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Field Evaluation of the Super Seahawk and Marco Class V Oil Skimmers

Technology Development Report
EPS -4-EC-78-2

Environmental Impact Control Directorate
May, 1978

FIELD EVALUATION OF THE SUPER SEAHAWK AND MARCO CLASS V OIL SKIMMERS

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A Report Submitted to:

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

EPS-4-EC-78-2
May, 1978

REVIEW NOTICE

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

ABSTRACT

Two oil spill recovery devices, the Super Seahawk and the Marco Class V, were evaluated at Esquimalt Harbour near Victoria, British Columbia in August 1977. The former is manufactured by Bennett Pollution Controls Limited, North Vancouver, B.C. and the latter by Marine Construction and Design Company, Seattle, Washington. The two devices were evaluated on the basis of the parameters: Oil Recovery Rate (ORR), the rate at which the device recovers oil; Oil Recovery Factor (ORF), the volume of oil recovered by the device versus the volume presented to it; Oil Content Factor (OCF), the percentage of oil in the liquid recovered by the device; and Emulsification Factor (EF), the percentage of water in the oil which was recovered by the device. These parameters were measured during trials in which three types of fresh oil (Alberta Crude, Diesel and Bunker C) were spilled in limited quantities (less than one barrel) directly in front of the skimmers. The trials took place under environmental conditions ranging from clear skies and calm seas to rain and slight chop.

No quantitative data were obtained for the Super Seahawk due to the small amount of oil it was able to collect. The device was considered to require extensive redesign.

In the case of crude oil trials, Oil Recovery Rates for the Marco Class V ranged from 0.3 to 7.9 litres per minute. The Oil Recovery Factor ranged from 4.4% to 91% and the Emulsification Factor from 34% to 1%. For diesel oil trials, Oil Recovery Rates ranged from 3.2 to 14.1 litres per minute. The Oil Recovery Factor ranged from 35% to 78% and the Emulsification Factor from 45% to 1%. Only three trials were carried out using Bunker C. The Oil Recovery Rates obtained were 12.5, 13.7 and 14.2 litres per minute. The Oil Recovery Factor approximated 100% in each case. The Emulsification Factors were 24%, 17% and 19%.

In addition to the quantitative results, judgement values were made on construction, ease of operation and safety. The Marco Class V was judged to be acceptable for all three criteria. The Super Seahawk was judged to be acceptable in construction and operation, but potentially unsafe if manned in seas with wave heights exceeding one metre.

RESUME

Les appareils de récupération des hydrocarbures Super Seahawk et Marco Class V ont été éprouvés dans le havre Esquimalt, près de Victoria en août 1977. Le premier est fabriqué par Bennett Pollution Controls Limited, North Vancouver, et le second par Marine Construction and Design Company, Seattle. L'évaluation s'est fondée sur les paramètres suivants: débit de la récupération des HC (DRHC) par l'appareil; le rendement de la récupération (RRHC), rapport du volume de HC récupéré au volume à récupérer; la teneur en HC (%HC) du mélange récupéré; et le coefficient d'émulsion (%E), c'est à dire le pourcentage d'eau dans les HC récupérés. Ces paramètres ont été mesurés au cours d'essais avec trois sortes d' "huile fraîches" (brut de l'Alberta, gasoil, Bunker C) déversées directement devant les écrèmeurs en quantité limitée (moins d'un fût). Les essais se sont faits dans des conditions atmosphériques qui allaient du ciel clair et de la mer calme à la pluie et au léger clapotis.

Aucune donnée numérique n'a pu être obtenue pour le Super Seahawk, étant donné le peu d'HC qu'il a été en mesure de recueillir. L'appareil devrait être repensé en grande partie.

Pour ce qui concerne le Marco Class V, avec le brut, le DRHC a varié de 0,3 à 7,9 ℓ/mn. Le RRHC a varié entre 4,4 et 91% et le %E entre 34 et 1%. Avec la gasoil, le DRHC a varié entre 3,2 et 14,1 ℓ/mn. Quant au RRHC, il a fluctué entre 35 et 78%, et le %E entre 45 et 1%. Trois essais seulement ont été faits avec le Bunker C. Le DRHC a été de 12,5 de 13,7 et de 14,2 ℓ/mn. Le RRHC a égalé près de 100% chaque fois, et %E a été respectivement de 24, 17 et 19%.

Les données numériques ont été complétées par une appréciation de la construction, de la maniabilité et de la sécurité des appareils. Le Marco Class V a été jugé acceptable au regard de ces trois critères. Quant au Super Seahawk, sa construction et sa maniabilité ont été jugées satisfaisantes, mais son emploi comporterait des risques en mer si les vagues dépassent un mètre.

FOREWORD

Beak Consultants Ltd., Canguard Consulting Ltd. and Associated Engineering Services Ltd. conducted this study under contract to the Environmental Emergency Branch (EEB), Fisheries and Environment Canada. The scientific authority was Mr. L.B. Solsberg of this Branch who received support from staff of the EEB office, Pacific Region.

The assistance received by a number of authorities during the course of these trials is acknowledged: the Canadian Coast Guard and the Canadian Department of National Defence, particularly the staff of the Queen's Harbourmaster, who provided vessel support, lifting equipment, barges and VHF portable radios, all of which proved invaluable to the conduct of the experiments.

The Marco Class V unit was made available for these trials by the U.S Navy while the Super Seahawk was supplied by the manufacturer, Bennett Pollution Controls Limited, North Vancouver.

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1 INTRODUCTION

The Research and Development Division of the Environmental Emergency Branch, Environmental Protection Service, has been charged with the responsibility of participating in and encouraging the development and testing of oil skimming devices. Two skimmers, the Super Seahawk and the Marco Class V, were tested in August 1977 at Esquimalt Harbour as part of the continuing evaluation program.

Ideally, self-contained, self-propelled, oil recovery systems destined for use in Canadian harbours should fulfill certain primary requirements. They should

- be transportable by land and sea
- be capable of operating in sea states up to Force 3 on the Beaufort Wind and Wave Scale
- be safe and easily operated
- be capable of offloading recovered liquids with speed and at sea
- have a means of separating oil from water.

In addition, they should not be prone to problems caused by debris and should not cause large quantities of oil to be emulsified during recovery and transfer processes.

In-situ testing itself presents difficulties. In conducting such tests oil has to be spilled upon the sea (or river, or lake) in such a way as to ensure that minimal pollution occurs. If too much oil is spilled and the skimmer proves to be inefficient, environmental damage could ensue. If too little oil is spilled, the test cannot realistically determine the capabilities of the device. Tests are usually attempted in a variety of sea states, weather and ocean conditions permitting.

Both oil skimmers described herein were tested at Esquimalt Harbour near Victoria, British Columbia.

The Super Seahawk oil skimmer was supplied by Bennett Pollution Controls Ltd., North Vancouver, B.C. Trials began on August 12, 1977 and during the following week (August 15-19) various techniques were used to evaluate the unit, employing Alberta crude as the test oil. In general the trials were unsuccessful.

The Marco Class V oil skimmer, supplied by the U.S. Navy, was shipped in three modules on two flatbed trucks from Oakland, California. The centre section arrived during the first week of August. The two side hulls arrived on August 20. The modules were coupled to the centre section during the morning of August 22 and the Marco Class V was in the water by noon. Field trials were carried out between August 23-25 with Alberta crude, diesel, a combination of Bunker C and diesel and finally, Bunker C only.

For each skimmer the following subject areas are discussed in this report:

- Collection Principle
- Physical Specifications
- Test Results and Discussion, and
- Comments on Design and Performance

These data have also been summarized and appear in Section 2, entitled "Principal Findings". Raw data from which factors and results have been deduced are contained in Appendix B.

