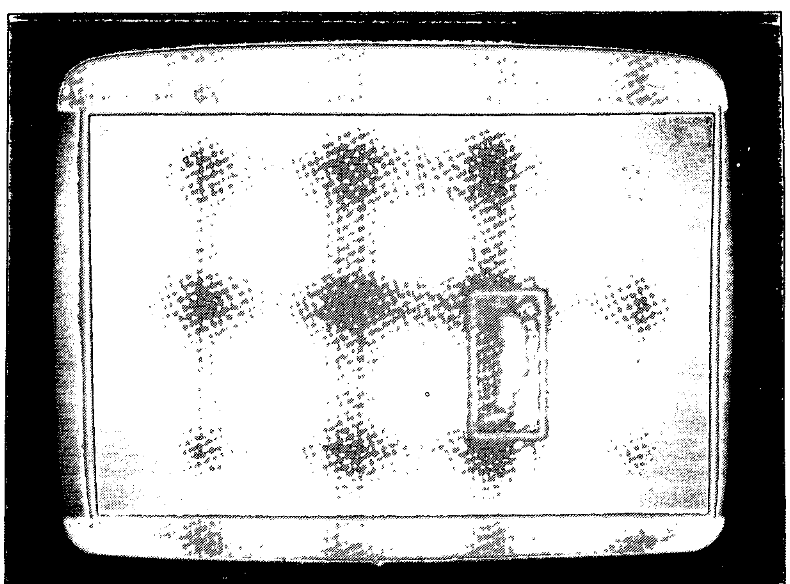
PLATE 11: 'Emulsion Balls'

PLATE 12: COMPARISON OF REAL TIME AND POST OPERATIONAL IMAGE ANALYSIS

REAL TIME

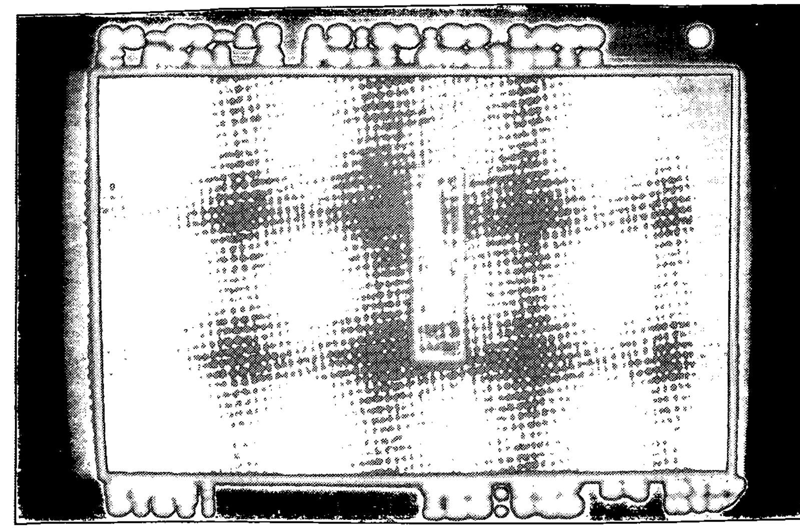


Time: 13:07:16 Area: $1627m^2$

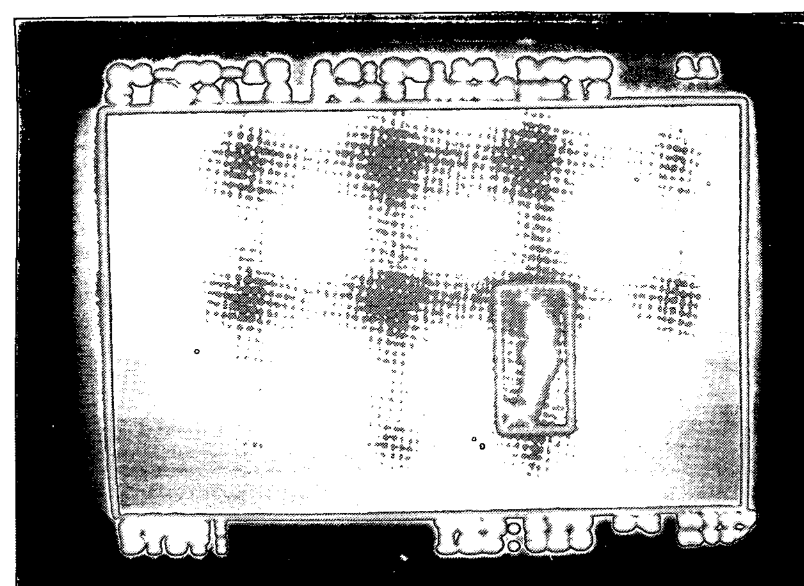


Time: 13:27:40 Area: $1090m^2$

POST OPERATIONAL



Time: 13:07:16 Area: $985m^2$

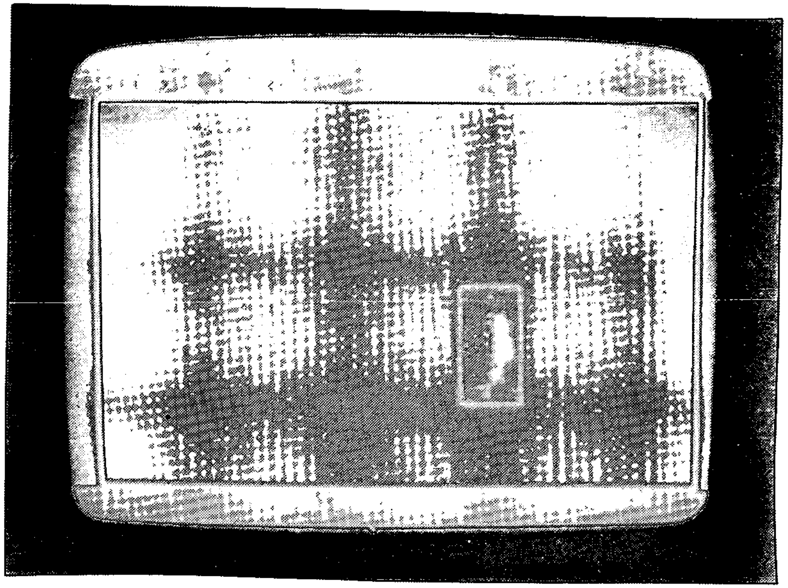


Time: 13:27:40 Area: $934m^2$

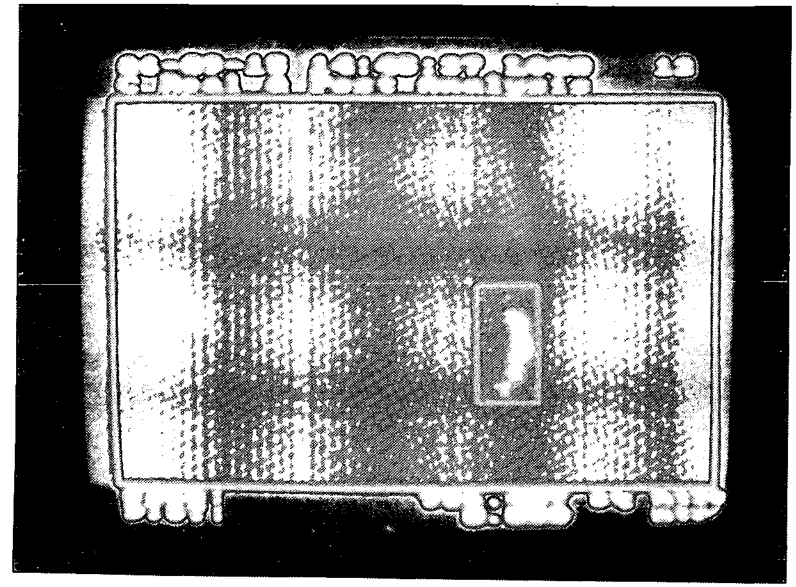
PLATE 12: (Cont'd)

REAL TIME

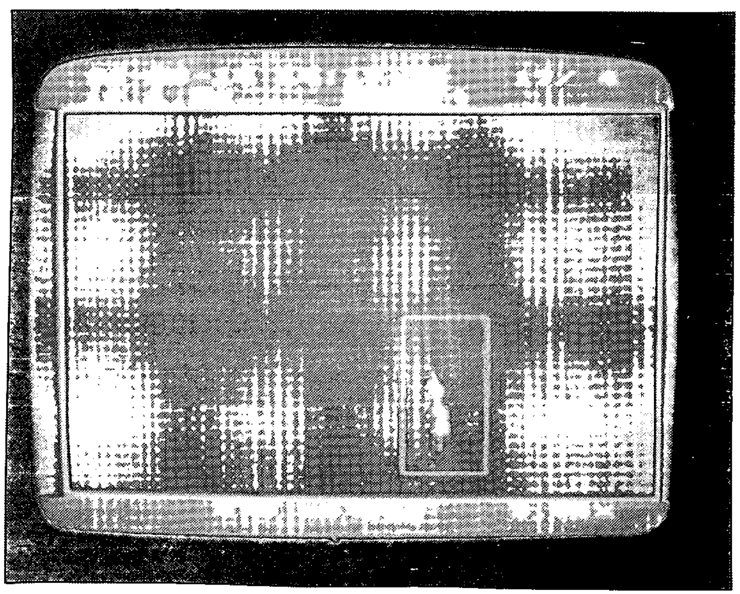
POST OPERATIONAL



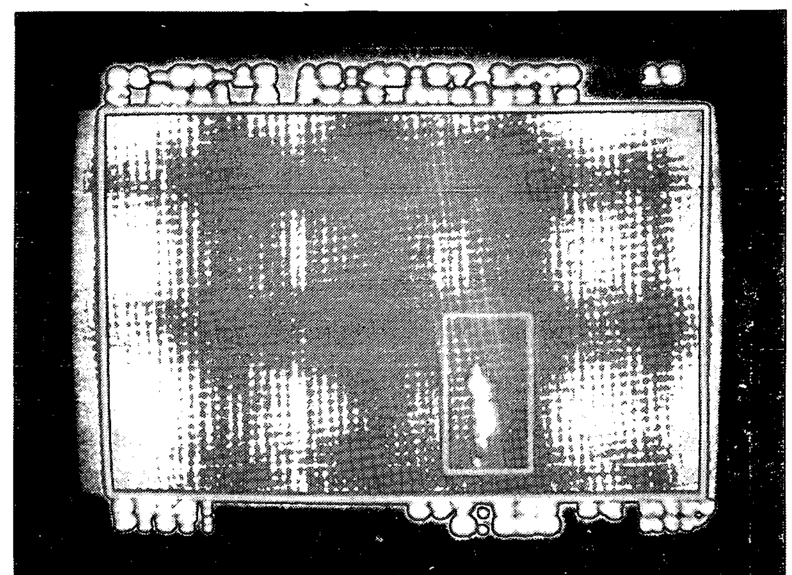
Time: 13:51:59 Area: 984m^2



Time: 13:51:59 Area: 936m^2



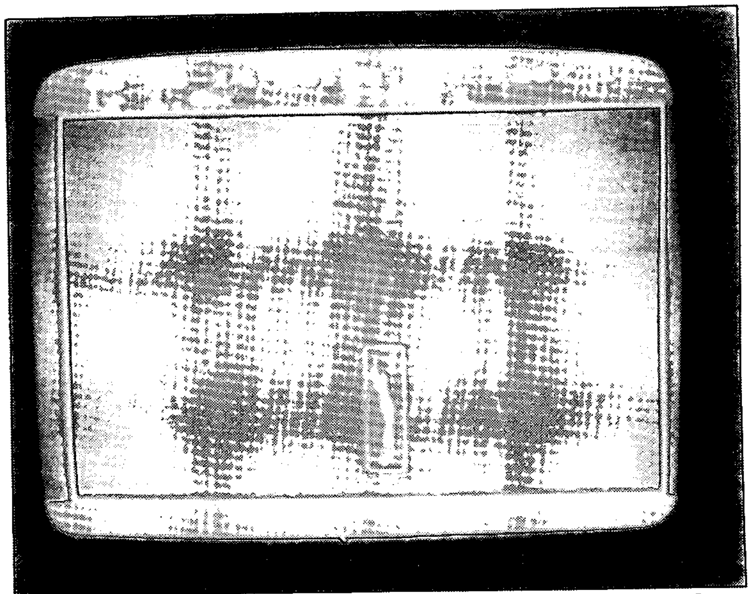
Time: 14:17:33 Area: 675m^2



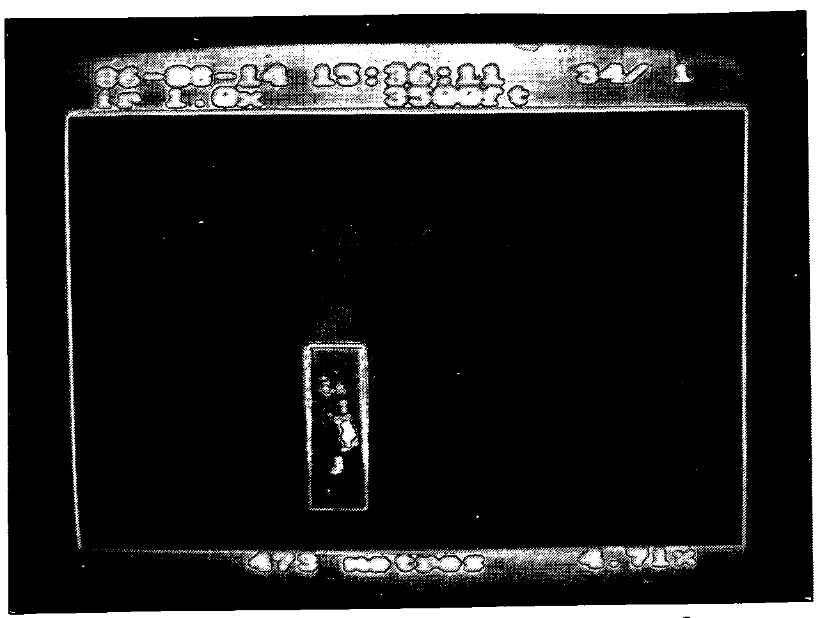
Time: 14:17:33 Area: 698m^2

PLATE 12: (Cont'd)

REAL TIME

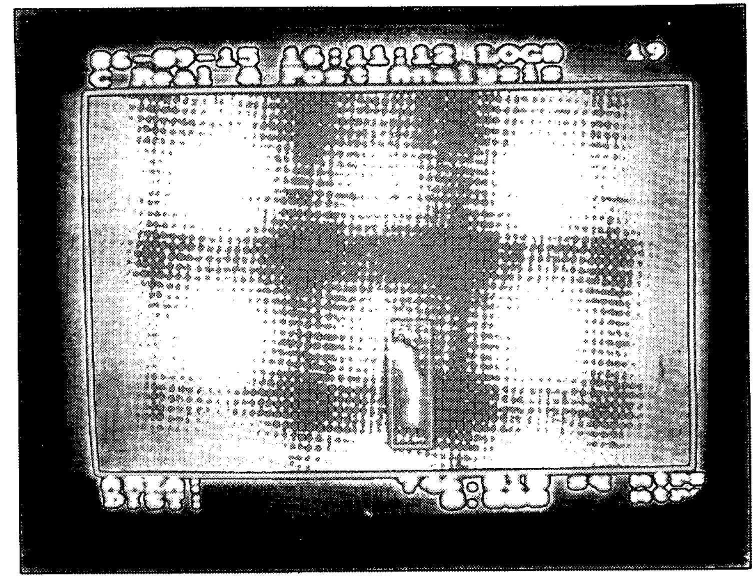


Time: 15:05:13 Area: 788m^2

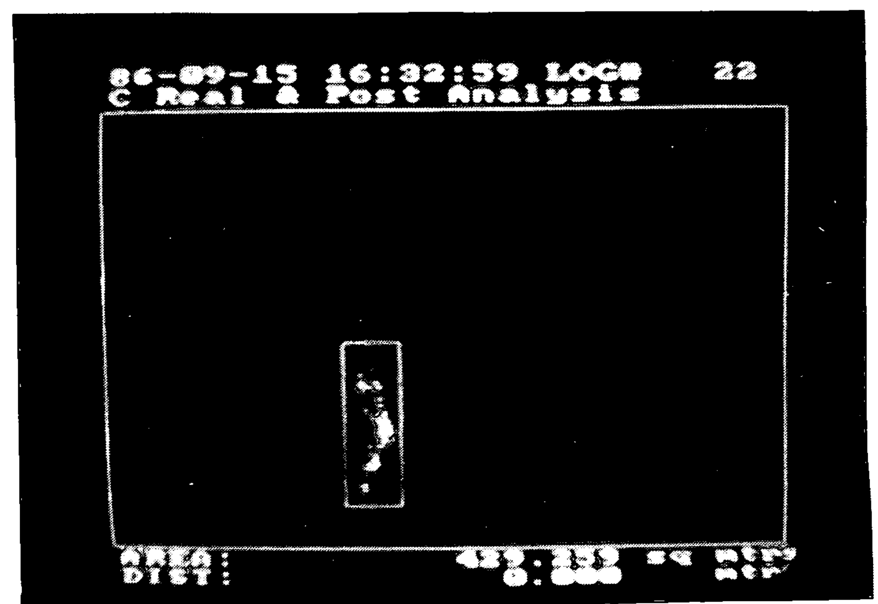


Time: 15:36:11 Area: 473m^2

POST OPERATIONAL



Time: 15:05:12 Area: 746m^2

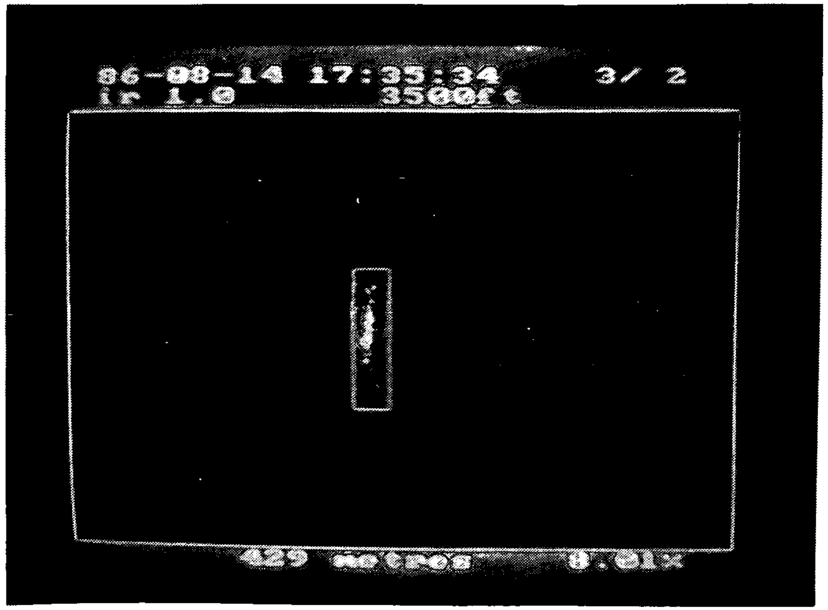


Time: 15:36:11 Area: 429m^2

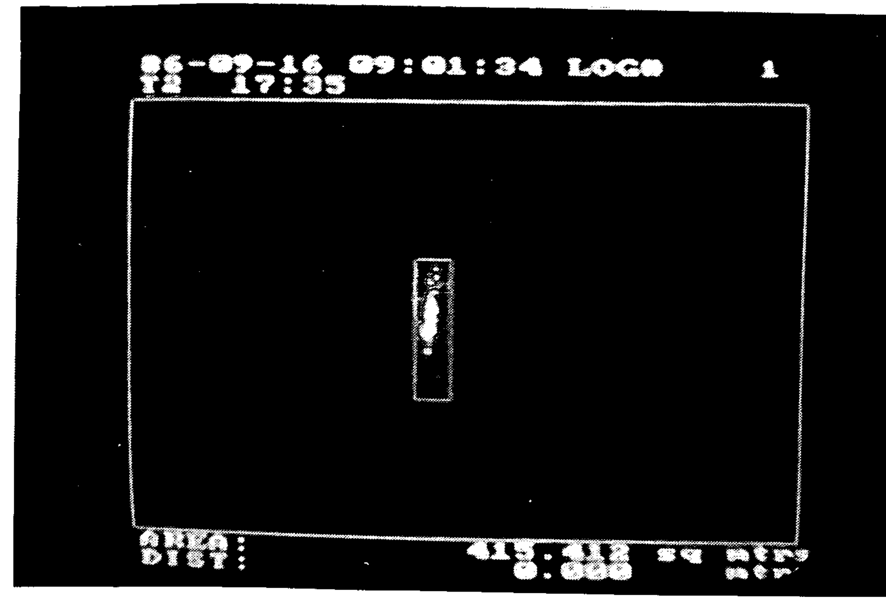
PLATE 12: (Cont'd)

REAL TIME

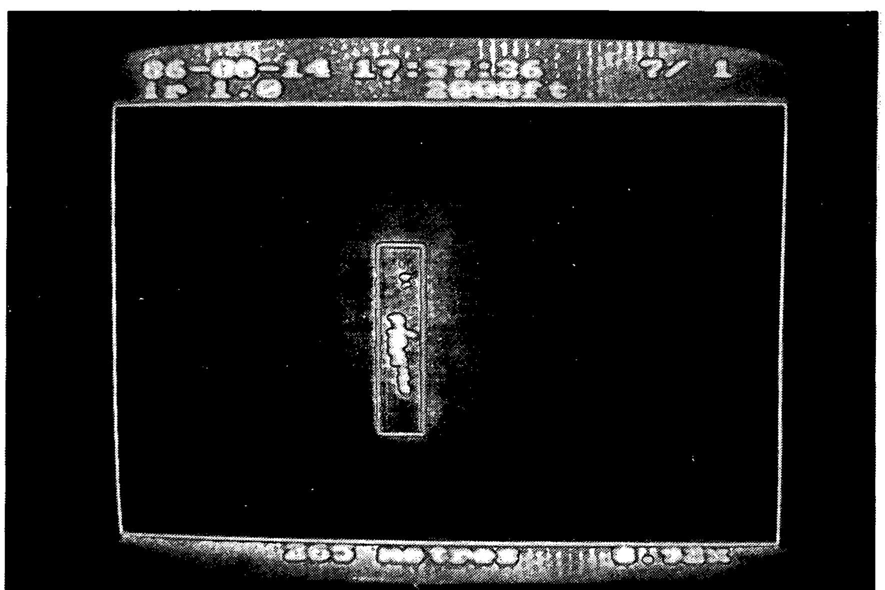
POST OPERATIONAL



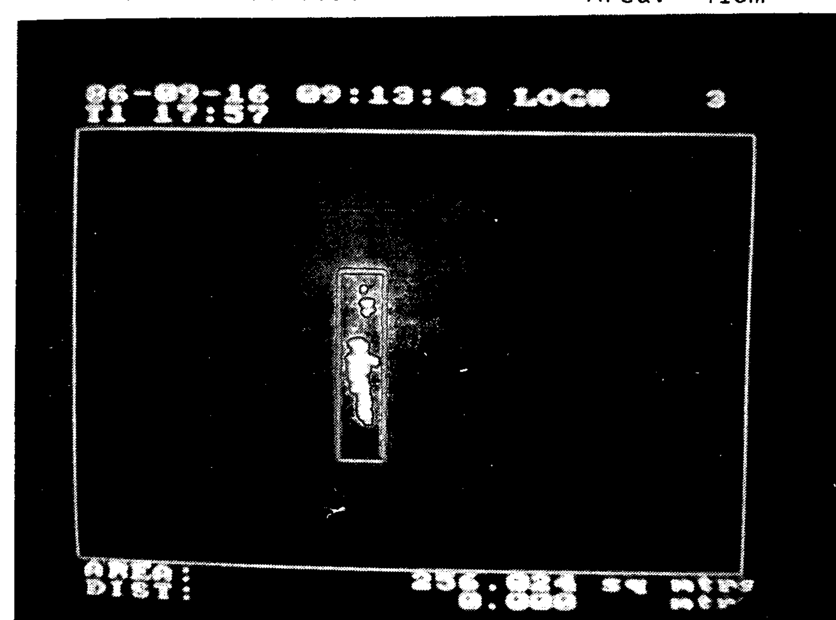
Time: 17:35:34 Area: 429m^2



Time: 17:35:34 Area: 415m^2



Time: 17:57:36 Area: 265m^2



Time: 17:57:36 Area: 256m^2

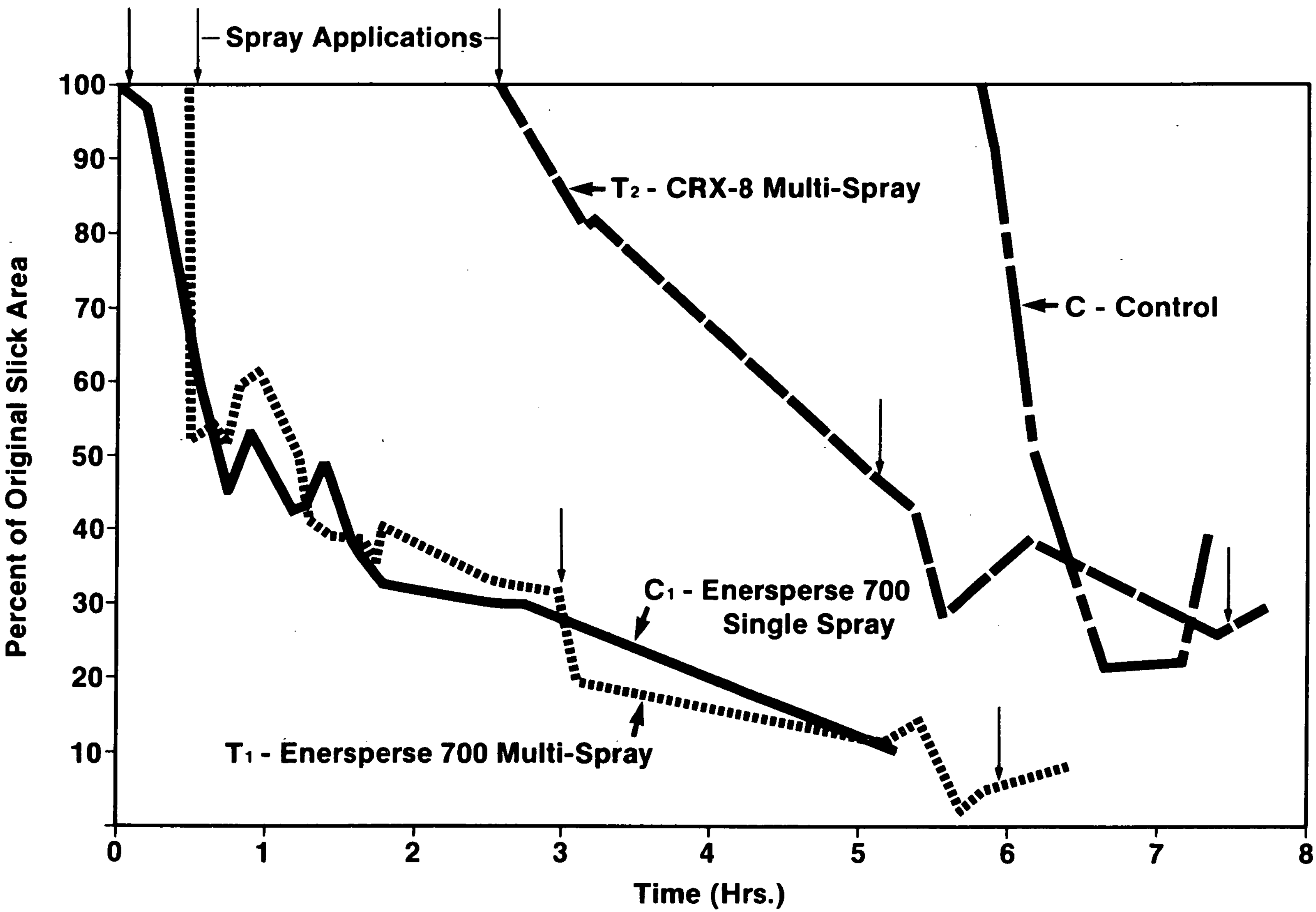
TABLE 5: THICK OIL AREAS DETERMINED BY VIPS 300C IMAGE ANALYZER IN REAL-TIME

Slick C_1 (Enersperse 700)		Slick T_1 (Enersperse 700)		Slick T_2 (CRX-8LT)		Slick C (unsprayed)	
Area (m^2)	Elapsed* Time	Area (m^2)	Elapsed Time	Area (m^2)	Elapsed Time	Area (m^2)	Elapsed Time
755		755		680		791	
796	:03	1874		835	:04	734	:04
1031	:07	SPRAY 1	:02	751	:09	398	:20
1570	:10	1040	:08	749	:14	365	:25
1748	:13	1068	:12	SPRAY 1	---	168	:51
1690	:16	1030	:15	795	:19	180	1:18
1697	:20	1103	:28	721	:24	299	1:21
1608	:24	1142	:32	752	:42		
SPRAY	:30	926	:52	792	:46		
1704	:42	764	:56	670	1:11		
1059	1:02	728	1:00	835	1:15		
794	1:15	723	1:16	SPRAY 2	2:58		
928	1:18	692	1:20	425	3:00		
751	1:42	754	1:24	401	3:04		
778	1:46	706	2:06	361	3:27		
857	1:50	649	2:12	236	3:39		
668	2:07	SPRAY 2	2:30	317	4:13		
589	2:11	633	2:37	220	5:30		
535	3:05	351	2:42	SPRAY 3	5:44		
533	3:10	437	4:31	242	5:47		
179	5:45	227	4:46				
		269	4:58				
		71	5:21				
		94	5:28				
		SPRAY 3	5:30				
		160	5:53				

* Elapsed time in this table refers to the amount of time that has passed since first images of each slick were recorded. It does not refer to amount of time since slick was released.

Figure 7

Change In Area Of Thick Oil Over Time



Analysis of Figure 7 indicates that 50 percent reductions in areas of thick oil occurred at approximately 40 and 50 minutes, respectively, for slicks C_1 and T_1. The reduction to 50% of initial thick area for the T_2 slick took approximately three hours. In contrast the 50% reduction in thick oil areas for the unsprayed control slick (C) was achieved in only 15 minutes. Over the five to six hour period of the trial, the C_1 and T_1 slicks were reduced by approximately 90% while the T_2 and C slicks attained maximum reductions of 75% and 80%, respectively. The reductions in C occurred in less than one hour.

It is interesting to note that the dramatic visual effect described in the previous section, immediately after slick T_1 was sprayed a second time with Enersperse 700, can be seen in the graph of area reductions in Figure 7. On this graph, the second spray of T_1 is shown at three hours and immediately after this spray there is a sharp reduction in area of approximately 12 percent over a period of seven minutes.

No further data were collected on the day of the trial, however the remote sensing aircraft returned to the vicinity of the trial on the next day (August 15) and found remnants of all four slicks. At this time most of the slicks were visible only as a sheen although a small amount of thick oil was also observed. A final reconnaissance by the CCRS jet occurred on August 16 and only sheen was observed. The results of this overflight are described in McColl et al (1987).

4.4.2 Post Operational Analysis

Analyses of the 3/4" tapes using the spectral data analyzer produced some interesting results. The real time analyses yielded only two types of image; that produced by the IR detector which was interpreted as thick oil ($>$ 100 um) and that produced by the UV detector (sheen). However, when the tapes were viewed after the trial, it was discovered that the images actually consisted of three regions. In addition to the two region's described above, the tapes also showed a third region that was produced by the IR detector. This third region was invariably found in close proximity to the thick oil areas and was somewhat less intense than the image produced for this oil (Figure 8).

In order to investigate this phenomenon, the areas occupied by this third region (the grey area) were calculated and compared to the areas observed for the thick lenses of oil. The results of this comparison are shown in Figures 9 to 12. Comparison of the areas occupied by these two regions for the three sprayed slicks (C_1, T_1, and T_2) indicates that there was a general increase in the area of the grey region as the thick oil area decreased with time. Conversely, the grey area observed in the unsprayed control (C) was much smaller than those observed in the sprayed slicks and it tended to diminish, with time. A comparison of the curves for these four ratios is shown in Figure 17.

In order to further investigate this phenomenon, the grey region:thick oil area ratios were calculated for each slick. These are shown in Figures 13 to 16. These graphs indicate that maximum ratio's of 22:1, 45:1 and 16:1 developed for slicks C_1, T_1 and T_2 respectively. In contrast, the maximum grey region:thick oil area ratio observed for the unsprayed control slick was 2.5:1. This would suggest that the application of dispersant to the three sprayed slicks was in some way responsible for producing these large grey areas.