2 PRINCIPAL FINDINGS

2.1 Introduction

The object of this series of tests was to determine the oil collection and operational characteristics of the two devices in a variety of environmental conditions with two or more types of oil. An ideal device would recover all the oil presented to it, pick up no water with the oil, and form no oil-and-water emulsions. Although the ideal device does not exist, its characteristics suggest parameters which may be used to quantify performance of actual skimmers:

1. Oil Recovery Factor (ORF) - the ratio of the volume of oil recovered by a device to the volume of oil presented to it, expressed as a percentage;
2. Oil Content Factor (OCF) - the ratio of the volume of recovered oil to the total volume of the recovered liquid, expressed as a percentage; and
3. Emulsification Factor (EF) - the ratio of the volume of water in the oil phase to the total volume of recovered oil, expressed as a percentage.

In addition to these non-dimensional parameters, a very practical dimensional parameter is the Oil Recovery Rate (ORR) which is the rate at which the device recovers oil, usually expressed in litres per minute (ℓ/min). These four parameters formed the basis for measuring the performance of the two oil skimmers. Unfortunately in the case of the Super Seahawk there was not sufficient oil picked up to allow quantifiable measurements to be made.

Clearly, such parameters are functions of environmental conditions as well as the amount and type of oil spilled. The condition of equipment and the skill and experience of the operators also affects performance, but the former is assumed to be, for the purposes of field testing, in good condition and operated in a competent manner. At present, a non-dimensional formulation incorporating several parameters has not been developed to describe performance, nor is it likely to be, since skimmers are not only of radically different design but also of quite different principles of operation. Non-quantitative judgments may be found in "Test Results and Discussion" and "Comments on Design and Performance" of Section 3.

2.2 Test Details

2.2.1 Super Seahawk. In order for the Super Seahawk (a sloping ramp/weir skimmer, see Figure 3) to function as an oil collection device, it must be used in conjunction with two sections of barrier. The sea trials, which were to start on August 11, were delayed, however, by one day when the crew from Bennett Pollution Controls experienced problems in assembling boom components. The booms used with the first trials in Esquimalt Harbour were Bennett 75 cm offshore barriers which were inflated to slightly above atmospheric pressure by a centrifugal blower (Hydra Air, Onan Engine BF/MS/Pilot Model Exp. 76203 BDE 263). Partial inflation was carried out while the booms were lying on the dock. They were then lifted and placed in the water by crane; some problems were experienced during this operation due to twisting or dislocating of the booms. Limited abrasive damage also occurred as the boom were dragged over the pavement of the jetty surface. Once in the water the booms were straightened out with the aid of a small boat and inflation was then completed. Almost one hour was needed to complete attachments to the plenum tube of the boom. The booms were placed in the water at 10:45 a.m. and were ready for final inflation at 12:55 p.m. During this period three men worked constantly in positions which would have been precarious had the booms been laid out in a rougher sea.

The Super Seahawk also was lifted by crane into the water. Air trapped in the collapsible cone section had to be forced out before the separation/collection cone could be lowered - the cone should be lowered before the device is placed in the water.

Connecting the boom skirts to the skimmer involved shackling two steel bars from the ends of the boom to the skimmer. Being more buoyant than the skimmer, the booms bounced around relative to the skimmer on 10-20 cm waves. This attachment was difficult and would be further hampered in <u>any</u> kind of sea. Once deployed, the barriers performed extremely well.

On August 12 the Super Seahawk was taken out and towed with booms in order to familiarize the personnel of the two tugs from the Department of National Defence with the operations. The skimmer was ballasted with 150 lbs of lead and several adjustments were made to the underwater guide plane in order to correct the towing attitude of the skimmer and to achieve a flow of oil up the ramp, over the wave grid and into the sump.

On August 15 the first proper towing tests were carried out on the Super Seahawk using two Department of National Defence tugs, WILDWOOD and BEAMSVILLE. The skimmer had a strong tendency to fishtail, with the skirts and metal arms making a zig in the end of the V-shaped configuration of booms and skimmer. The sea was flat calm. One to two vortexes formed at the intake of the skimmer. Towing speed was just under 2 knots, which was the slowest possible towing speed without losing the desired V-shape configuration of the booms.

Two tugs were used to hold the booms in the V-shape form, with one of them also towing a small scow from which oil was to be spilled. Initially, an attempt was made to secure the scow between the two tugs, but that method proved to be unsatisfactory because the configuration of the booms was altered. A second scow was secured behind the skimmer to provide a working platform for oil recovery operations and for the skimmer's hydraulic pumping systems. The extra drag of the scow reduced the fishtailing of the skimmer.

On the forward scow, from which oil was to be spilled, a SPATE pump, hoses, and drums of oil were positioned, and a plywood spillboard was constructed. On the scow towed behind the Super Seahawk were several numbered empty oil drums, a 250 gallon ullage bin, a second SPATE pump, and the Super Seahawk's own hydraulic pumping system.

Movements were directed from the LOCHINVAR, a 19 m (62 ft) oceanographic vessel, and instructions relayed by radio to the assisting tugs.

Oil was spilled from the barge or scow towed ahead of the V-configuration of the booms at a towing speed of 2 knots. It was pumped with the SPATE pump from a barrel with pumping time and volume measured. Levels of oil in the barrels were measured with a dipstick before and after pumping. Oil collected in the skimmer was to be pumped into empty drums on the recovery barge and there sampled and measured.

2.2.2 **Marco Class V.** The Marco Class V is a self-propelled skimmer operating on the principle of an endless belt of absorbent material into which oil is drawn by the forward motion of the craft and by the action of an induction pump fixed below it. It is available as a modular unit and it was this model that was examined.

The side hulls and centre section of this skimmer (Figure 1) were offloaded by naval crane at Delta Jetty, Esquimalt, and bolted together on the jetty with little difficulty, although there was some anxiety regarding the ability of the hulls to free stand in winds in excess of 20 knots during assembly. (The centres of gravity of the side hulls were either miscalculated or the tallies misplaced.) In order to effect a stable load for the forklift truck to position the side hulls for bolting to the centre section, each side hull had to be weighted at one end with 100 lbs of lead. The method of inserting the locating pins was satisfactory and offered little resistance to assembly. Because the engine is radiator cooled, all equipment could be operated without difficult while the vessel was on dry land, enabling all predeployment tests to be carried out before launching. The instruction manuals provided with the equipment under title NAVSEA 0994-LP-015-6010 and 7010 were exceptionally well written and easy to understand. The instrumentation was very readable as well and presented no difficulties.

After the vessel was prepared for operation and all the shore tests were completed, it was hoisted by crane and lowered into the water where a short familiarization period for handling was undertaken. The vessel was easy to control and maneuver after a short trial period. The pilot house was not installed, but would have been an advantage during the rainy weather which prevailed in later trials. No problems were encountered with the propulsion system. The engine noise was excessive even though the engine was covered with a sound-absorbing box. The main deck arrangement is shown in Figure 2.

After the initial run with the skimmer (in which a barrel of crude oil was spilled with negligible oil pickup), the belt-squeeze roller was found to be inoperative. Further investigation revealed that the two belt-squeeze cylinders were electrochemically sealed and were not functioning. The cylinders were removed, flushed, and soaked in oil overnight to free the cylinder rods and return springs. Although the cylinders did function after reinstallation, they will eventually require replacement. The cause of the cylinder failure was due to water in the pneumatic system and poor grade of materials in the cylinders.