Finally, a comparison was made of the areas of sheen (as detected by the ultra violet detector) for each slick and the sheen:thick oil ratios. Figures 18 to 21 show the total areas occupied by sheen for the four slicks. Figure 22 shows a comparison of the sheen:thick oil ratios for the four slicks. Maximum areas of sheen for the four slicks were approximately 285,000 m^2, 500,000 m^2 190,000 m^2 and 100,000 m^2 for slicks C_1, T_1, T_2 and C respectively (Figure 23). When comparing the ratio's of sheen area to thick oil area, the maximum values were approximately 50:1, 260:1, 40:1, and 7:1 for slicks C_1, T_1, T_2 and C respectively.

Figure 8

Typical Infrared (IR) Image

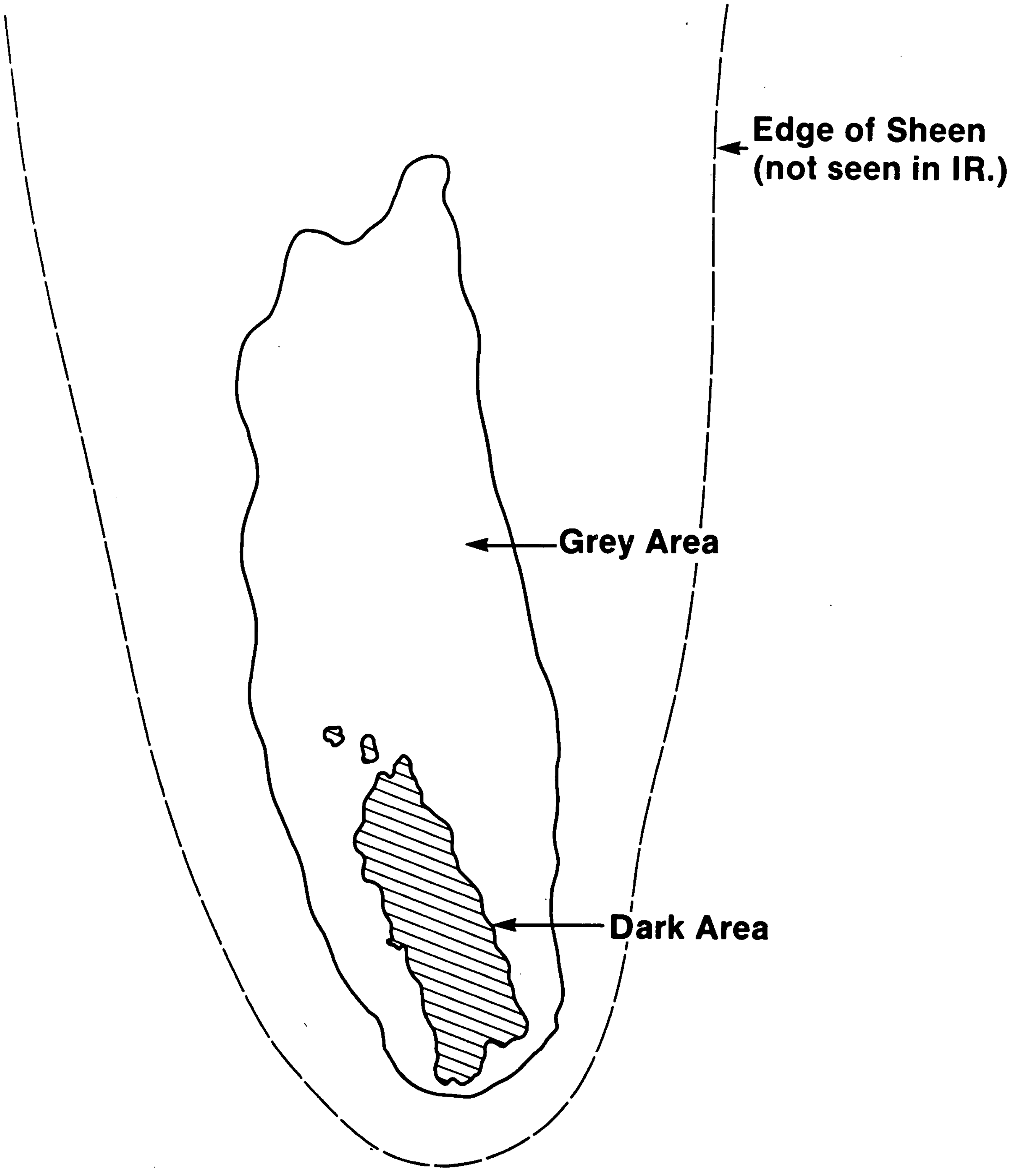


Figure 9

Comparison Of Area Of Thick Oil And Grey Region Produced By IR Detector Control Slick C1

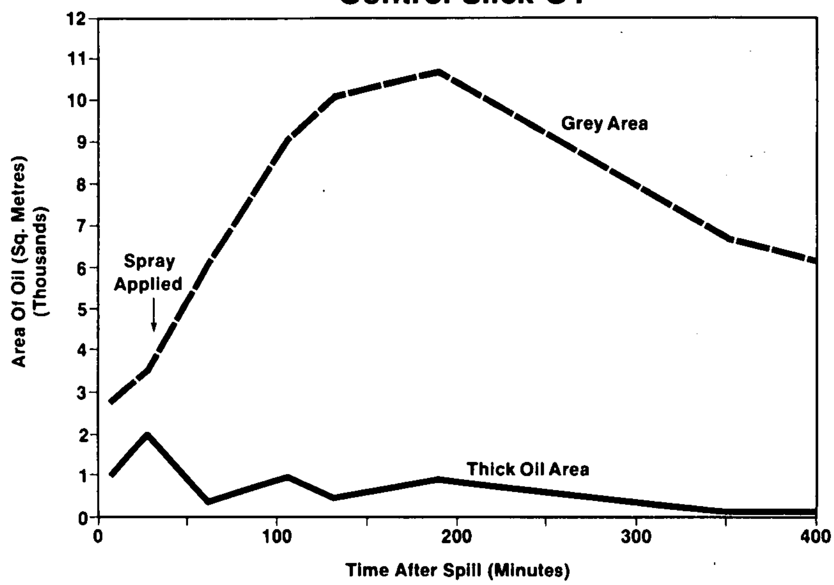


Figure 10

Comparison Of Area Of Thick Oil And Grey Region Produced By IR Detector Test Slick T1

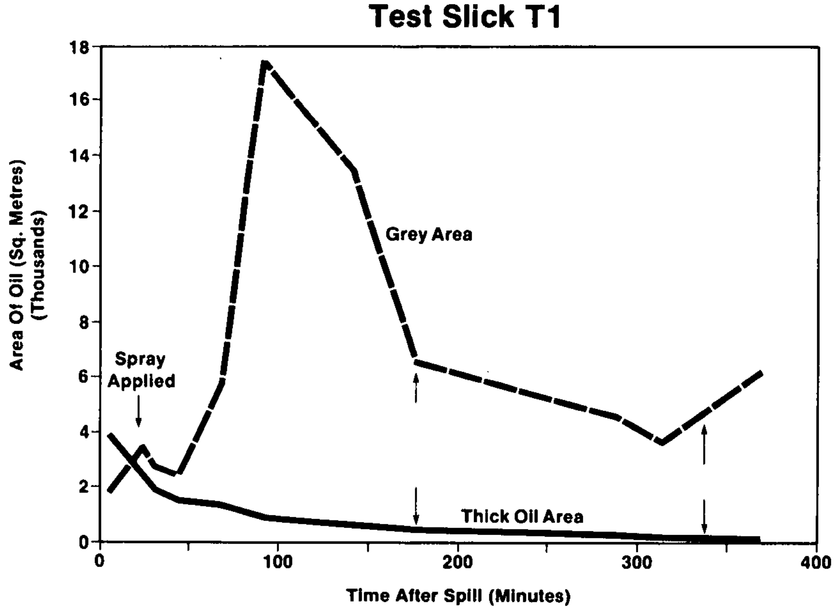


Figure 11

Comparison Of Area Of Thick Oil And Grey Region Produced By IR Detector Test Slick T2

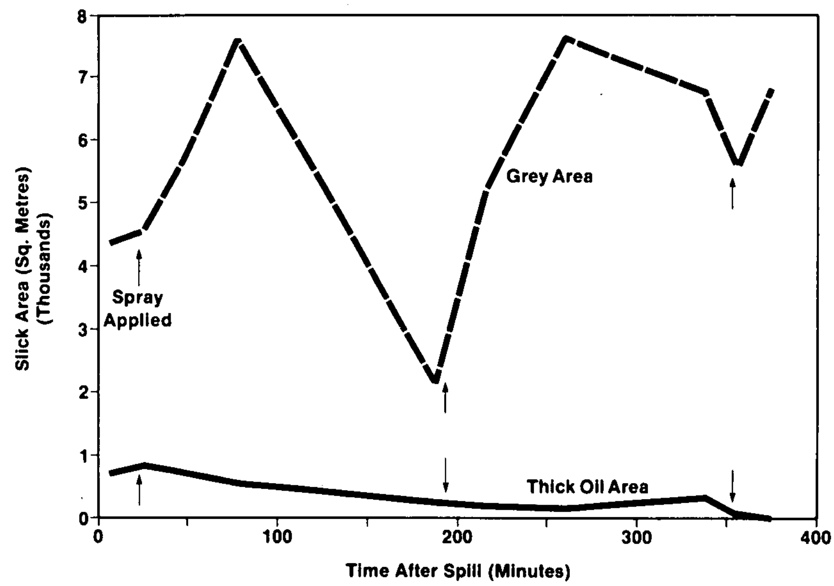


Figure 12

Comparison Of Area Of Thick Oil And Grey Region Produced By IR Detector Control Slick C

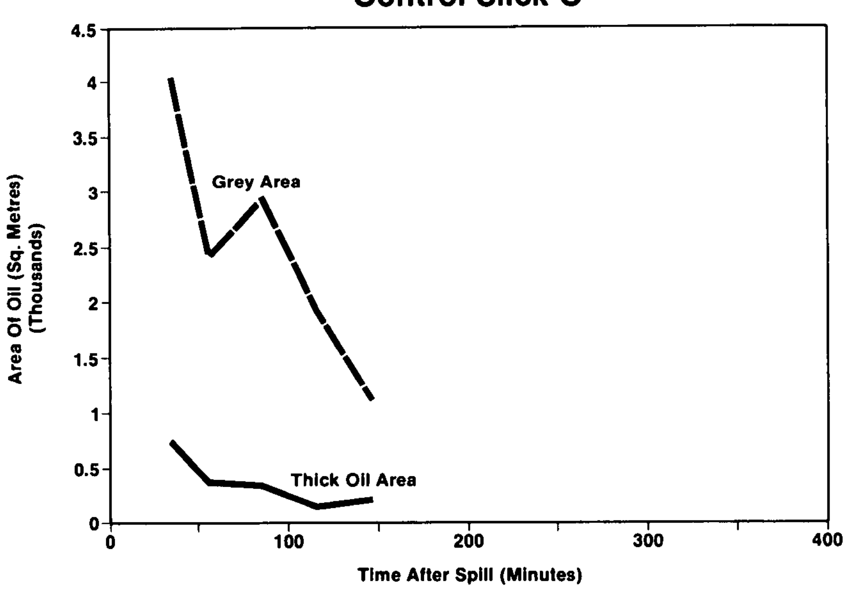


Figure 13

Control Slick C1–Grey Region: Thick Oil Ratios

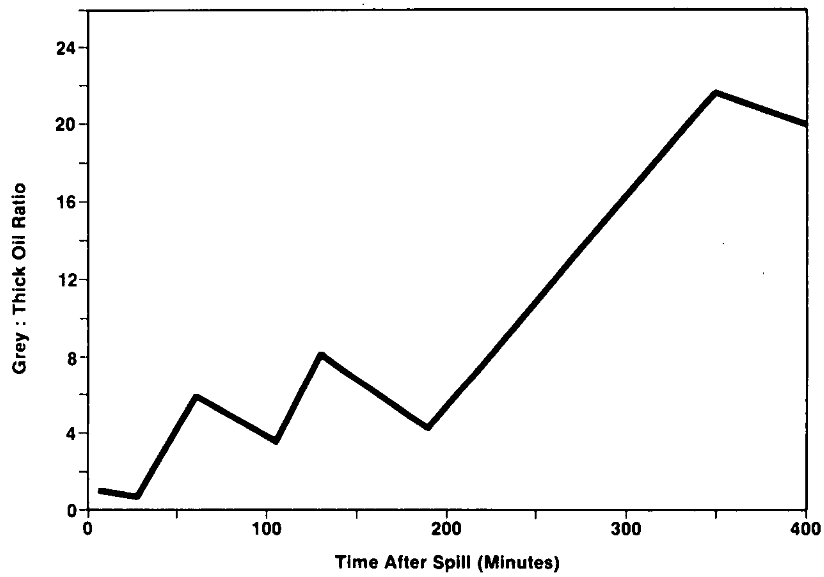


Figure 14

Test Slick T1 – Grey Region: Thick Oil Ratios

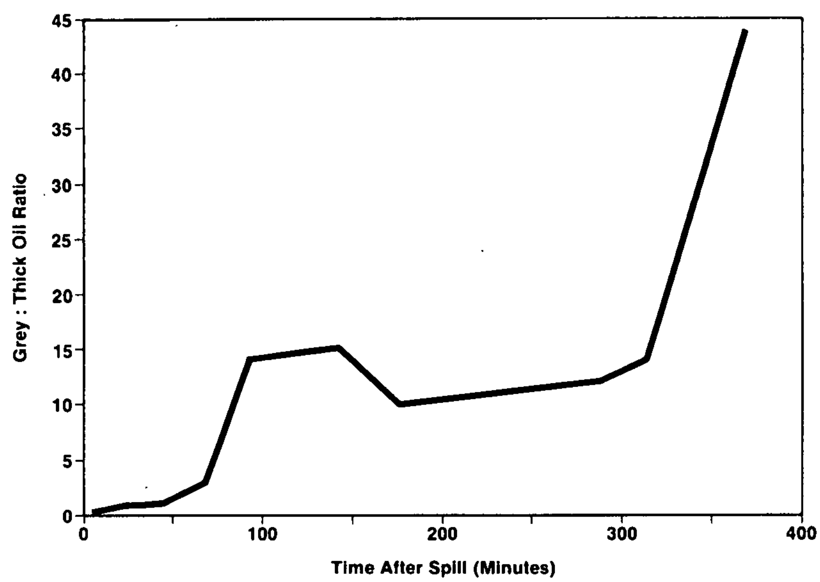


Figure 15

Test Slick T2 – Grey Region: Thick Oil Ratios

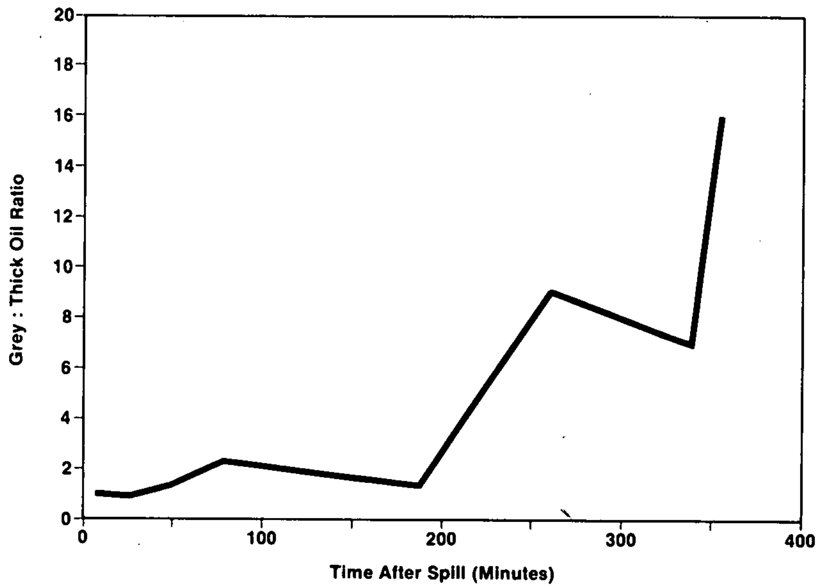


Figure 16

Control Slick C – Grey Region: Thick Oil Ratios

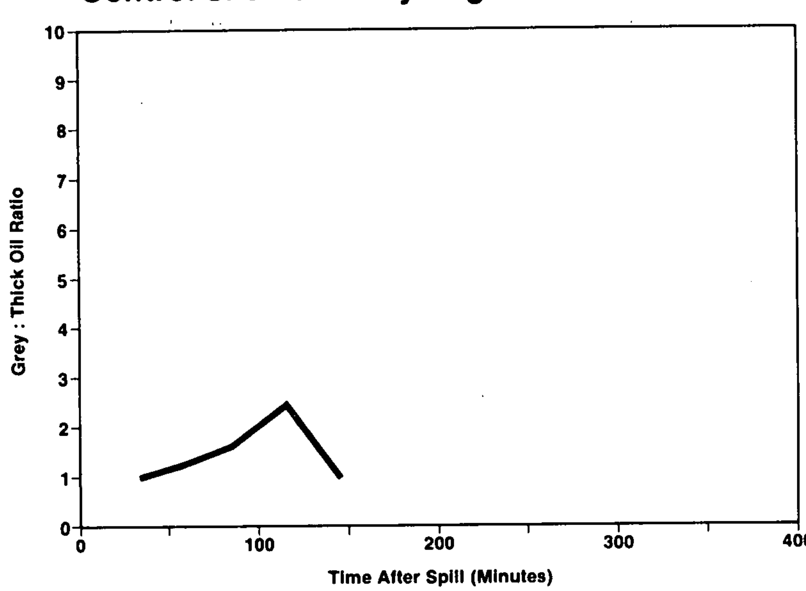


Figure 17

Comparison Of Ratios Of Grey Region To Thick Oil Areas For All Four Slicks

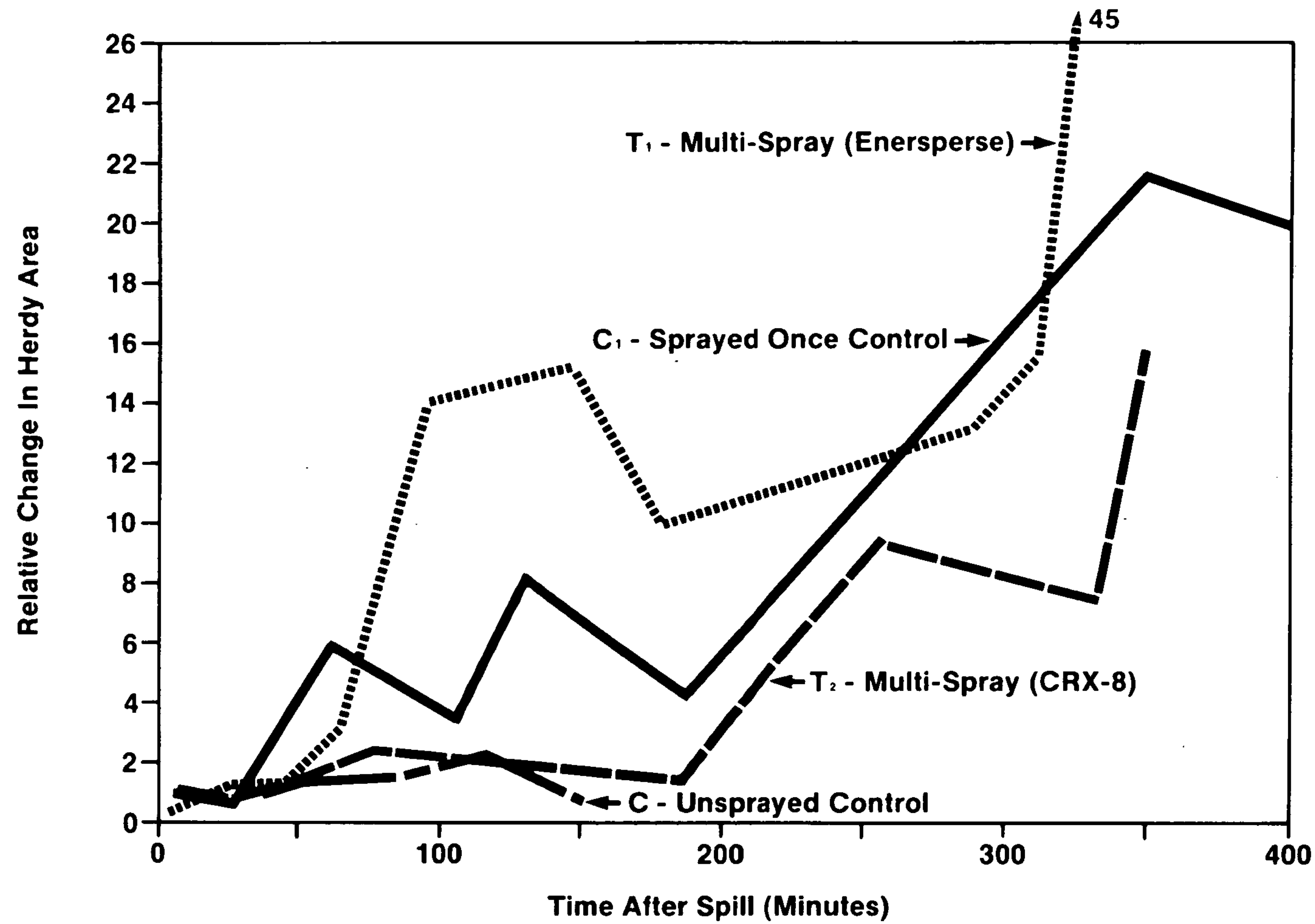


Figure 18

Control Slick C1 – Area Of Sheen

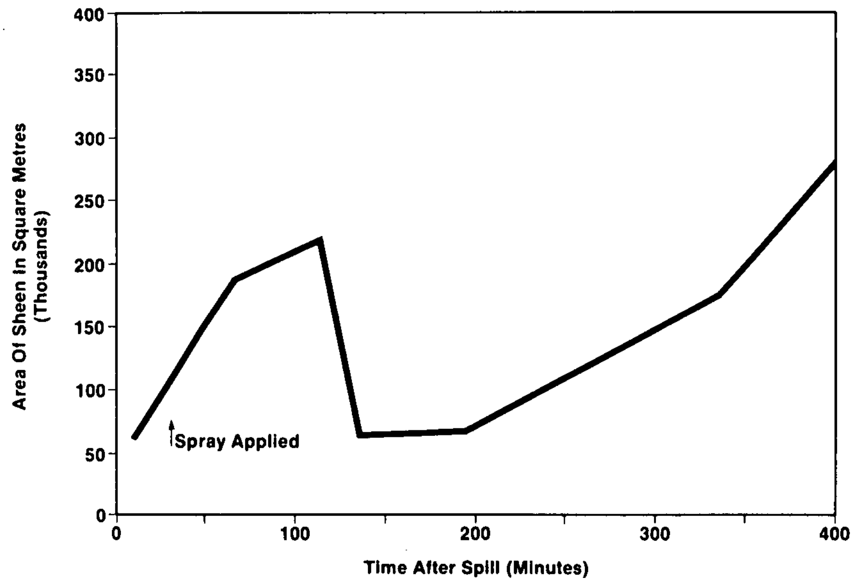


Figure 19

Test Slick T1 – Area Of Sheen

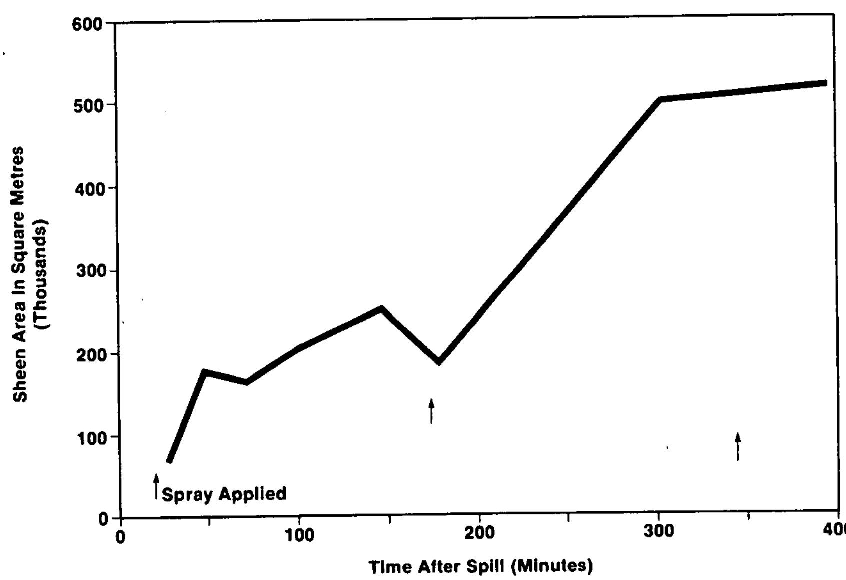


Figure 20

Test Slick T2 – Area Of Sheen

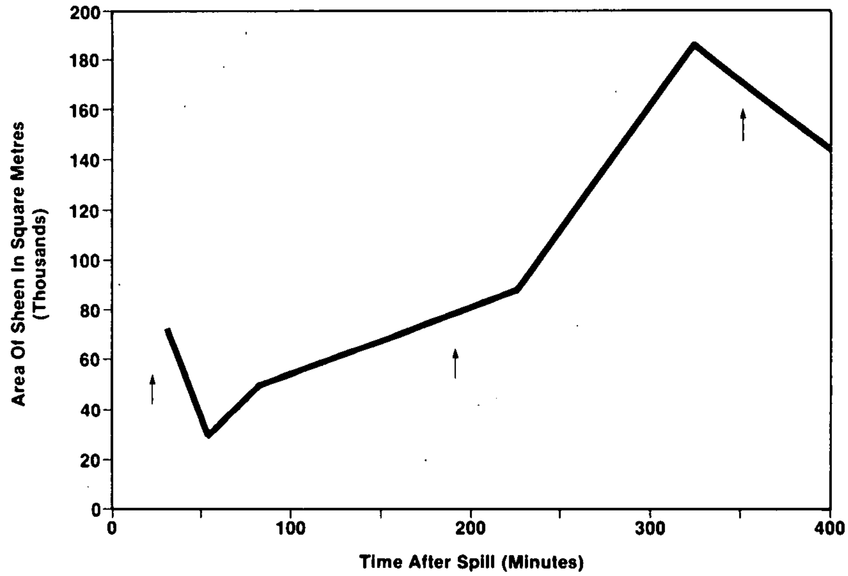


Figure 21

Control Slick C – Area Of Sheen

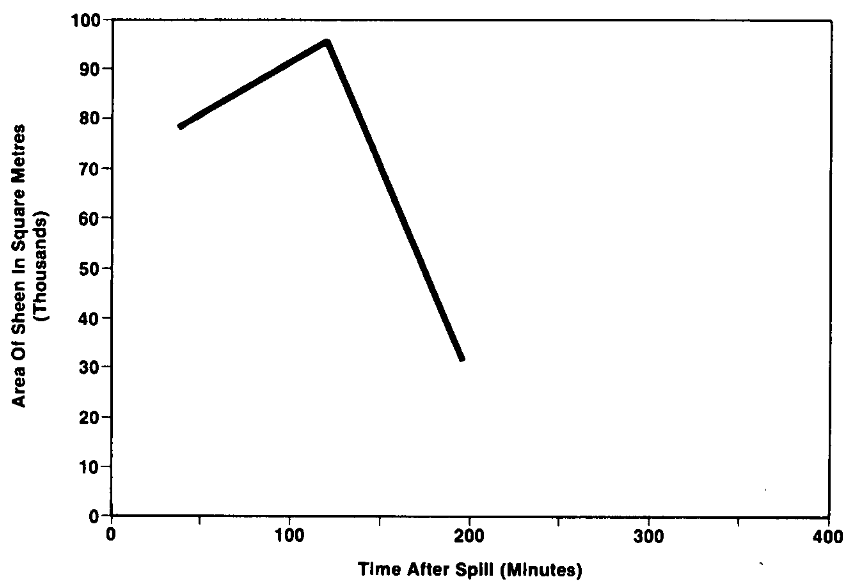


Figure 22

Comparison Of Sheen : Thick Oil Ratios For The Four Slicks

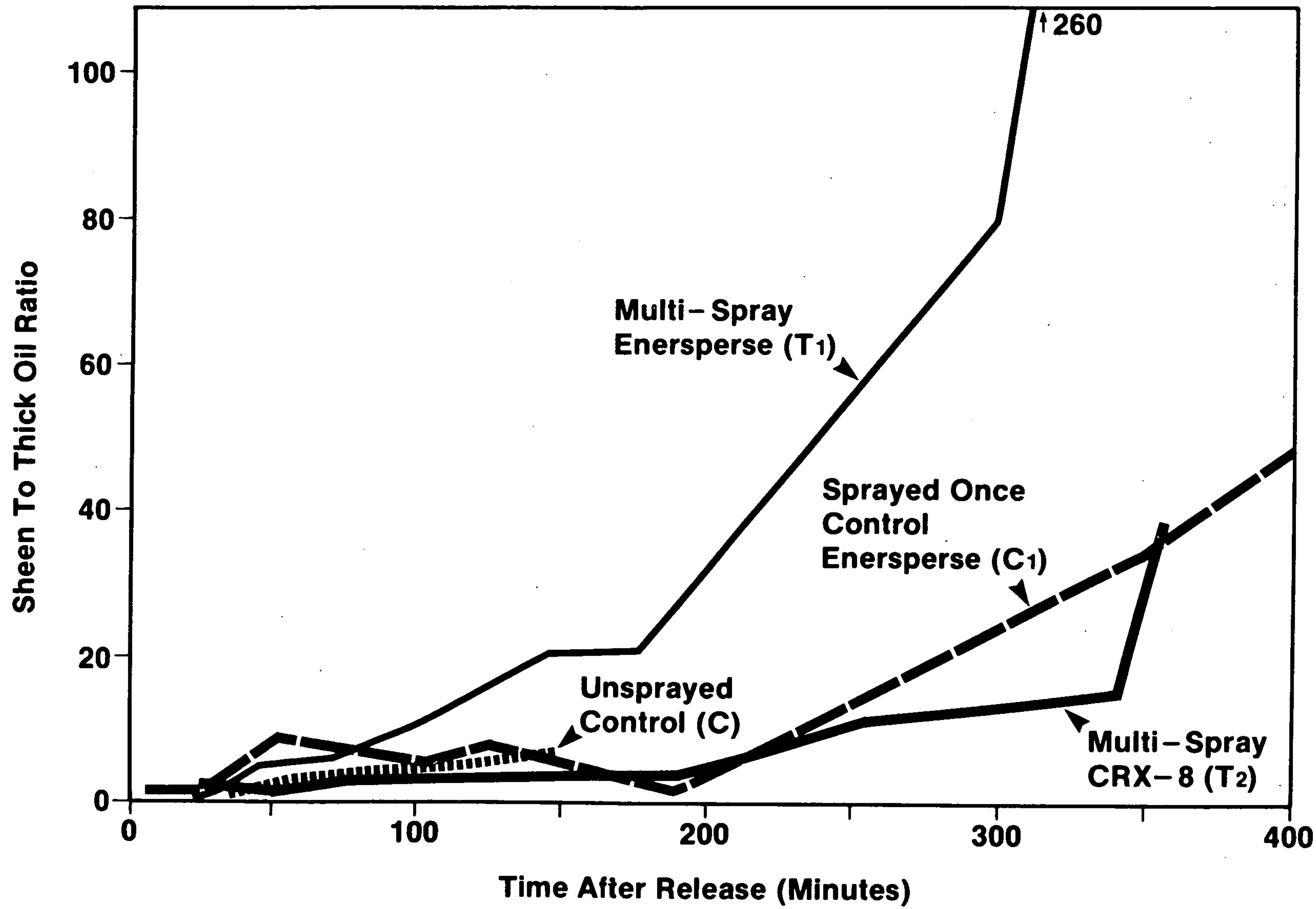
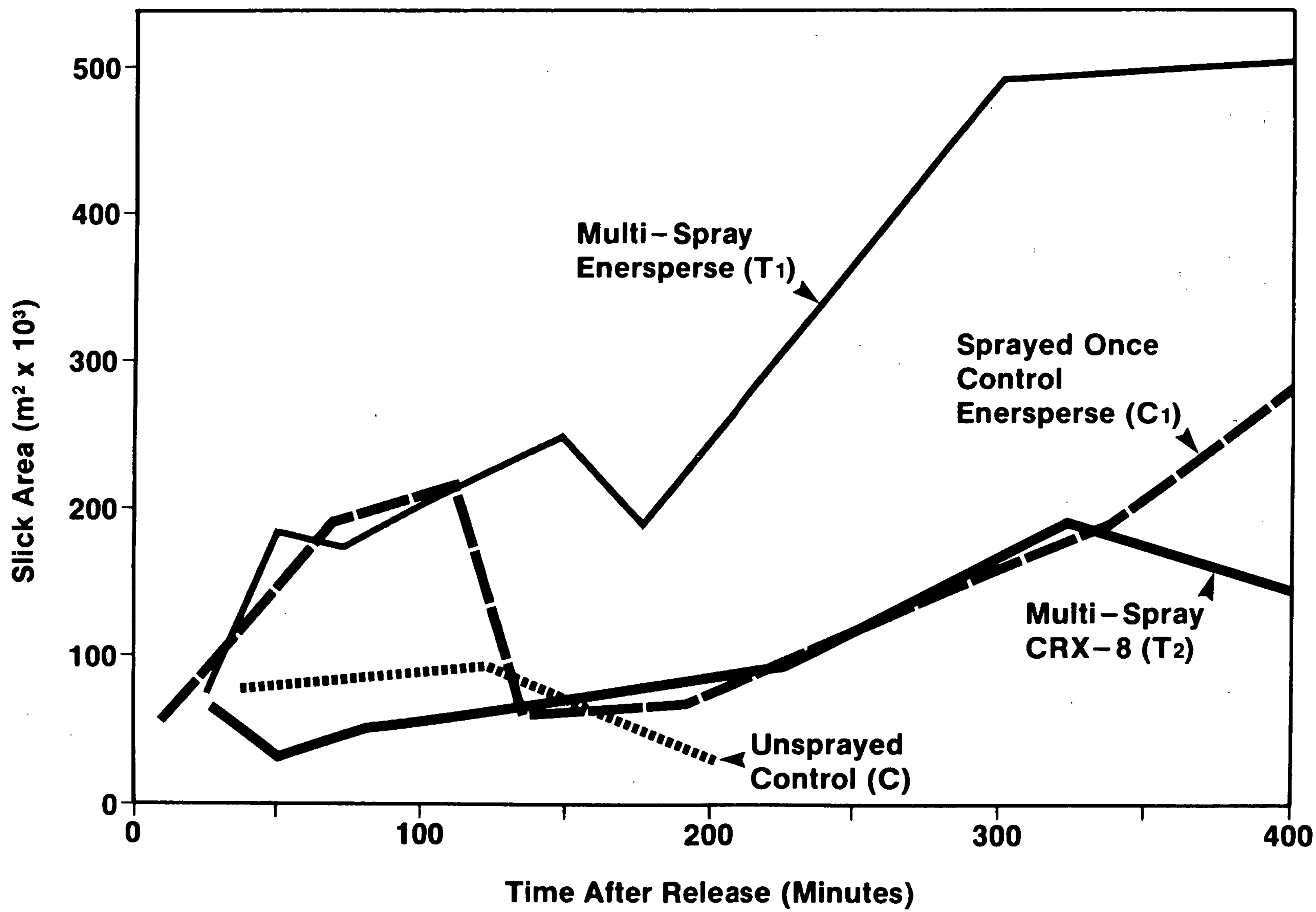