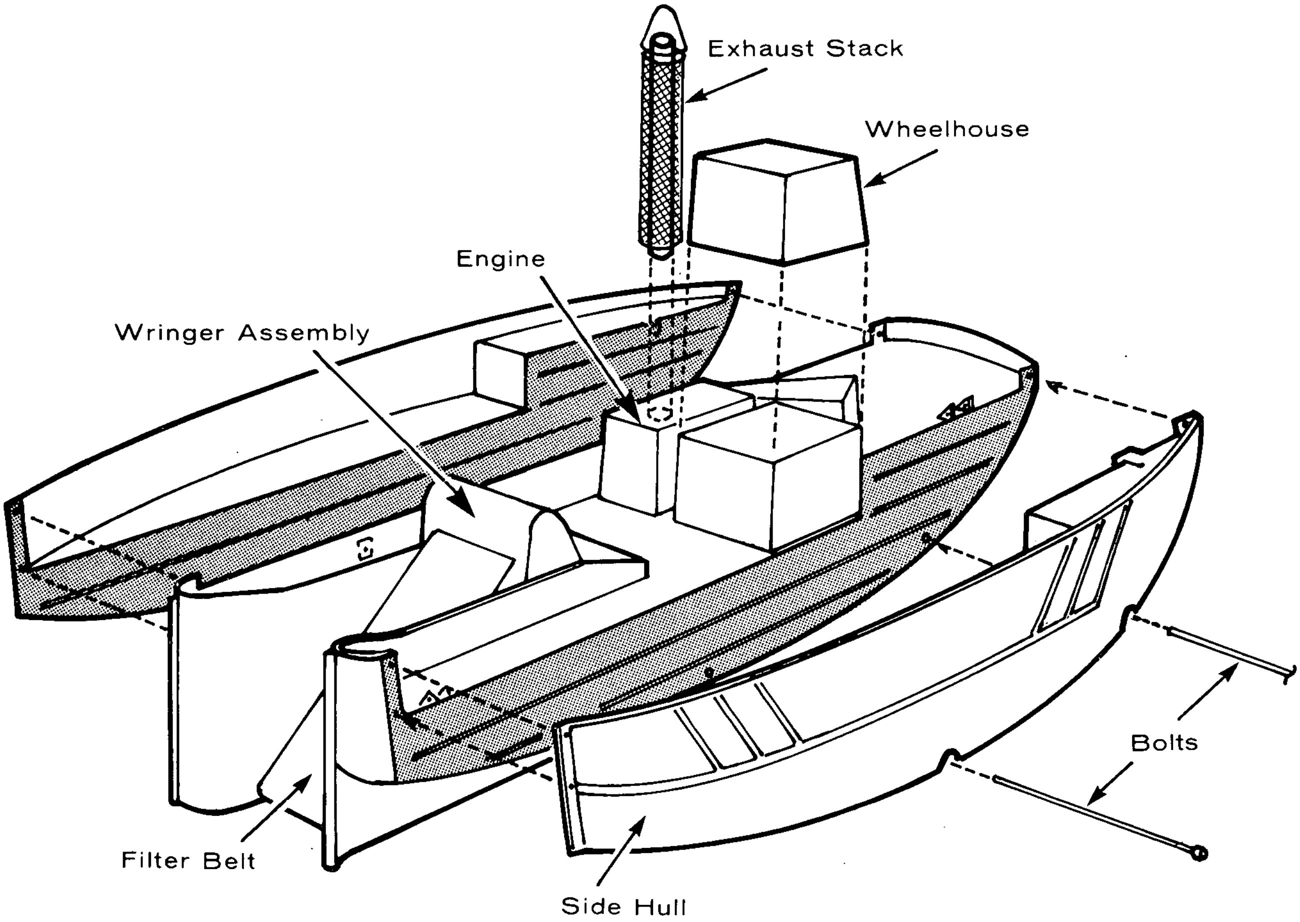


Fig.1 - MARCO CLASS V SKIMMER—Modular Transport Concept
(Dissassembly Scheme for Transport)

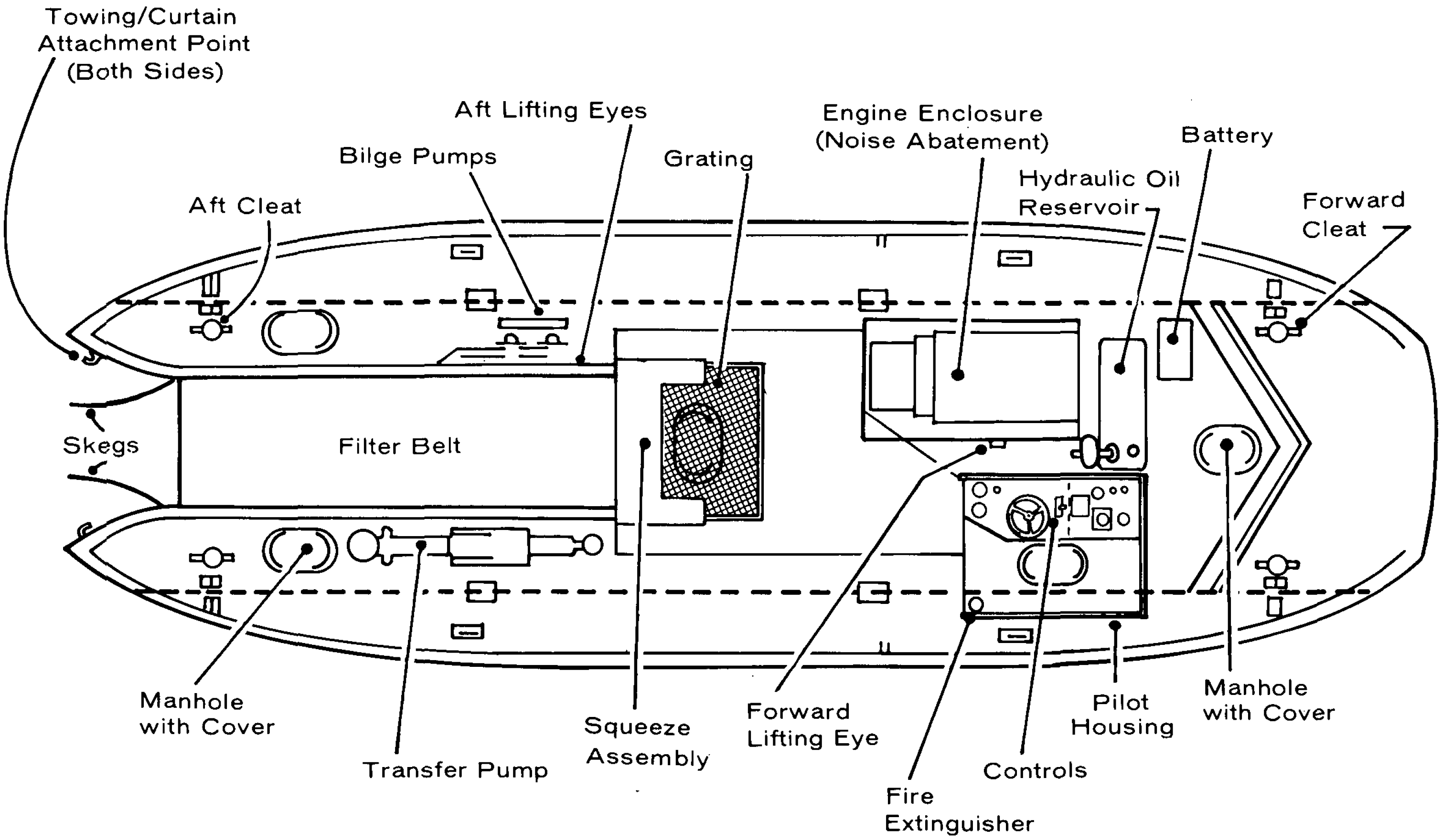


Fig.2 - MARCO CLASS V SKIMMER—Main Deck Arrangement

A new nylon belt was installed with an alligator clip seam prior to the tests. Pads were quickly installed on this belt due to the use of Velcro fasteners. Other functions of the filter-belt module were satisfactory. The raising and lowering of the module and the variation of the belt speed were performed smoothly. An aluminum cross support on the filter-belt module had broken welds when the skimmer was received and it was necessary to reweld this bar in place. In addition, a compression line in the engine compartment had to be rewelded.

Oil was spilled using a SPATE pump affixed on the port side of the skimmer. The pump drew oil from barrels positioned on both sides of the skimmer and spilled through a hose whose nozzle was lashed to a spillboard positioned between the catamaran hulls of the skimmer.