Figure 23

Change In Areas Of Sheen In Control And Test Slicks



4.4.3 CCRS Program

As mentioned previously, the Canada Centre for Remote Sensing (CCRS) also collected infrared and ultraviolet data during the trial. The data collected on the day of the trial was very similar to that collected by the equipment in the twin otter (McColl et al, 1987). In addition to the data collected on the day of the trial (August 14), the Falcon also did an overflight on August 16. During this flight, the equipment on board was able to locate the remnants of four slicks. Assuming that these remnants were the same slicks released on the 14th and that their orientation remained unchanged, the following table (Table 6) was constructed (Fingas, personal communication):

TABLE 6: INTERPRETATION OF DATA COLLECTED BY CCRS ON AUGUST 16*

SLICK CODE	C_1	T_1	T_2	C
Treatment	Single spray Enersperse	Multi-spray Enersperse	Multi-spray CRX-8LT	Unsprayed
Area (m^2)	$4.36X10^5$	$3.81X10^5$	$6.27X10^5$	$1.96X10^6$
Area Ratios	1.1	1	1.9	5.1
Estimated volume of oil remaining (m^3)	0.031	0.027	0.044	0.136
Original volume released (m^3)	2.5	2.5	2.5	2.5
% of original oil remaining	1.24	1.08	1.76	5.43
% lost from original slick	98.76	98.92	98.24	94.57
% difference from control (C)	4.20	4.63	3.68	0

* This table indicates that two days after spraying, the amount of oil remaining on the waters surface was essentially the same for both the sprayed and unsprayed slicks.

5.0 DISCUSSION

In this trial, the nominal dispersant-to-oil ratio for the two test slicks (T_1 & T_2), after three spray passes, was approximately 1:2. These ratio's are much higher than those recommended by dispersant manufacturers. Normally ratios between 1:20 and 1:10 are suggested. Even if the assumption is made that half of the sprayed dispersant did not contact the desired target (because of spray drift, swath extension beyond slick, or droplet penetration through slick) then the D:O ratio would still be in the order of 1:4; far more than is theoretically necessary to completely disperse the slicks.

As in previous experimental spills, (Gill and Ross, 1982; Gill et al, 1985; COAATF, 1986; Bocard et al, 1987) the visual observations during this trial support the belief that significant dispersion was occurring upon application of the chemicals. After each spray pass, the formation of a coffee coloured dispersed oil cloud was observed in the water under all three sprayed slicks. This effect was most dramatic after the second spray application of Enersperse 700 on slick T_1. These visual observations would lead the observer to the conclusion that a significant amount of oil had been dispersed. The fact that the second application of dispersant produced such a marked effect also indicates that there was a significant amount of oil left on the surface after the first spray pass which had not interacted with dispersant. This view is also supported by the fact that there were obvious lenses of thick oil left on the surface of the water even after three spray passes had been completed.

The presence of the emulsion balls on the surface of the water in the sprayed slicks suggests that some mechanism other than dispersion was also at work. It is probable that a significant amount of the treated oil, rather than going directly into the water column as dispersed oil droplets, formed emulsion balls instead. Some initial laboratory work done after the trial suggests that these balls form only in the presence of dispersant and are a water-in-oil-in-water emulsion. (TANG, Personal Communication).

Initial comparison of the real time curves of thick oil area reduction does not provide a convincing argument for the use of dispersant as a countermeasures technique. Although all three treated slicks seemed to quickly diminish in size after being sprayed, the unsprayed control slick exhibited an even greater rate of reduction than the treated slicks. It would be tempting to dismiss the control slick because it was released in a manner different than the treated slicks and at a time when the wave energy was considerably higher (1.5m vs 1.0m). However, two unsprayed slicks which were released in the same manner as the test slicks and at lower sea states earlier in the week (Aug 11) exhibited similar reductions in thick oil area with time.

It seems anomalous that the unsprayed control slick (C) should disperse more quickly than the sprayed slicks (C_1, T_1, T_2). Four possible explanations for this anomaly follow: 1) the oil lost from the thick area of the control slick was bleeding into the surrounding sheen whereas the sprayed slicks were actually being dispersed into the water column; 2) the areas depicted as thick oil in the control slick (C) were actually thicker than those observed in the test slicks and therefore contained more oil; 3) the creation of the emulsion balls retarded the dispersion process in the sprayed slicks; or 4) the application of dispersant in addition to inducing dispersion and emulsion ball formation also promoted lateral spreading of the oil.

The first explanation is not supported by the remote sensing data. If the thick lenses of oil in the control slick were feeding the surrounding sheen at a rate faster than the sprayed slicks, then one would expect the sheen (and possibly the grey area) in this slick to be larger and have a higher sheen:thick oil ratio than the test slicks. This is not the case. In section 4.4.2, the control slick sheen was shown to be smaller than the test slick sheens and the sheen:thick oil ratios the same or smaller than for the test slicks. This finding is consistent with the results of the 1981 and 1983 dispersant sea trials (Goodman and Ripley, 1984).

There is also no evidence to support the second explanation that the control slick was thicker than the sprayed slicks. Data collected by the CCRS Falcon indicated that the temperature of the thick oil lenses in the unsprayed control (C) was similar to the thick oil lenses in the sprayed slicks (McColl, personal communication). This suggests that the thickness of the thick oil in these lenses was not greater than in the control slick.

The third and fourth explanations seem most plausible. The emulsion balls were observed only in the sprayed slicks and only in the area considered to be 'thick oil'. They were not present in the unsprayed control slick (C). It is unclear how these balls would appear to the infrared detector, but since they contained considerable oil and since they floated at or slightly above the water's surface, it is probable that they would appear as thick oil to the remote sensing equipment. The large grey areas observed in the post operational image analysis were 'cooler' than the thick oil areas (R. Goodman; Personnal Communication); and it is postulated that these areas represent areas of spreading which appear cooler to the infrared detector because of increased rates of evaporation caused by the larger surface areas.

Assuming that the third and fourth explanations are correct, the following mechanism for dispersant/oil interaction can be constructed:

- The untreated slick (C) gradually released its oil to the water column as the thick oil areas were observed to decrease in size.

- Upon release, the sprayed slicks (C_1, T_1 and T_2) spread to an equilibrium thickness prior to being treated.

- Upon being sprayed, some of the oil in these slicks went into the water column and was observed as a dispersed cloud; some oil spread laterally and was observed as a large grey area in post operational image analysis; and some of the sprayed oil in the thicker lenses formed emulsion balls.

- Because emulsion balls appeared to the infrared detector as thick oil, the 'thick oil' areas in the sprayed slicks appeared to be the same size or larger than the thick oil area of the control slick; even though there was less total oil in these areas and some oil had been lost from these areas through lateral spreading and evaporation and through chemically induced dispersion. This is a feasible explanation only if the assumption is made that emulsion balls contained a considerable amount of water and therefore a given area of emulsion balls interpreted by the infrared detector as thick oil actually contained less oil than a similar 'thick area' in the unsprayed slick.

- The fact that area changes were observed immediately after the second applications of dispersant suggests that in addition to the emulsion balls, there was still 'dispersable' oil present in the sprayed slicks which reacted to these subsequent spray passes.

- Since the emulsion balls readily broke apart and dissipated upon contact (i.e. it was difficult to collect them), it is possible that over time and with prolonged exposure to more wave action, these balls would release their oil to the sea possibly in the form of dispersed droplets or as a sheen on the water's surface.

The observations of the CCRS Falcon on August 16 require further comment. If taken at face value, these data would suggest that at most there was a 4.63% increase in dispersion efficiency between the unsprayed control and the most effectively dispersed slick. This interpretation, however, does not take into account the effect of time. Because chemical dispersants act primarily to 'speed up' natural dispersion, one would expect that over time the differences observed between sprayed and unsprayed slicks would not be remarkable. In other words, by the time the CCRS data was collected (approximately 48 hrs after spraying), the unsprayed control may have 'caught up' to the sprayed slicks in terms of total amount of oil dispersed.

A final point worth noting is that the single treatment with Enersperse 700 on slick C_1 seemed to be as effective, over time, as the multiple applications of Enersperse (T_1) and somewhat more effective than the CRX-8LT multi-spray (T_2). This would suggest that it is unnecessary to spray a slick more than once, and that given a good initial application, all that is required is time for the dispersant to take effect (provided environmental considerations permit).

In summary, no strong conclusions on the efficacy of using dispersants as a countermeasures tool can be drawn from this trial. Although it is clear that some type of dispersant action occurred when the slicks were sprayed; it is unclear why the sprayed slicks did not dissipate more quickly than the control nor why the addition of more dispersant, achieving very high D:O ratios, did not increase the observed effect. The results of these trials are similar to others conducted world wide (Nichols and Parker, 1985). In most cases there is a strong visual sense that slicks react rapidly and dramatically to the application of the dispersant. However, it would appear that relatively small quantities of oil are represented by this phenomenon (Gill et al, 1985).

Is this an artifact of the remote sensing technique used in this trial? It is assumed that the thickness of the oil varies with time in the same manner for both treated and untreated slicks. This may not be true! The wave heights were slightly larger during the later part of the day; the solar heating was less. These are possible reasons for the observations to be in error, but there is inadequate data to calculate the magnitude of the errors involved. There are clearly many unresolved problems in terms of the interpretation of remote sensing data including: the effect of emulsion balls, the correction for solar input energy variation with time and the cause of the different temperature regions found within the slicks.

While the results of the trial do not provide conclusive data on dispersant effectiveness, it is clear that from visual observations these chemicals do enhance initial dispersion of oil at sea. There is still much to understand of the processes involved. Pending the development of a protocol to obtain a true and complete mass balance, the field measurement of dispersant effectiveness will have a large degree of uncertainty and a very large error factor.

CONCLUSIONS

1. Alberta Sweet Mixed Blend (ASMB) can be dispersed, to a certain degree, at relatively low water temperatures (6°C).

2. Some mechanism, which results in the formation of 'emulsion balls', interferes with the dispersion process and results in an overall reduction in dispersant effectiveness.

3. It is unclear how the emulsion ball phenomenon is detected by the remote sensing equipment. This uncertainty in interpreting the infrared data makes determination of dispersant effectiveness much more difficult.

4. Pending the resolution of these uncertainties, it is important that the use of remote sensing equipment for determining dispersant effectiveness be supported by an adequate ground truthing program.

5. It is logistically possible to conduct an aerial dispersant application operation in the Arctic and there is some evidence (mostly visual) that dispersants produce the desired effect. However, the degree of uncertainty regarding dispersant effectiveness that remains after these trials suggests that a decision to use dispersants be taken only after very careful consideration of other alternatives.

6. DISPERSANT APPLICATION GUIDELINES

The third objective of this project was to 'define the logistical and cost requirements to support a dispersant operation in which a large percentage (90-95%) of a slick is removed from the water's surface'. In addition, the original study proposal indicated that the report would contain detailed guidelines for the operational application of dispersants. This section of the report will use the information gathered during the trial to develop a set of guidelines on the operational use of dispersants. In reading this section, however, it should be remembered that the results of this trial are inconclusive and any dispersant use decision should carefully consider other alternatives.

The method used to prepare these guidelines was to: 1) develop an oil spill scenario for the Beaufort Sea; 2) describe the equipment, materials, manpower, and time that would be required to address the scenario using dispersants; and 3) establish costs for such a response.

The logistical efforts required for responding to the scenario were then generalized into a set of guidelines applicable to a wider range of offshore spill scenarios.

6.1 BEAUFORT SCENARIO

A development well is being drilled from an artificial island in the Beaufort Sea. The island is located at 70°00'N; 133°00'W in 25m of water.

There is a large 10,000 bbl (1600m^3) storage tank on the island which contains approximately 9000 bbl (1400m^3) of crude oil which has been produced from the well during extended flow testing. The oil has the following properties:

API gravity	:	30.8
density	:	0.8711 @ 21°C
dynamic viscosity	:	5.4 @ 20°C
pour point	:	-31.9°C

On August 15, the storage tank buckles because of a structural flaw in the tank. A large crack appears approximately 1m from the bottom of the tank and approximately 8000 bbl (1200m^3) of oil is released. Because of the force of the release, the dyke surrounding the tank is breached and the oil starts flowing toward the sea.

The drilling crew on the island responds quickly and uses a bulldozer to repair the breach in the dyke. Their quick action causes 15% of the oil (1200 bbl) to be retained within the dyke. Meanwhile the remaining 85% of the spilled oil (6800 bbl) leaves the island and enters the sea. The oil creates a number of large discontinuous slicks in the vicinity of the island. The wind is blowing from the north-east at 35 km/hr. The water temperature is 6°C and the air temperature is 10°C. Visibility is good (10 km) with broken clouds at 3000m. The sea is 'choppy' with waves ranging between 1.0 and 1.5m.

While the drilling crew is repairing the dyke, other workers on the island mobilize a small cache of spill response equipment (100m of containment boom, 2 morris mI-30 skimmers, some sorbent material, and a portable storage tank) and attempt to collect some of the oil floating near the island. Their efforts recover an additional 5% of the spilled oil (400 bbl) leaving the remainder (6400 bbl) on the sea. This oil leaves the area of the island and, because of the prevailing winds and currents, moves toward shore.