Oil collected by the skimmer was squeezed out into a 90.8 ℓ sump (24 gal) from which it was then removed by a SPATE pump secured on the starboard side of the skimmer and pumped to a set of four decanting barrels on the stern.

The level of oil was measured in the drums before and after spilling. The duration of pumping was timed to give discharge rates. In the decanting drums, oil-water level was measured with a graduated dipstick on which 'Oil-Water Level Indicator' was smeared as required. Generally, it was found to be more satisfactory to measure the total volume of liquid in the receiving barrel and then to measure the level of oil on the surface of the barrel with a graduated 1 in. diameter glass tube.

Samples were taken of the collected oil and analyses conducted to determine the degree of emulsification introduced by the skimmer.

2.3 Test Results

2.3.1 Super Seahawk. In the first trial, of the 55 ℓ (14 gal) of oil released, approximately 1 ℓ (1/4 gal) was recovered, which leads to an oil recovery factor of about 2% and an oil recovery rate of about 0.3 ℓ/min. Either because of the manner in which samples were taken or the small amount of oil collected, the emulsification factor was in excess of 40%.

In subsequent runs, attempts were made to improve the performance of the Seahawk. The small amount of oil collected prevented meaningful measurements or sample collection. At the end of the trial an overall estimate was made which showed that about 5.7 ℓ (1.5 gal) had been collected out of a total of 235 ℓ (62 gal) released. The oil recovery factor was thus around 2% to 6% depending on how much oil was assumed to remain in the skimmer cone section. The oil recovery rate never exceeded 0.5 ℓ/min and the oil water content for the days trials averaged approximately 40% water.

In its present form, the Super Seahawk is judged to have limited use as an oil recovery device. It had particular difficulty picking up thin layers of oil due to the design of the boom-skimmer connection and the intake ramp which created vortices, drawing the thin oil layer below and past the skimmer. Redesign could reduce these problems. These points are elaborated upon in Sections 3.1.3 and 3.1.4. Unfortunately, the testing of this device was considered premature.

2.3.2 Marco Class V. There are insufficient data from which to draw firm quantitative conclusions. A summary of results obtained from the tests with the three types of oil is contained in Table 1.

TABLE 1 SUMMARY OF RESULTS - MARCO CLASS V

Factor	Alberta Crude		Diesel		Bunker C	
ORR (ℓ/min)	6	(6)	5	(5)	16	(4)
OCF (%)	13	(5)	13	(5)	24	(4)
ORF (%)	61	(6)	52	(5)	82	(2)
EF (% water)	8	(5)	2	(2)	18	(3)

Bracketed quantities indicate number of samples from which average value of factor was computed.

Since there were a small number of samples taken (shown in brackets) figures were rounded off to nearest whole number unit (ℓ/min for ORR and nearest per cent for dimensionless factors). The samples were too small to yield meaningful standard deviations. These figures represent guidelines only and should not be construed as rigorous measures of Marco Class V performance. Considerable differences can be expected with amount of oil spilled, skill and experience of operating crew, and environmental conditions. The figures are indicative of the relative successes of the Marco V in picking up different types of oil.

The Marco V handles heavy Bunker C better than lighter crude and diesel. The oil recovery rate was almost a factor of three better for Bunker than it was for crude or diesel. The absolute rate (16 ℓ/min) is not impressive, but would be expected to be much higher if the Marco were operated in a thicker layer of oil. The oil recovery factor is almost 50% higher than for the other two oils and, at 80%, is considered to be very good. The Marco V emulsified Bunker C more than crude or diesel, but an emulsification factor of 18% is not considered to present serious problems. The oil collection factor was better with Bunker C than the other two oils; an OCF of 24%, however, is considered low. Clearly, the Marco V tends to collect a lot of water (about three parts water to one part Bunker) which means that extensive decanting would be needed during field operations.

Table 1 indicates that there is little difference in the performance of the Marco V in picking up Alberta crude or diesel. This is misleading since observations in the field suggested that the Marco V handled crude better. Diesel fuel was observed to surface beside and behind the Marco V. Fuel droplets could be seen rising to and then spreading over the surface. The induction pump drew some diesel through the belt, taking it down with the water flow to resurface later as described. Because the diesel runs were made after the crude runs, the diesel may have been effective in loosening the crude trapped in the belt, allowing it to be squeezed out into the sump. This would result in an apparent higher performance in the ability of the Marco to pick up diesel fuel.

The overall assessment of the Marco Class V oil skimmer is that it is an effective machine in high viscosity oils and becomes less so as viscosity decreases. It tends to pick up large amounts of water even with high viscosity oils. The amount of water picked up becomes greater with lower viscosity oils. A feature of the Marco Class V is that controls may be adjusted to suit the type of oil and environmental conditions; these include the speed of the vessel, the speed of the belt and the induction pump pressure. The drawback of the feature is that an experienced crew is needed to take advantage of such variability to achieve optimum performance for a given condition.

Additionally, it should be noted that hull interference in particular sets up at vessel speeds greater than approximately 2 knots. Vortices were observed to be shed at the prows of the hulls so that the majority of tests were conducted at relative velocities approximating 1.5 knots. This factor should be taken into account when assessing the overall capability of the Marco Class V.

3 EQUIPMENT EVALUATIONS

3.1 Super Seahawk

3.1.1 Collection Principle. The Bennett Super Seahawk is a larger version of the original Bennett Seahawk. Whereas the Seahawk was designed to operate in a fixed position in a current, the Super Seahawk was designed to be towed through the water by two booms. Oil trapped by the booms is directed over a weir and forced into an inverted cone below the water (Figure 3). The oil and water separate in the cone due to their difference in specific gravity. Oil is transferred by a hydraulic pump into an oil receiving vessel. The Super Seahawk incorporates a single weir with a wave-breaking grid which also acts as a trash rack. The purpose of the grid is to assist in the oil-water separation by reducing emulsification due to internal water movement as the unit is towed into an oil spill. The Super Seahawk is fitted with its own hydraulically driven centrifugal pump. The hydraulic power is supplied from a separate module. For the Esquimalt tests, the manufacturer incorporated an aluminum extension and foil on the front of the skimmer to enhance flow-through characteristics.

3.1.2 Specifications.

Dimensions -	Width (overall)	3.05 m (maximum)
	Length (overall)	3.05 m (maximum)
	Height (shipping)	2.40 m
	Draft (deployed)	3.25 m
	Approx. Shipping Weight (net)	1,200 kg
	Shipping Dimensions	3.05 m x 3.05 m x 2.4 m

The shipping dimensions are achieved by compacting the cone (Figure 4).

Hull Structure - The Seahawk skimmer hull is constructed of 8 mm fibreglass reinforced plastic with "glassed-in" wood reinforcements at all lead points. The hull consists of a number of fixed foamed-in-place sections and separate floodable ballast tanks. To provide additional strength a stainless steel ring is bolted around the

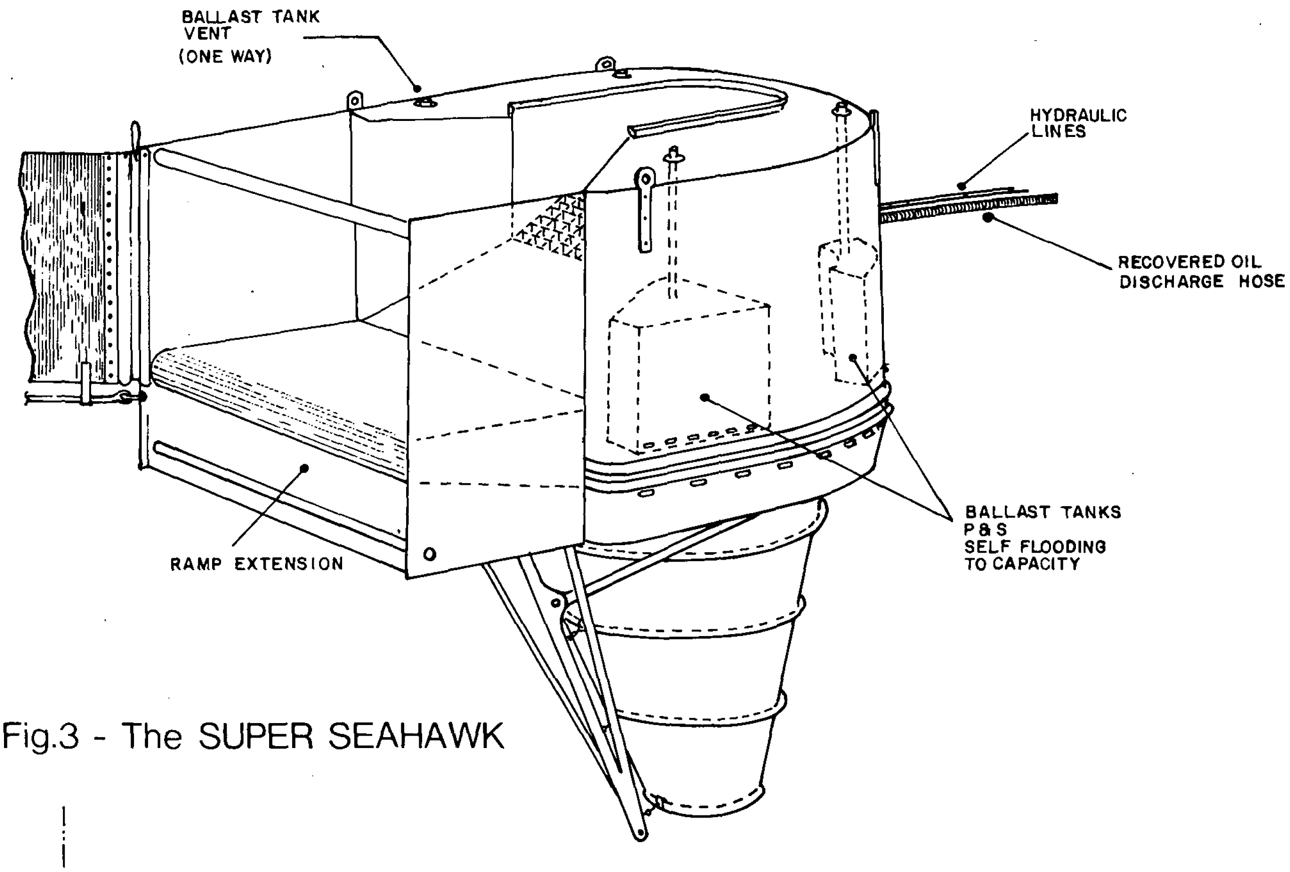
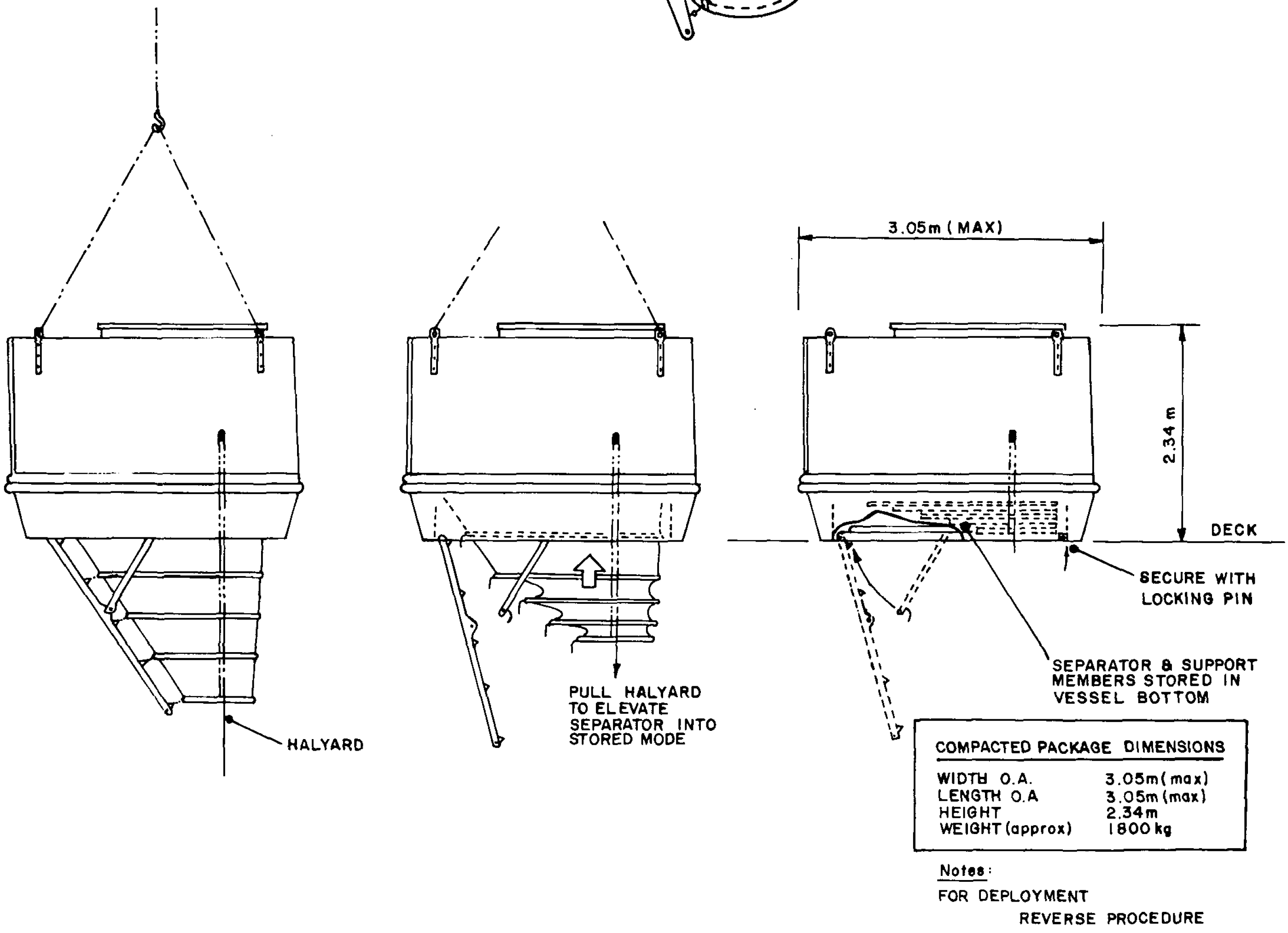


Fig.3 - The SUPER SEAHAWK



COMPACTED PACKAGE DIMENSIONS	
WIDTH O.A.	3.05m (max)
LENGTH O.A	3.05m (max)
HEIGHT	2.34m
WEIGHT (approx)	1800 kg

Notes:
FOR DEPLOYMENT
REVERSE PROCEDURE

Fig.4 - Preparation of the Super Seahawk for Shipment and/or Storage

periphery of the skimmer. This ring takes the towing and boom connection loads. Appropriate lifting and towing attachments are provided. The inside of the hull is fitted with an aluminum wave-suppression grid which assists in the oil separation and inhibits the emulsification of the oil and water in higher sea states.

Hull Auxiliary Components - The separation cone is fabricated from PVC-covered polyester fabric. It is of heat-welded construction to give greater strength and impermeability. The shape of the separation cone is maintained while under tow by nylon hoops which are secured to the support assembly.

A rubber bumper is provided around the periphery of the skimmer at the water level to minimize collision damage.

Standard Bennett boom connections are provided on the skimmer, but compatibility with booms of other manufacturers can be provided by means of adaptors.