A trajectory model is used to determine the movement and fate of the oil. It predicts that the oil would contact the shoreline on the Tuktoyaktuk peninsula between McKinley Bay and Hutcheson Bay within 3 days. Consultation with the 'Environmental Atlas for Oil Spill Response' (Environment Canada, 1987) and the 'Guide to Dispersant Use Decision-Making for Oil Spills in the Canadian Souther Beaufort Sea' (ESRF, in press) suggests that the use of dispersants is warranted. In addition, the Environment Canada Guidelines on the Use and Acceptability of Oil Spill Dispersants (Environment Canada, 1984) is consulted, and approval for dispersant use is obtained from the appropriate government agencies.

Even though all of the oil could not be prevented from reaching shore within the 3 day time frame, the decision is made to apply dispersant to the remaining slicks when they are one third of the way to shore. This decision is made on the assumption that any reduction of the amount of oil reaching shore will result in reduced environmental impact and lower cleanup costs.

Calculations are made to determine the amount of oil that will require treatment. In order to do these calculations, the assumptions are made that after 1 day, 45% of the oil that left the island will evaporate and that 30% of the remaining oil will disperse naturally. Therefore, the amount of oil left after one day at sea would be:

- after evaportation [6400 - (6400 x .45)] = 3520 bbl

and - after natural dispersion [3520 - (3520 x .30)] = 2414 bbl

Converting to metric measure, the total amount of oil requiring treatment is (2464 x 164 = 404,095 L).

The decision is made to apply the dispersant to the oil at a dispersant:oil ratio of 1:10. The dispersant will be applied using helicopters and underslung buckets (2 Bell 212 helicopters and 2 spray buckets are available).

At the above ratio (1:10) 40,409 litres (246 bbl) of dispersant would be required to completely treat the slicks. Therefore, each spray system (helicopter and bucket) must deliver 20,205 L of dispersant. Assuming that each spray bucket can deliver 400 L per sortie, this means that each spray system must fly 50 sorties (100 total).

Because all of the sprayed dispersant will not contact the oil (spray misses target, slick penetration, etc.) an additional 20% or 8081 litres of dispersant must be applied which means an additional 20 sorties (10 per system).

It is assumed that a decision was made prior to this spill, that the company involved would be prepared to deal with a moderate to large sized spill (10,000 - 20,000 bbl). They therefore have sufficient dispersant available at their operations base in Tuktoyaktuk. Because the transit time from Tuktoyaktuk to the spraying site is too long (1 hr), it is decided to use the artificial island from which the spill occurred as the base of operations.

One day's supply of dispersant is flown to the island using a Sikorsky - S61 helicopter. The rest is delivered by ship.

Logistic support required to conduct the operation includes:

- a fixed wing spotter aircraft (twin otter)
- a command aircraft (twin engine helicopter)
- spray aircraft (2 twin engine helicopters)
- 295 bbl of dispersant
- fuel on island for helicopters

Assuming that flying time from the island to the spray area is ten minutes, the time to complete a single spray sortie would be as follows:

- 10 min. flight to spray area
- 20 min. to spray dispersant
- 10 min. flight back to island
- 20 min. to refill bucket

Therefore each sortie would take approximately one hour and all 100 sorties (50 for each spray system) would take 100 hours. An additional 20 hours should be added for refueling time, mechanical problems, poor weather, etc. for a total of 120 hours to complete the operation.

Because the 120 hours involves two aircraft, each would be required for approximately 60 hours. In addition, the command helicopter would also be needed for that length of time (60 hours). The Twin Otter would be required less after the slicks have been located. It will be assumed that 30 hours would suffice.

Therefore a summary of the time required by each of the logistic components is as follows:

Sikorsky S-61	4 hrs.
Ship	1 day
Spray System 1	60 hrs.
Spray System 2	60 hrs.
Command helicopter	60 hrs.
Twin Otter	30 hrs.

If the assumption is made that the dispersant applied to the slicks is 90-95% effective, then the foregoing effort should complete the operation. However, if the dispersant is less effective, additional dispersant and spray sorties may be required. For the purposes of these calculations, it will be assumed that the required degree of effectiveness has been achieved and that no additional spray effort is required.

6.2 COST

The results of this trial do not provide a convincing argument for the use of dispersants as an offshore countermeasures technique. However, if the decision were made to use dispersants, as described in the foregoing scenario, the following expesnes would be incurred. These costs are based on approximate 1986 Arctic operating costs that would apply to an operator using the equipment described above.

Dispersants - 250 bbl @ $1000/bbl	= $250,000
Helicopter Support (Dispersant delivery)	
- 4 hrs. @ 3500/hr	= $ 14,000
Ship Support - 1 day @ $15,000/day	= $ 15,000
2 x Spray helicopter - 60 hrs. @ 3500/hr.	= $210,000
Command helicopter - 60 hrs. @ 1800/hr.	= $108,000
Twin Otter - 30 hrs. @ 1300/hr.	= $ 39,000
Total Cost	= $636,000

The calculation of cost assumes that all of the required logistic support is available for the quoted prices and that the operation runs smoothly and without interruption. Should this not be the case, additional costs may be incurred.

In summary, the cost of responding to a medium size spill in the Southern Beaufort Sea using a very effective dispersant is approximately $600,000 This cost will, of course, change if any of the assumptions made in constructing this scenario are altered. For example, it was assumed that the dispersant used in the scenario was 90% effective. If the chemical was only 50% effective, the cost, logistics being sufficient, might be in the order of $1,080,000.

6.3 GUIDELINES FOR THE OPERATIONAL APPLICATION OF DISPERSANTS

The following guidelines have been developed by generalizing the specific dispersant application steps described in the preceeding scenario. It is intended as an operator's check list for the application of dispersants during an offshore spill response. Although these items are listed in a numerical order, many of the activities can be done in parallel with one another. Doing so will reduce the overall time required to implement a response.

1.0 Upon notification of spill, obtain as much information as possible about the situation:

- Location
- Exact Time of Spill
- Total Quantity Spilled
- Oil properties
  - . API gravity
  - . density
  - . dynamic viscosity
  - . pour point
  - . source
- Meteorological and Oceanographic Condition:
  - . wind speed and direction
  - . ocean current vector
  - . water temperature
  - . air temperature
  - . visibility
  - . ceiling
  - . precipitation
  - . sea state (wave heights, etc.)

2.0 Determine whether conventional spill response equipment (booms, skimmers, etc.) can be used to deal with the spilled oil.

3.0 Predict the movement of the oil and determine whether the oil is likely to impinge on any sensitive environmental sectors (e.g. shorelines, bird colonies, etc.)

4.0 Determine the environmental impact of using and not using dispersants in the particular situation at hand. This will require that some assumptions regarding dispersant effectiveness be made.

5.0 If the use of dispersants would reduce the overall impact of the spilled oil, then dispersant use should be considered.

6.0 Seek approval for dispersant use from appropriate federal agency. During this step, consult with the 'Guidelines on the Use and Acceptability of Oil Spill Dispersants' (EPS, 1984). Also ensure that the dispersant to be used is on Environment Canada list of acceptable dispersants.

7.0 Decide on a location at which to apply the dispersants. As a general rule, dispersant application and effectiveness will be more successful if the chemical is applied close to the source of the spill.

8.0 Having selected a location for the spray operation, calculate the amount of original oil spilled that will have been dissipated by evaporation and natural dispersion. The difference between this and the original spill amount will be the amount requiring treatment.

NOTE: the percentages of oil lost to evaporation and natural dispersion will depend on a wide variety of factors including: oil type; water temperature; wind speed, etc. A calculation should be made in each case.

9.0 If possible, it would be worthwhile at this point to do a small scale effectiveness test using the dispersant of choice on the oil that has been spilled. If the dispersant is effective, then a full scale application may be feasible. If the dispersant is not effective, then another dispersant should be tried or the decision to spray should be reconsidered.

10. Based on the amount of oil left to be sprayed (after evaporation and natural dispersion), calculate the amount of dispersant required. At a 1:X dispersant to oil ratio, the amount of dispersant required is calculated using the following formula:

$$D = \frac{S}{X}$$

where: D = number of barrels of dispersant required
S = number of barrels of oil remaining in slick after evaporation and natural dispersion
X = the dispersant to oil ratio (usually between 10 and 20)

11.0 Decide what system will be used to spray the dispersant onto the slick.

12.0 Determine the amount of additional logistic support that will be required to support the selected spray system.

13.0 Calculate the time required to make one spraying sortie by using the following equation:

$$t_s = (2.t_d) + t_{sp} + t_r + t_f$$

where t_s = time for single spraying sortie
t_d = flight time from dispersant storage to spray site
t_{sp} = time to spray contents of each spray unit at this spill site
t_r = time to refill spray unit
t_f = time required to refuel (this would not be done after every sortie, but would average over several flights)

14.0 Calculate the total time required to spray the slicks using the following equation:

$$TT = \left(\frac{S.DOR}{D}\right)\left(\frac{ts}{U}\right)$$

where TT = total time required to spray entire slick (in hours)
S = Number of barrels of oil remaining in slick (after evaporation and natural dispersion)
D = Number of barrels of dispersant per spray system
U = Number of Spray Systems
ts = Time for single sprayhing sortie (in hours)
DOR = Dispersant to oil ratio

15.0 Arrange for logistic support to assist spray systems. At a minimum this should include:

- fixed wing aircraft to locate slicks
- helicopter to direct spray operations
- ship and air support to deliver dispersant to base of spray operations
- vessel or aircraft to determine spray effectiveness
- ground crew for dispersant loading, refuelling mechanical repair.

16.0 Once logistics are in place, and favourable weather window is available, spraying can proceed. This should be done by flying directly into the prevailing wind at a bucket altitude of approximately 10m and a forward air speed of 150 km/hr. Wind direction can be determined by deploying a coloured smoke flare prior to the operation. Dispersant spray swaths should be laid down in a parallel fashion starting at one side of the slick and proceeding across the slick with as little swath overlap as possible. The pilot in the spray helicopter should be able to select an approrpiate flight path over the slick, but he should be advised by an aircraft at higher altitude regarding initiation and cessation of spraying on each spray pass.

17.0 After the initial spray application has been completed, the slick should be monitored either from the air or from sea level and a decision made regarding the need for additional spray application.

18.0 Costs incurred in carrying out such a spray operation can be calculated using the equations listed on the following page.

COST

Response Cost ($/bbl) = Treatment Cost ÷ Volume Treated

Treatment Cost = Dispersant Cost + Aircraft Mobilization Cost + Aircraft Spraying Cost

$$\text{Dispersant Cost} = \text{Area Treated} \times \text{Dosage} \times \left[\begin{array}{c} \text{Unit} \\ \text{Dispersant} \\ \text{Cost} \end{array} + \begin{array}{c} \text{Dispersant} \\ \text{Transport} \\ \text{Cost} \end{array} \times \begin{array}{c} \text{Transport} \\ \text{Distance} \end{array} \right]$$

Aircraft Mobilization Cost = Call out Fee + Cost per Distance

$$\text{Aircraft Spraying Cost} = \text{Flying Unit Cost} \times \left[\begin{array}{c} \text{Flying} \\ \text{Distance} \\ \text{to Spill} \end{array} + \begin{array}{c} \text{Flying} \\ \text{Distance} \\ \text{at Spill} \end{array} \right]$$

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APPENDIX I

FIELD NOTES DESCRIBING OIL DISCHARGE PROCEDURES AND TUGGER 1 LOG

DISPERSANT TRIAL
PAUL WOTHERSPOON FIELD NOTES
ABOARD THE CANMAR TUGGER 1
P. WOTHERSPOON, B. MACKIE, D. TILDEN

86-08-11

0432	Depart Tuk Base. Herschel following in 1 - 2 m seas.
0730	Commence equipment preparation.
0810	On location 133°30'W, 70°04.7'N.
1000	Command Chopper (CC) on-site, unannounced; request if ready: No.
1020	Complete tank hook-up and modifications to hose transfer system. Output end of hose floats on water surface.
	Await go-ahead for release of Slick 1 (Control 2).
	RS Twin Otter on-site. Notifies that cloud cover too low.
	RS Twin Otter and CC return to Tuk Base for refuelling.
1030-1400	No communication, clear skies continue to form, 0.5 m seas.
1400	Tugger notifies Tuk Base that site conditions are ideal. What is the problem? CC now preparing for departure from Tuk Base.
1500	CC and RS arrive at site.
1518	Spill 1 (Control 2) release from Tank 1, 2.5 m^3 released at 70°04.7'N, 133°22'W. Total release time 2 minutes, 27 seconds. No Orion buoy requested. Output hose snakes back and forth on surface. Tugger speed dead slow - less than a knot.
1522	Instructed by CC to move to second site.
1545	Spill 2 (Control 1) release from Tank 2, 2.5 m^3 released at 70°07.7'N, 133°22'W. Total release time 2 minutes, 18 seconds. No Orion buoy requested.
1555	Notified by CC that dispersant bucket inoperable.
1600	Prepare drums for transfer to spill tanks.
1620	Informed tests finished for day. Also problems with RS Twin Otter.
1745	Repair of pump diaphragm and camlocks completed.

1800 Lash deck for return to Tuk. Herschel accompanying due to fog. ETA Tuk 2300.

2315 TA Canmar wharf.

86-08-12

ETD Canmar wharf 0930.

0900 Tuk Base repairs to Herschel boom and Tugger deck pumps.

1012 TD Canmar wharf. Visibility 1/10 mile.

1030 Repair 2" Homelite pump and transfer 13 drums crude each to Tank 1 and Tank 2. Support output hose with second guide line to prevent snaking.

1310 Crude transfer complete.

1415 TA at site. Await operation decision from Tuk. Visibility 1/10 to 1/4 mile.

1500 Tests cancelled due to low visibility.

1505 Proceed with Herschel to Arnak Island.

1640 One mile N of Arnak 400 yards visibility Herschel released.

1700 Return to 4 miles NE Arnak for night.

86-08-13

WOW all day at Arnak and site. Visibility max. 1/4 mile.

1500 Fog clears moderately until complete horizon visibility at 2000. Herschel crew return to Tuk for night via Arnak and chopper.

86-08-14

0600 Await word on Herschel crew.

0945 Depart Arnak with Herschel for test site. ETA site 1100.

1106 On location. Unable to contact Vanderkooy or Swiss at Tuk Base.

1145 Still awaiting word from Tuk Base whether to proceed with rigging up tanks.

1200	CC on site. Informed to release. Unable to do so as unprepared.
1216	Tank 3 release at 70°02.4'N, 133°18.8'W. Release time 2 minutes, 45 seconds. Orion buoy #4 deployed. No snaking of discharge hose.
1225	Commence refill of Tank 3: 13 bbl.
1242	Tank 2 release at 70°04'N, 133°22'W. 30 seconds after start, pump shut down due to excessive vacuum in tank.
1243	Recommence Tank 2 release. Total release time 2 minutes, 15 seconds. Orion buoy #5 deployed.
1427	Tank 1 release at 70°06.01'N, 133°23.2'W. Total release time 2 minutes, 45 seconds. Orion buoy #6 deployed. Cleaned transfer lines with seawater.
1500	Complete refill of Tank 3.
1630	Depart site for Tuk Base.
1715	Instructed to return to site for fourth spill. Unable to use same transfer lines due to short notice. Oil will have to be released 0.5 m above water surface.
1804	Tank 3 release at 70°0.85'N, 133°23'W. Total release time 2 minutes, 50 seconds. Orion buoy #2 released. Tugger remains at site to view spray operation.
1900	Equipment packed and lashed.
2030	Await Herschel at Farwell buoy.
2145	Transfer to Herschel ETA Tuk 2300.
2325	TA Tuk Base.

OBSERVATIONS

- Although command handled the communication network well, more frequent status reports would have made better use of time, fuel and manpower.
- Operational personnel (marine and aviation) were the trial's backbone and are to be commended for their efficient support.
- Input from marine design during the trial's planning stage may have developed a better support and deployment apparatus for the fluorometer.