An extension of the sloping ramp was fabricated from aluminum and secured to the forward end of the skimmer by the manufacturer prior to the Esquimalt tests. Below this structure, a narrow aluminum hydrofoil was inserted across the width of the ramp. The foil position was adjustable; it served to induce a flow of water or otherwise direct the passage of liquid towards the ramp.

Clarification of dimensions and the principle of operation is provided by Figure 8.

Pump - The Seahawk skimmer pump is a vertical-axis centrifugal pump driven by a hydraulic motor. The pump has a design capacity of 1,334 ℓ/min of water at 15 m head. The pump speed is varied by controlling the flow rate of the hydraulic pump.

Hydraulic Power Unit - The hydraulic power unit is self-contained and consists of an air-cooled diesel engine (Sundstrand). The manually controlled variable volume pump is directly connected to the engine, hydraulic oil and diesel oil storage tanks to provide continuous operation in excess of 18 hours. Hoses and valves are provided with the unit. The entire package, mounted on a single bedplate, has the following dimensions:

Length	4.6 m
Width	2.3 m
Height	2.3 m
Weight	5,400 kg

3.1.3 Test Results and Discussion. The first test run was aborted by a mass of kelp which entered the mouth of the boom configuration and had to be cleared by an attendant skiff. This clearing of debris took 30 minutes.

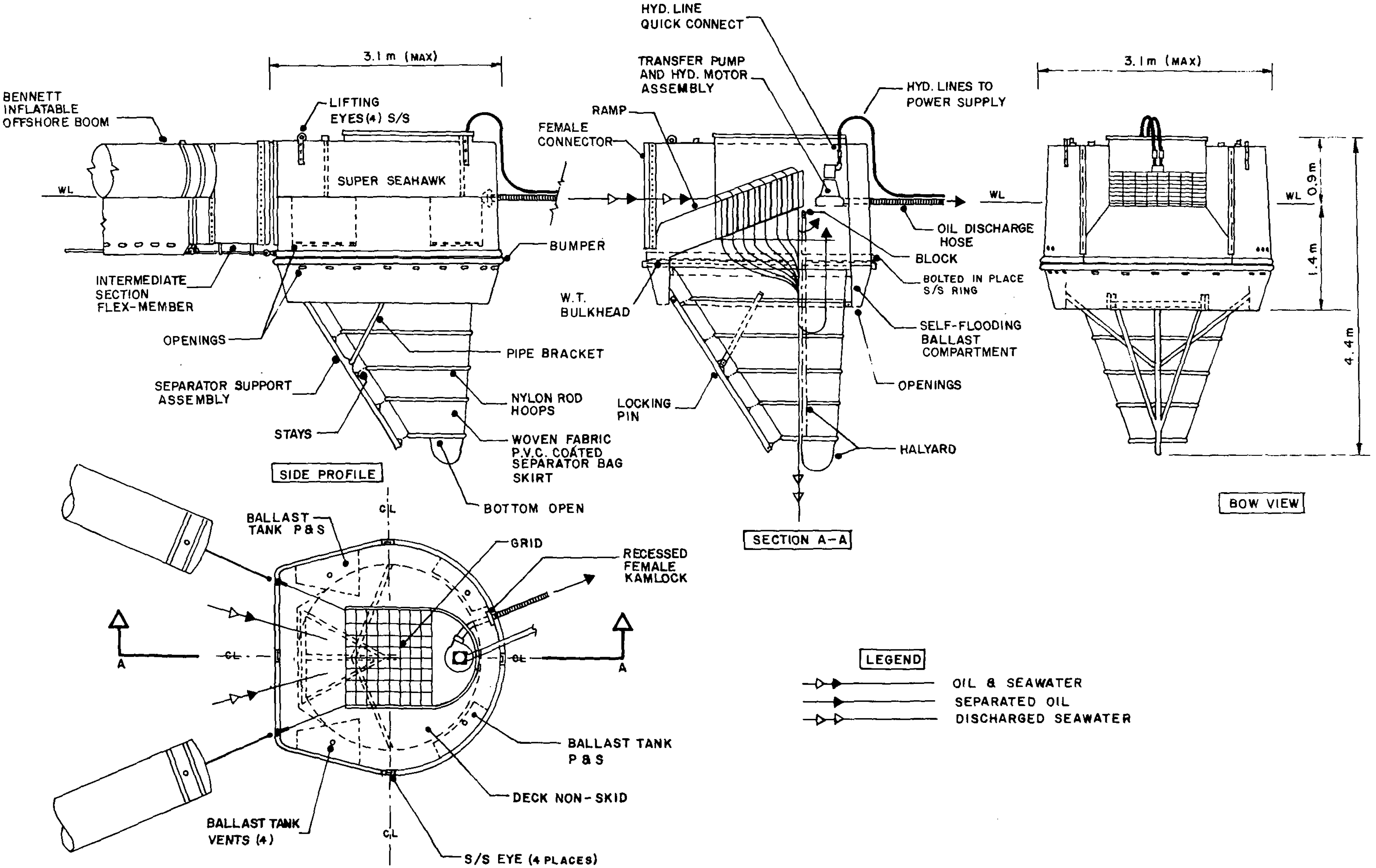


Fig.5 - Details of SUPER SEAHAWK

The first trial occurred at 11:50 on August 16 when 55 ℓ (about one-third barrel) of Alberta crude was spilled. Air temperature was 19°C and water temperature about 9°C. The wind was blowing at 4 knots and there was a significant wave height of 10 cm. The oil was released at a rate of about 57 ℓ (15 gal) per minute. Towing speed was just under 2 knots. In this run, the oil released went off towards the port boom so that some oil might have been missed entirely by the boom system.

Oil was also lost to the stern of the barge behind the skimmer, resulting in the sea surface acquiring a continuous rainbow sheen coloured with thicker brown patches. Oil appeared on the surface of the water halfway down each side of the barge and a few metres behind. Rather little of the spilled oil found its way up the metal ramp and into the sump of the skimmer. Paired vortices forming in the mouth of the skimmer, created by catenaries in the skirt-to-boom-to-skimmer configuration, appeared to be sucking oil down and past the skimmer itself.

From this test spill, four millimetres of oil (less than 1 ℓ) were collected in the sump, or about 6% of the oil spilled.

The vortex theory was tested by towing the skimmer at the same speed and ballasting, and by spilling 2 gallons of oil directly onto the metal ramp of the skimmer's weir. Some of this oil was drawn back by vortices and lost, but not more than 1 litre. When the oil went into the skimmer's sump, towing was continued at the same speed and no oil was observed lost. Therefore, the skimmer did not lose oil out of the bottom of the collapsible cone.

At 13:45 hours, August 15, a third experimental spill was carried out, again at a towing speed of about 2 knots.

A volume of 170 ℓ (45 gal) of Alberta crude was pumped out in 12 minutes. Visual observations inferred that almost all of this oil went into the boom configuration, but very little was collected by the skimmer. A 400-metre long slick formed behind the pickup barge, with most of the spilled oil being lost. The area was repeatedly swept by the booms and skimmer, but little oil was recovered.

At the end of the day the oil collected in the sump was recovered by pumping and bailing and put into open-top standard (44 gal) barrels. Oil-water levels were then measured with a graduated glass tube.

About 5.7 ℓ (1.5 gal) had been collected by the skimmer. Some small amounts of oil remained in the skimmer after collection, but did not exceed 7 ℓ (less than 2 gal). Therefore, on the first day of testing about 5% [235 ℓ (62 gal)] of the spilled oil was recovered by the Super Seahawk.

Because of poor performance in pickup, it was decided that further oil would not be spilled in Super Seahawk tests.

3.1.4 Comments on Design and Performance. The most effective action causing small floating objects, and presumably oil, to move over the weir was that of a slight chop which tended to slosh objects into the sump or over the debris grating.

Small floating objects tended to remain for several seconds in the mouth of the skimmer, even at towing speed, due to the action of the previously mentioned vortices.

Further towing trials were carried out with the Super Seahawk and the 1.6-metre diameter Viking boom. Observations from the Super Seahawk itself showed that at operable speeds (around 2 knots and less) correct ballasting could produce water flow up and over the metal ramp and weir, but at such speeds the device demonstrated a tendency to nose under the water.

During an actual spill situation, the skimmer would have to be manned in order to clear the grating of debris, and if not manned, would require tending. The working platform is quite inadequate for this purpose and should be widened, fitted with safety railings and non-slip decking, preferrably a grating. Although not a design consideration, facilities to allow for the manhandling of debris should be considered for the skimmer, particularly in view of the focussing effect of the booms on flotsam.

The deployment of the boom and towing rigging was awkward. The booms should be deployed and made ready to receive the Seahawk before the skimmer is offloaded from the delivery vehicle and lowered into the water.

Further design effort is needed to develop a method of attachment of the skimmer to the booms. The lifting eyes, although apparently secured for safety purposes, pulled away from the fibreglass body of the skimmer. Unfortunately, the deployment and operation of this device was undertaken for the first time by the manufacturer and the absence of previous experience led to the shakedown of the Super Seahawk taking place coincident with its evaluation.

All involved conceded that the trials on this equipment were premature. If the manufacturer considers redesign, his attention, it is felt, should be drawn to reworking the entrance ramp, the trash rack and the overall shape of the device. The trials showed that this vehicle was not designed for speeds in excess of one-half knot and at such velocities the hydroplane device does not react sufficiently to cause trim variation.

Two final comments illustrate some of the basic design difficulties. The fishtailing of the Super Seahawk was not unexpected since any cylindrical object placed in a uniform flow sheds alternating eddies (vortex street). Proper hydrodynamic design could eliminate this problem. The vortices at the mouth of the skimmer resulted from a design which allowed expansion of the flow before reaching the weir. If the flow had been continuously channelled along contracting side walls, vortices would not have resulted. Again, proper hydrodynamic design could have prevented this problem.

3.2 Marco Class V

3.2.1 Collection Principle. The Marco Class V is a self-propelled, aluminum, 11 m (36 ft) oil skimming device which can maneuver either under its own power into an oil slick or be towed by tugs with deployed booms secured to the filter-belt end of the unit (see Figure 6). There is some confusion in assigning forward and aft with the Marco Class V since forward in the towing mode is opposite to forward in the skimming mode. Figure 7 serves to define the four points of the Marco Class V in order to clarify subsequent discussion.

The belt theoretically captures any oil from the water. The filter belt is made of reticulated polyutherane foam with cell dimensions averaging three to five pores per linear centimetre. Both oil and water flow onto the belt at the same rate and the separation of oil from the water occurs due to the oil-holding characteristics of the belt. An induction pump installed in the well of the vessel maintains a well water level less than that of the outside sea surface and causes the water to be drawn through this pump back to sea. The oil and water retained on and in the belt is then squeezed by a pneumatically driven roller from the filter belt and enters the sump through an opening provided directly below the drive and squeeze rollers. An offloading pump is then used to draw the water from under the oil in the sump and decant it into the pickup well in front of the filter belt. The water may also be recirculated through the total system. The recovered oil and oil-water emulsion in the tanks are subsequently pumped and decanted into a separate disposal vessel. The filter-belt principle of operation is schematically illustrated in Figure 8.

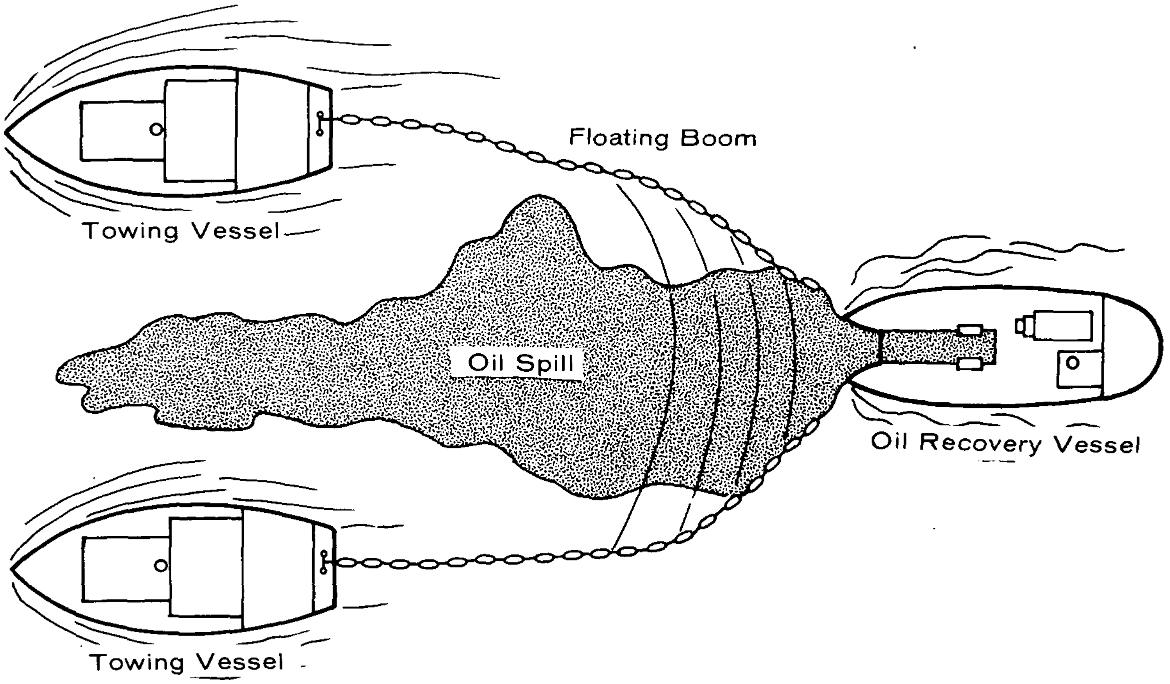
3.2.2 Specifications.

Dimensions -

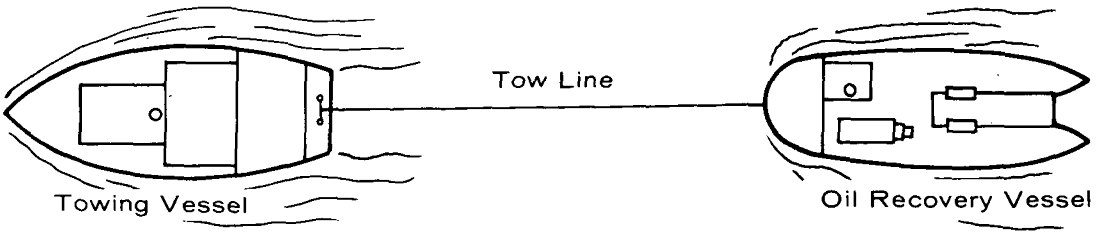
Length (overall)	10.97 m
Beam (overall)	3.66 m
Depth (midship)	1.55 m
Draft (full load)	1.27 m
Height (overall)	5.18 m
Height (pilot house top removed)	2.72 m
Displacement (light ship)	7,847.3 kg
Displacement (full load)	17,145.1 kg
Fuel Oil Capacity	18.5 ℓ
Hydraulic Oil Capacity	19.8 ℓ
Sump Tank Capacity	6,665 ℓ (40 bbl U.S.)
Induction Pump	12,000 joules/sec (16 hp)

Machinery -

Main Engine	Detroit Diesel Engine 4-53 74,600 joules/sec (100 hp) @ 2400 rpm
Speed (Fwd.)	2.6 m/s (5 knots)
Speed (Astern)	1.5 m/s (3 knots)
Main Propulsion Unit	Marco T-40 Thruster; full 360° rotation of thruster provides propulsion and steerage (Figure 9)