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DOME PETROLEUM LIMITED
MANAGER'S LOG BOOK — TUGGER I

1608 80-04

VESSEL: Canmar Tugger   AT / FROM: McKinley Bay   TO / AT: Tuktoyaktuk   COST CENTRE/AFE No: [illegible]   DATE: Sunday [illegible]-08-[illegible] (YEAR MONTH DAY)

TIME	COURSES TRUE	GYRO	STAN.	STEER	ERROR GYRO	ERROR STAN.	WIND DIRECTION	WIND FORCE	SKY	SEA	VISIBILITY	BAR	AIR TEMP	SEA TEMP	LOG	ICE CONDITIONS	REMARKS
01:00	1/2 secured [illegible]																Fire & security watch maintained [illegible]
02:00	alongside [illegible]																
03:00																	
04:00																	
05:00																	0518 Depart McKinley Bay.
06:00	207°	250°	206°	-													0557 [illegible] 238° × 6.8' Depart channel [illegible] 270° T.G.
07:00	263°	267°	202°	-													0618 [illegible] 212° × 6.3' [illegible] 250° G. 267° T. (+3° err) 0700 [illegible] 267° [illegible]
08:00	"	"	"				NE	1	o	Mod	8'	01.7	6°C	-	-	o.w.	0800 [illegible] 186° 7.0'
09:00	231	231															0811 [illegible] 165° × 6.0' [illegible]
10:00																	0902 [illegible] 0915 a/c 318° 0930 [illegible]
11:00																	[illegible] 124° × 6.6' [illegible] 1030 [illegible]
12:00	1/2 secured at [illegible]						Lt Var		oc	Calm	15'	02.5	16°C	-	-	o.w.	1145 Tied Tuktoyaktuk [illegible]
13:00	Dock (North end).																1240-1830 Loading equipment for [illegible]. 1330-1400 [illegible]
14:00																	[illegible]
15:00	1/2 secured at [illegible] dock																1500-1518 Shift ship to outboard of Supplier VI
16:00	outboard of Supplier II						Var	2	oc	Mod	15'	02.7	18°C			o.w.	
17:00																	Electrician working on [illegible] system.
18:00																	
19:00																	19[illegible] [illegible]
20:00																	
21:00							d	4	oc	Sm	15'	02.2	15°C			o.w.	
22:00																	
23:00																	
24:00																	Fire & security watch maintained.

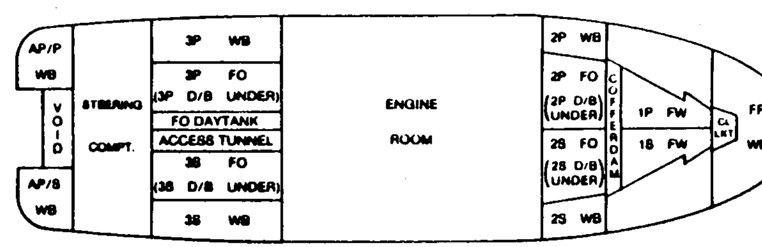
WATCH	LOOKOUT	REGULATION LIGHTS EXHIBITED	SAFETY EQUIPMENT CHECKED
00:00 TO 04:00			
04:00 TO 08:00			
08:00 TO 12:00			
12:00 TO 16:00		SICK LIST	DRAUGHTS
16:00 TO 20:00			FWD 12'02"
20:00 TO 24:00			AFT 13'08"
			MEAN 12'11"

CREW ON BOARD

Name	Position
J. [illegible]	Master
[illegible]	1/E
D. [illegible]	2/E
[illegible]	3/E
J. [illegible]	[illegible]
G. [illegible]	[illegible]
[illegible]	"
[illegible]	"
[illegible]	"
[illegible]	Cook
D. [illegible]	Messman

TANK CONTENTS

BALLAST		FRESH WATER	
FP	MT	1P	6.76
2P	Full	1S	7.36
2S	Full		
2D/BP	Full	TOTAL	13.1
2D/BS	Full	FUEL OIL	
3P	"	2P	MT
3S	MT	2S	MT
3D/BP	1"	3P	5.6
3D/BS	MT	3S	
A/PP	MT	DY TK	
A/PS	"		
TOTAL	32.3	TOTAL	5.6



[signature] MASTER'S SIGNATURE   CHIEF OFFICER'S SIGNATURE

FILES R9, CALGARY

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DISP. TRIAL Aug 11-15

DOME [illegible]EUM LIMITED
MANAGER'S LOG BOOK — TUGGER I

VESSEL Canmar Tugger? At/From Tuktoyaktuk TO IUK? COST CENTRE/AFE No 6735000 DATE 36-08-11 (YEAR MONTH DAY)

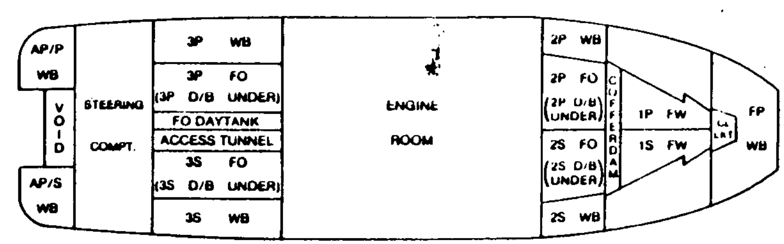
TIME	COURSES TRUE	COURSES GYRO	COURSES STAN.	COURSES STEER	ERROR GYRO.	ERROR STAN.	WIND DIRECTION	WIND FORCE	SKY	SEA	VISIBILITY	BAR	AIR TEMP	SEA TEMP	LOG	ICE CONDITIONS	REMARKS
01:00	1/2 [illegible]																[illegible] watch maintained [illegible]
02:00	[illegible]																[illegible]
03:00																	
04:00							E	3	c	.	10'	00.8	9°c			o.w.	
05:00																	0430 Dep [illegible] 0451 [illegible] in company [illegible]
06:00	353	353															0501 At [illegible] 0550 At [illegible] 352° [illegible]
07:00	345°	345°	304°														0558 At [illegible] 345° [illegible], 0725 [illegible] 276° x 9.6
08:00	000	000	318°				NE	3	c		10	1002	8°c			o.w.	0725 [illegible] 344° x 2.5 A/c 000
09:00																	0800 [illegible] 323° x 2.2 [illegible]. 0810 slowed speed - general area of Trial
10:00																	0930 A/c 335° slow speed to stay in area of Trial
11:00																	1000 Holding pos. 70°03.4'N 133°13'W waiting signal for command [illegible]
12:00		VAR					NE	2	c		10	1003	8°c				to start releasing oil for dispersant Trial
13:00																	1200 Pos. 70°04.1'N 133°18.2'W holding for go ahead.
14:00																	1518 Releasing first oil into water from 70°04.7'N 133°23'W
15:00																	1520 [illegible] 2 km north of first oil 1605 [illegible] releasing 2nd oil
16:00	Various as required						ENE	3	[illegible]	[illegible]	15'	05.0	12°c			o.w.	Pos 70°22'N 133°21'W - 1648 [illegible] 2 km north for 3rd Test
17:00																	[illegible] Trial ended due to damaged equipment [illegible]
18:00																	
19:00	179°	179°	158°														1806 [illegible] 240° x 10' [illegible] 179° [illegible]
20:00	-	..	.				Lt [illegible]		f	[illegible]	[illegible]	05.5	8°c			o.w.	2000 [illegible] 243° x 10.3' [illegible] in company [illegible]
21:00	165°	165°	129°														2026 [illegible] 165° [illegible]
22:00	172°	172°	136°														2142 At [illegible] 172° [illegible]
23:00	144°	144°	102°														2213 At [illegible] 144° [illegible]. 2243 At [illegible]
24:00	At [illegible]						NNW	3	f	[illegible]	[illegible]	06.5	9°c			o.w.	2312 [illegible]

WATCH	LOOKOUT	REGULATION LIGHTS EXHIBITED	SAFETY EQUIPMENT CHECKED
00:00 TO 04:00			
04:00 TO 08:00			
08:00 TO 12:00			
12:00 TO 16:00		SICK LIST	DRAFTS
16:00 TO 20:00			FWD 12'06"
20:00 TO 24:00			AFT 13'08"
			MEAN 13'01"

CREW ON BOARD	
J. [illegible]	Master
[illegible]	C/O
D. [illegible]	2/O
[illegible]	3/O
[illegible]	[illegible]
G. [illegible]	Seaman
[illegible]	"
[illegible]	"
[illegible]	"
[illegible]	Cook
[illegible]	[illegible]
[illegible]	Seaman
R. [illegible]	"
D. [illegible]	"

TANK CONTENTS

BALLAST		FRESH WATER	
FP	MT	1P	5.33
2P	Full	1S	6.33
2S	Full		
2D/BP	Full	TOTAL	11.65
2D/BS	Full	FUEL OIL	
3P	1"	2P	15.0
3S	MT	2S	
3D/BP	1"	3P	33.0
3D/BS	MT	3S	
A/PP	MT	DY TK	-
A/PS	1'0"		
TOTAL	33.3 m³	TOTAL	48.0



MASTER'S SIGNATURE [signature]
CHIEF OFFICER'S SIGNATURE [signature]

FILES R9, CALGARY

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DOME PETROLEUM LIMITED

MANAGER'S LOG BOOK — TUGGER I

1606 82-04

Tue

VESSEL Tugger 1 — from Tuktoyaktuk — TO — COST CENTRE/AFE No. 6735000 — DATE 86 (YEAR) 08 (MONTH) 12 (DAY)

TIME	COURSES TRUE	COURSES GYRO	COURSES STAN.	COURSES STEER	ERROR GYRO	ERROR STAN	WIND DIRECTION	WIND FORCE	SKY	SEA	VISIBILITY	BAR	AIR TEMP	SEA TEMP	LOG	ICE CONDITIONS	REMARKS
01:00	Secured alongside [illegible] 6 – [illegible]										1/4	1008	8°				[illegible]
02:00																	[illegible]
03:00																	
04:00									F		1/4	1009	8°				
05:00																	
06:00																	
07:00																	
08:00							LT	VAR	F		1/4	1009	6°				
09:00																	0815-0940 [illegible] 90 [illegible] 0940-1010 [illegible]
10:00																	1015 [illegible] 1033 [illegible] 1048 [illegible]
11:00	Underway																1112 [illegible] 312° [illegible] 313° [illegible]
12:00	352°	352°	312°				NW	1	F	Rip.	1/4	1009	6°			o/w	1145 [illegible] 1200: N. [illegible] 3NM
13:00																	1300: ARNAK BRG: 0785TT RG: 11.2 NM
14:00																	1400: AMAUILIGAK: BRG 312°TT RG 13.3 NM: 1415 STOP AWAITING [illegible]
15:00	214°	214°	181°			ø	LT	VAR	F	CALM	1/4	1010	4°			o/w	[illegible] 1500: TODAYS TRIAL CANCELLED DUE TO UNSUITABLE WEATHER
16:00																	CONDITIONS. ESCORTING M/V HERSCHEL TO ARNAK. [illegible]
17:00																	1515: AC [illegible] ARNAK 218° [illegible] M.V. HERSCHEL AT
18:00																	ARNAK ISLAND @ 1640 / STANDING BY UNTIL RESUMPTION OF TRIALS
19:00																	1700: [illegible] ARNAK 4 NM [illegible] 1720 STARB/MAIN ENGINE SHUT DOWN
20:00							E	2	F	1/2	1/2	1009	6°			o/w	1850-1915 [illegible]
21:00																	[illegible]
22:00																	2200 [illegible] 261° [illegible] 13.3 [illegible]
23:00																	
24:00							E	3	F	1/2	1/4	1007	6°			o/w	Posn 68° [illegible] N 133° [illegible] W

WATCH	LOOKOUT	REGULATION LIGHTS EXHIBITED	SAFETY EQUIPMENT CHECKED
00:00 TO 04:00			
04:00 TO 08:00			
08:00 TO 12:00			
12:00 TO 16:00			
16:00 TO 20:00			
20:00 TO 24:00			

SICK LIST

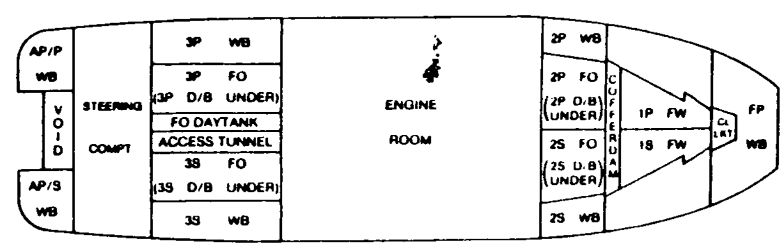
DEEP DRAFTS: FWD 12' 10" — AFT 13' 08" — MEAN 13' 03"

CREW ON BOARD

Name	Rank
[illegible]	Master
[illegible]	C/O
[illegible]	2/O
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	"
[illegible]	"
[illegible]	"
[illegible]	Cook
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	"
[illegible]	"

TANK CONTENTS

BALLAST		FRESH WATER	
FP	MT	1P	5.8
2P	Full	1S	3.8
2S	Full		
2D/BP	Full	TOTAL	8.6
2D/BS	Full	FUEL OIL	
3P	1"	2P	
3S	MT	2S	
3D/BP	1"	3P	
3D/BS	MT	3S	
A/PP	MT	DY TK	
A/PS	1"		
TOTAL	32 m³	TOTAL	45



MASTER'S SIGNATURE — CHIEF OFFICER'S SIGNATURE

DOM[illegible]LEUM LIMITED

MANAGER'S L[illegible] BOOK — TUGGER I

VESSEL Tug I FROM 69° 50' N 133° 50' W TO COST CENTRE/AFE No 6735000 DATE 86 08 13 (YEAR MONTH DAY) W61

TIME	COURSES TRUE	GYRO	STAN	STEER	ERROR GYRO	STAN	WIND DIRECTION	FORCE	SKY	SEA	VISIBILITY	BAR	AIR TEMP	SEA TEMP	LOG	ICE CONDITIONS	REMARKS
01:00	VAR	To hold Posn					E	3	F	1m	–	1007	6°			o/w	Standing by [illegible] of Arnak K-06 for oil [illegible] [illegible] ice conditions
02:00																	
03:00		—	"	—													
04:00							E	3	F	½m	¼	1006	5°			o/w	Posn 69° 48.6' N 133° 44.7' W
05:00																	
06:00	020		343														0600 at Arnak K-06 [illegible] following [illegible] [illegible]
07:00																	0700: Pos ARNAK BRG 210°T RG 9.3NM
08:00	030		343				ENE	3	F	<1m	¼	1005	5°			o/w	0800: Pos: AMAULIGAK BRG 288°T RG 9.5NM / ON LOCATION STBY FOR WEATHER
09:00																	0900: C/O VAR TO HOLD POS.
10:00																	1000: Pos: AMAULIGAK BRG 285°T RG 8.4NM
11:00																	1100: Pos: AMAULIGAK BRG 283°T RG 8.8NM
12:00	VAR	To hold Pos:					ENE	3	F	<1m	¼	1005	6°			o/w	1200: Pos: AMAULIGAK BRG 285°T RG 8.25NM
13:00																	1300: Pos. AMAULIGAK BRG 285°T RG 7.77NM
14:00																	1400: Pos. AMAULIGAK BRG 289°T RG 7.37NM / 1435 [illegible]
15:00																	[illegible] UNDERWAY W/ [illegible] TO ARNAK K-06 Co: 235°T 13.9
16:00	205°		131°				ENE	2	F	<1m	¼	1005.5	8°			o/w	1600: Pos: ARNAK K-06 BRG 206°T @ 7.91NM Co 205°T 13.7
17:00																	1700: Pos ARNAK K-06 BRG 205°T RG 4.3NM / STANDBY UNTILL [illegible]
18:00																	1800 Pos: ARNAK K-06 BRG 207°T RG 3.8NM
19:00																	1900 Pos: ARNAK K-06 BRG 210°T RG 3.48NM
20:00		VAR					E	2	C	½m	10	1007	10°			o/w	
21:00																	
22:00																	
23:00	—	"	—														
24:00							E	2	C	½	10	1010	6°			o/w	Posn 69° 48.8' N 133° 42.9' W

WATCH	LOOKOUT	REGULATION LIGHTS	REGULATION EXHIBITED	SAFETY EQUIPMENT CHECKED
00:00 TO 04:00				
04:00 TO 08:00				
08:00 TO 12:00				
12:00 TO 16:00				
16:00 TO 20:00				
20:00 TO 24:00				

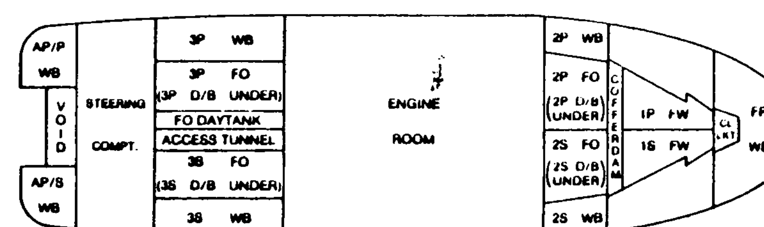
SICK LIST

DRAFTS: FWD / AFT / MEAN

CREW ON BOARD	
[illegible]	MASTER
[illegible]	C/O
[illegible]	C/E
[illegible]	2/E
[illegible]	ERA
[illegible]	SEAMAN
[illegible]	"
[illegible]	"
[illegible]	"
[illegible]	COOK
[illegible]	[illegible]
[illegible]	SUPER
[illegible]	"
[illegible]	"

TANK CONTENTS

BALLAST		FRESH WATER	
FP	mt	1P	full
2P	[illegible]	1S	[illegible]
2S	[illegible]		
2 D/B P	FULL	TOTAL	14.93
2 D/B S	"	FUEL OIL	
3P	1"	2P	
3S	mt	2S	
3 D/B P	1"	3P	
3 D/B S	mt	3S	
A/P P	mt	DY TK	
A/P S	1"		
	21		
TOTAL	[illegible]	TOTAL	63.0



MASTER'S SIGNATURE CHIEF OFFICER'S SIGNATURE

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DC ... ROLEUM LIMITED
MANAGER'S LOG BOOK — TUGGER I

THUR.

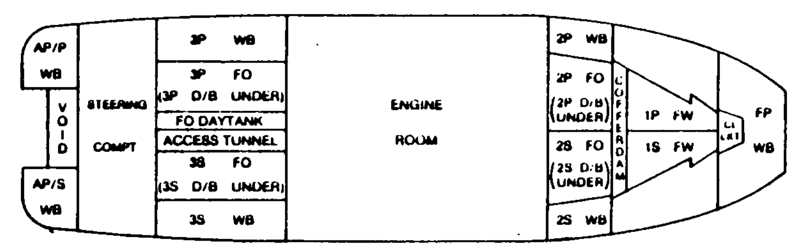
VESSEL TUG 1 FROM 69° 48.5' N 133° 47.9' W TO 69° 50.. N 133° 29' W COST CENTRE/AFE No 6735000 DATE 86 08 14 (YEAR MONTH DAY)

TIME	COURSES TRUE	COURSES GYRO	COURSES STAN	COURSES STEER	ERROR GYRO	ERROR STAN	WIND DIRECTION	WIND FORCE	SKY	SEA	VISIBILITY	BAR	AIR TEMP	SEA TEMP	LOG	ICE CONDITIONS	REMARKS
01:00	— VAR			—			E	2	C	½ smooth	10	1010	6°			o/w	Standing by north end Kok – pending wx for oil dispersant trials
02:00							NE	3	Fog	lm	¼	1011	4°			o/w	
03:00																	
04:00	—	"	—				NE	3	F	lm	½	1011	4°			o/w	
05:00							NE	3	C	10	lm						0445 Pos 69° 42.7' N 133° 43..
06:00																	
07:00																	0700 Pos ARNAK K-06 BRG 210°T RG 3 NM
08:00	— VAR —						NE	3	o/c	1m	10	1013	5°			o/w	0800: Pos ARNAK K-06 BRG 210°T RG 2.5 NM
09:00	030	030	345														0900: Pos ARNAK K-06 BRG 207°T RG 2.67 NM 0945 underway to [illegible]
10:00																	location w/ [illegible] 030°T 345 m/1000: ARNAK BRG 207°T RG 5.4 NM
11:00	050	000	003									1014	6°				1100: Pos AMAULIGAK BRG 290°T RG 9.45 NM [illegible] 030°T 003°C
12:00	— VAR —						NE	3	o/c	<.5m	10	1014	6°			o/w	1106 on location / 1200: Pos AMAULIGAK BRG 283°T RG 9.77 / 1216 start
13:00																	oil dispersant trials Pos Amauligak 282° 9.102 / 1240 - 1242 2nd slick
14:00																	1400: Amauligak BRG 280° RG [illegible] / 1427 - 1430 3rd slick Amauligak [illegible]
15:00																	1500: AMAULIGAK BRG 280° RG 8.92 NM
16:00	— VAR TO HOLD POS —						ENE	4	C	1m	10+	1015	7°			o/w	1600 Amauligak BRG 280° RG 8.89 NM / 1620 DISPERSANT TRIALS COMPLETED
17:00																	DEPART FOR TUK / 1700: Pos Amauligak BRG 294°T RG 9.25 NM WAITING INSTR[illegible]
18:00																	1730: [illegible] TRIAL LOCATION / 1800: Pos Amauligak BRG 282° RG 9.07 NM / 1802-1807 4th SL[illegible]
19:00																	1810: [illegible] TO TUK (@ 1807 [illegible])
20:00	124		118				ENE	3	bc	1	10	1017	7°			o/w	1900: Amauligak BRG [illegible]
21:00																	2010 Tuk [illegible] [illegible]
22:00	037		345														2130 [illegible] [illegible] [illegible] waiting [illegible] [illegible] [illegible]
23:00																	2200 depart [illegible] Tuk enroute McKinley Bay
24:00	053		008				NE	3	bc	1	10	1018	6°			o/w	2300 [illegible] [illegible] 69° 50' N 133° 29' W

WATCH	LOOKOUT	REGULATION LIGHTS	REGULATION DIMMED	SAFETY EQUIPMENT	CREW ON BOARD	
00-00 TO 04-00					[illegible]	master
04-00 TO 08-00					[illegible]	c/o
08-00 TO 12-00					[illegible]	c/e
12-00 TO 16-00					[illegible]	2/e
16-00 TO 20-00					[illegible]	[illegible]
20-00 TO 24-00					[illegible]	[illegible]
		SICK LIST		DRAFTS	[illegible]	"
				FWD	[illegible]	"
				AFT	[illegible]	"
				MEAN	[illegible]	cook
					[illegible]	[illegible]
					[illegible]	[illegible]
					[illegible]	"
					[illegible]	"

TANK CONTENTS

BALLAST		FRESH WATER	
FP	—	1P	5.90
2P	—	1S	7.61
2S	—	TOTAL	13.51
2D/BP	10.2	FUEL OIL	
2D/BS	10	2P	
3P	—	2S	
3S	—	3P	
3D/BP	—	3S	
3D/BS	—	DY TK	
A/PP	—		
A/PS	—		
TOTAL	20.2	TOTAL	



MASTER'S SIGNATURE — CHIEF OFFICER'S SIGNATURE

FILES R8, CALGARY

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DO. [illegible]ROLEUM LIMITED

MANAGER'S LOG BOOK — TUGGER I

VESSEL: Tug 1 FROM: 69° 50.0'N 133° 24'W TO: [illegible] McKinley Bay COST CENTRE/AFE NO: 6735000 DATE: 86 08 [illegible] (YEAR MONTH DAY) FRI

TIME	COURSES TRUE	COURSES GYRO	COURSES STAN	COURSES STEER	ERROR GYRO	ERROR STAN	WIND DIRECTION	WIND FORCE	SKY	SEA	VISIBILITY	BAR	AIR TEMP	SEA TEMP	LOG	ICE CONDITIONS	REMARKS
01.00	070		023				NE	2	C	1/2m	10	1020	2°			[illegible]	[illegible] McKinley Bay [illegible] 3 [illegible] ballast full
02.00	[illegible] as required.																0228 McKinley channel c/c 192°
03.00																	0254 [illegible] side of [illegible]
04.00																	
05.00																	
06.00																	
07.00																	07:20 Day watch on duty
08.00							ESE	3	[illegible]	1/2'	[illegible]	20.7	2°			[illegible]	0740-0750 [illegible] side of [illegible]
09.00	[illegible] on barge [illegible] south																Electrician & fitter [illegible]
10.00	side of [illegible]																1050 Dep'd [illegible] with barge. 1055 [illegible]
11.00																	1110 [illegible]
12.00	[illegible] Site						NE	3	[illegible]	[illegible]	10'	20.5	5°			[illegible]	
13.00																	1248-[illegible] 1350 Dep [illegible] Site
14.00	[illegible] alongside																1405 [illegible] south side of [illegible]
15.00	[illegible] south side of [illegible]																1432 [illegible]
16.00																	
17.00																	[illegible] with [illegible] installation
18.00																	
19.00																	19:00 [illegible]
20.00																	[illegible]
21.00							SWD	2	[illegible]	[illegible]	15'	20.5	5°				
22.00																	
23.00																	
24.00																	[illegible]

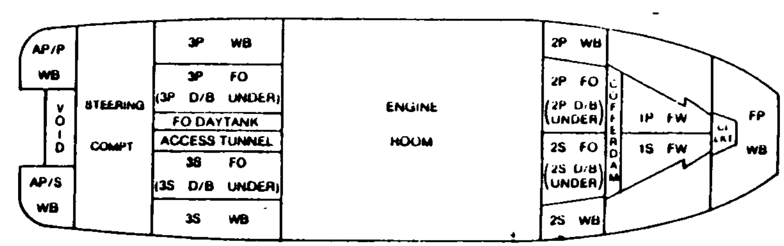
WATCH	LOOKOUT	REGULATION LIGHTS EXHIBITED	SAFETY [illegible]
00.00 TO 04.00			
04.00 TO 08.00			
08.00 TO 12.00			
12.00 TO 16.00		SICK LIST	DRAFTS
16.00 TO 20.00			FWD
20.00 TO 24.00			AFT
			MEAN

CREW ON BOARD

Name	Position
[illegible]	Master
[illegible]	c/o
[illegible]	C/E
[illegible]	2/E
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	"
[illegible]	"
[illegible]	Cook
[illegible]	[illegible]
[illegible]	[illegible]

TANK CONTENTS

BALLAST		FRESH WATER	
FP	—	1P	5.4
2P	—	1S	7.6
2S	—		
2 D/B P	10.3	TOTAL	13.0
2 D/B S	10	FUEL OIL	
3P	—	2P	
3S	—	2S	
3 D/B P	14.9	3P	
3 D/B S	14.9	3S	
A/P P	—	DY TK	
A/P S	—		
TOTAL	50.1	TOTAL	38



MASTER'S SIGNATURE

CHIEF OFFICER'S SIGNATURE

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APPENDIX II

DESCRIPTION OF CCRS DESAULT FALCON

AND REMOTE SENSING EQUIPMENT

The following passage which describes the remote sensing equipment on board the Canada Centre for Remote Sensing (CCRS) aircraft was extracted directly from a paper by McColl et al, 1987:

"The CCRS Falcon 20 aircraft was equipped with an electro-optical sensor configuration.

The prime sensor was the Daedalus MSS 1260 with the Alice MSS processor and Real Time Display Systems. The MSS sensor head mounted in the nose of the aircraft accommodates optional detector configurations including ultraviolet/infrared (UV/IR), dual IR, and multispectral IR.

The multiband digital MSS data were recorded on a Bell and Howell M14F high density digital tape recorder (HDTR). The colour real time display data were recorded on a Canon portable VCR for on-site review of the remote sensing data.

In addition to the MSS, a Wild RC-10 camera using Aero-negative 2445 film provided selected photo coverage of the trial sites.

The primary system for aircraft navigation was a Litton 51 inertial navigation system (INS). The INS aircraft position and attitude data are interfaced to both the MAID navigation processor and the MSS sensor. MAID data are recorded on a Kennedy CCT recorder mounted in rack with HDTR and INS systems. In addition, the MAID flight line data including time, position, altitude, aircraft heading, track angle, attitude and event marker are output to a line printer mounted in the navigation/camera rack. The line printer record is part of the permanent flight log."

APPENDIX III

DISPERSANT LOADING PROCEDURES;

AND RECORD OF AMOUNTS OF DISPERSANT USED

DISPERSANT LOADING

- Fly to island with 212 carrying bucket of Enersperse.
- Set down and wait for call to spray.
- Empty second bucket and fill with CRX-8LT.
- When call comes, 212 brings bucket of Enersperse.
- When empty bucket returns, fill with Enersperse.
- Wait on island with one bucket of Enersperse and one bucket of CRX-8LT.
- When call comes, 212 brings bucket of CRX-8LT.
- When empty bucket returns, fill with CRX-8LT.
- Wait on island with one bucket of Enersperse and one bucket of CRX-8LT.
- When call comes, bring whichever bucket is requested.
- Refill buckets each time they return with the same dispersant that they left with.
- Continue until exercise complete.

FLIGHT #	BUCKET	GAL. IN	RETURN AMOUNT	AMOUNT USED Imp.Gal.	AMOUNT USED Litres	DISPERSANT TYPE
1	B	150	35	115	523	Enersperse
3	B	150	60	90	409	Enersperse
5	B	150	70	80	364	Enersperse
2	A	150	60	90	409	CRX-8LT
4	A	150	27	123	559	CRX-8LT
6	A	150	60	90	409	CRX-8LT

APPENDIX IV

DESCRIPTION OF COMPUHEAT VIPS 300C

COMPUHEAT SERVICES CANADA INC.

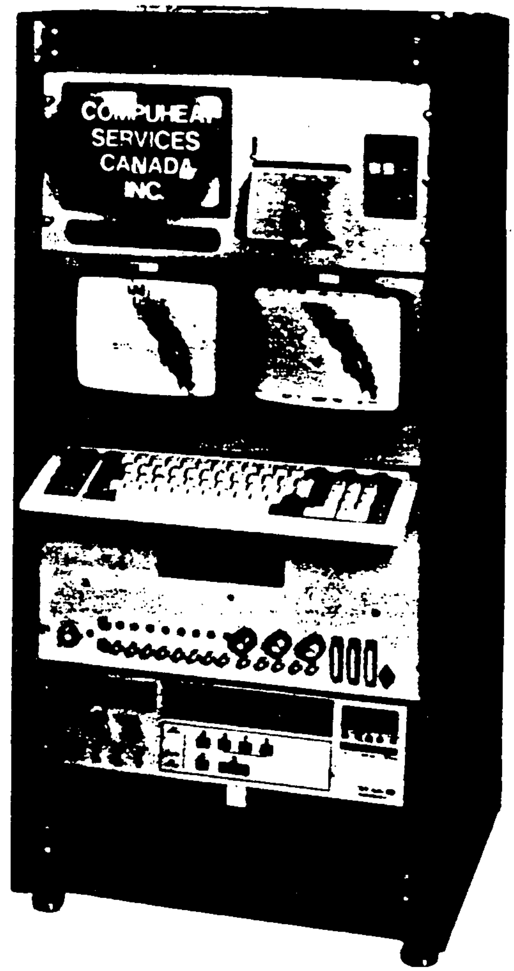
Oil Spill Detection & Analysis System

The '**VIPS 300C**' is a computerized portable system primarily designed for off-shore spill detection & analysis. This system can also be used in a wide range of other land, marine, and aerial remote sensing applications.

SYSTEM FEATURES:

- Calculates areas of thick and thin sheens of oil detected from I/R & U/V sensors. (Shown below is the IR18 Barr & Stroud Thermal Sensor).
- System portability allows rapid deployment in 'Aircraft of Opportunity'.
- Real-time image analysis from remote video sensors.
- Post analysis of recorded video data.
- Calculation results superimposed on analyzed images.
- Visual verification of calculated areas.
- Audit trail of area calculations.
- Records live images from remote sensors.
- Records analyzed images.
- Instant hard-copy prints of live/analyzed and recorded data.
- Modular design for ease of service, software & hardware retrofits.
- Manufactured in Calgary, Canada.

VIPS 300C



Enquiries To:
COMPUHEAT SERVICES CANADA INC.
#6, 343 Forge Road S.E.
Calgary, Alberta T2H 0S9
Canada. Tel: (403) 252-3133
Tlx: 03-826765

In Europe:
FRANK AYLES & ASSOCIATES LTD.
Pollution Control Division
120 Whitechapel High Street
London E1 7PT
England. Tel: (01-247-1926/7)
Tlx: 886069

SUPPLIERS OF CUSTOM SOFTWARE & HARDWARE FOR THE REMOTE SENSING INDUSTRY.

2.0 MAJOR FEATURES OF THE VIPS 300C SYSTEM

- Portability
- Instant calculations of areas and volume (volume is calculated on thickness data)
- Distance or point to point measurements
- Density slicing fo area ratios of thick and thin oil
- Percentage calculations
- side by side image comparisons
- overlaying of two images
- Sequential calculations for large oil slicks. (This mode is used when an oil slick extends beyond the field of view of the sensors. Area and volume are tabulated as the aircraft passes along the slick.)
- RS232 ports for data input or output
- Intercom for operator to observers
- Instant hard copy picture of live or processed data
- Real-time or post processing capability
- Time/date annotation
- Latitude/Longitude input capability
- Full data log retained in memory to coincide with images for retrieval after mission
- Colour image capability
- Discreet area calculation
- Binary image analysis