(a) MARCO CLASS V Oil Recovery Vessel Towed for Oil Recovery



(b) MARCO CLASS V Oil Recovery Vessel under Tow

Fig.6 - MARCO CLASS V in Pickup and Towing Modes

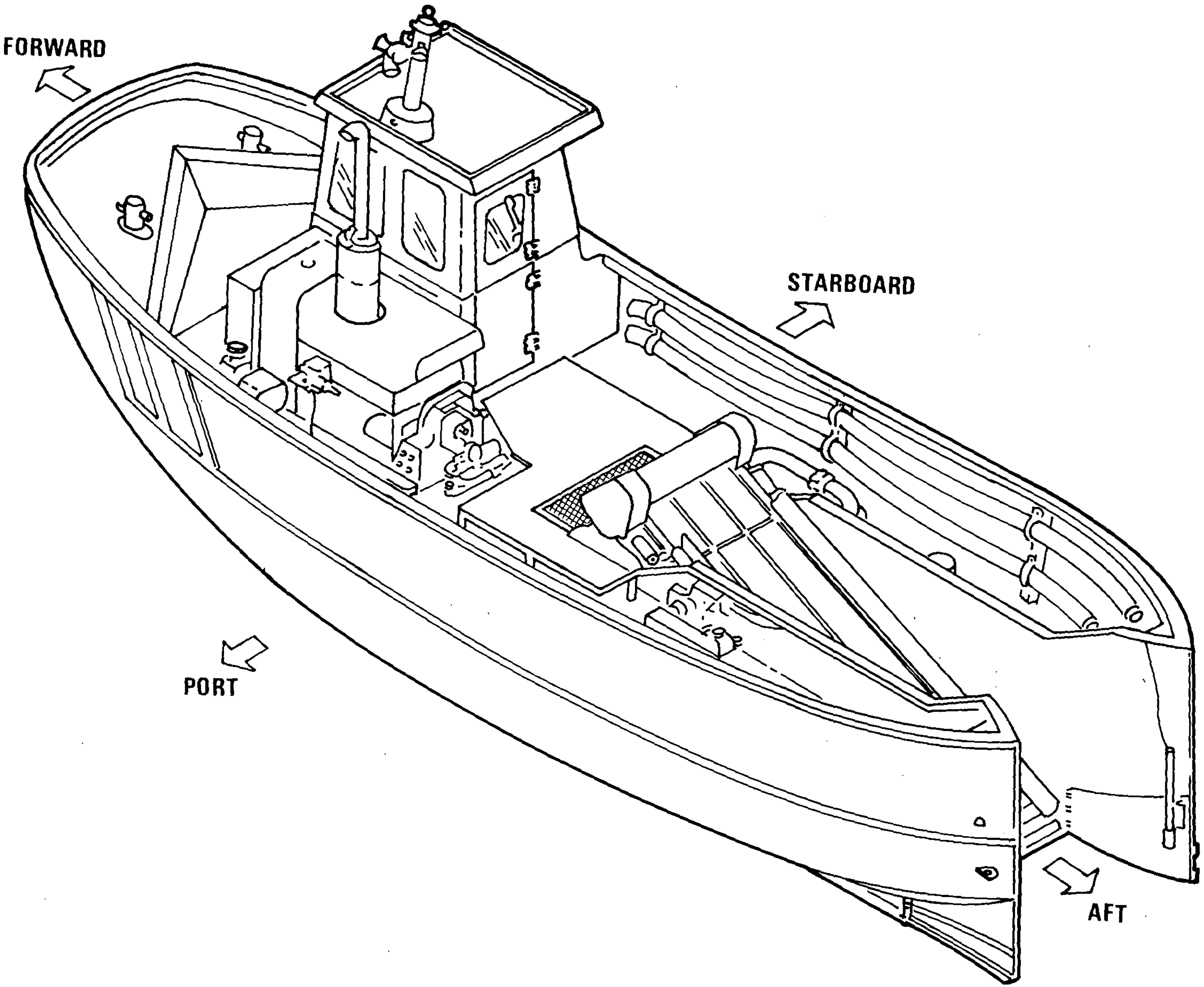


Fig.7 - MARCO CLASS V̲ SKIMMER—Operating Configuration

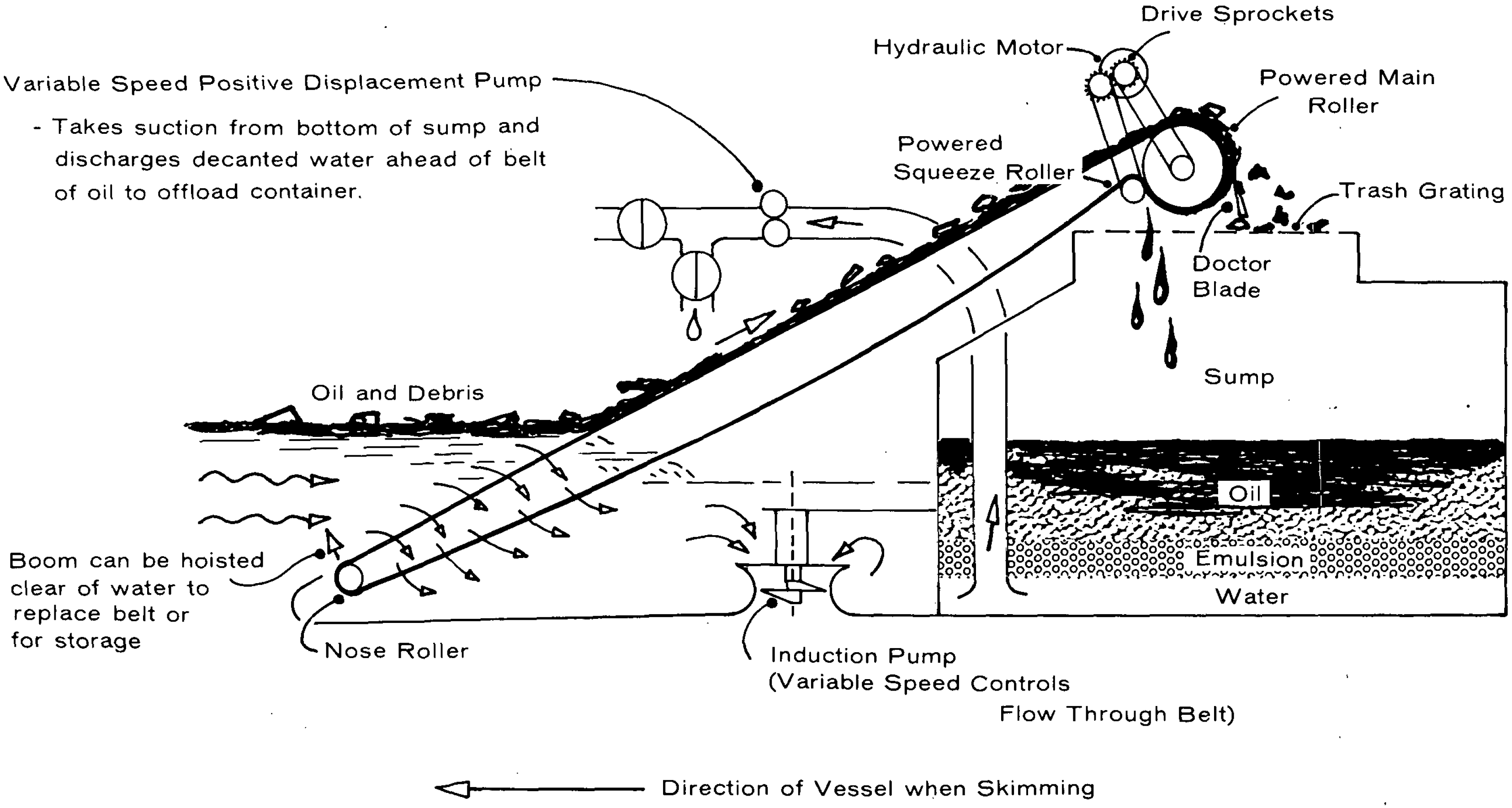


Fig.8 - Filter-belt Principle of Operation

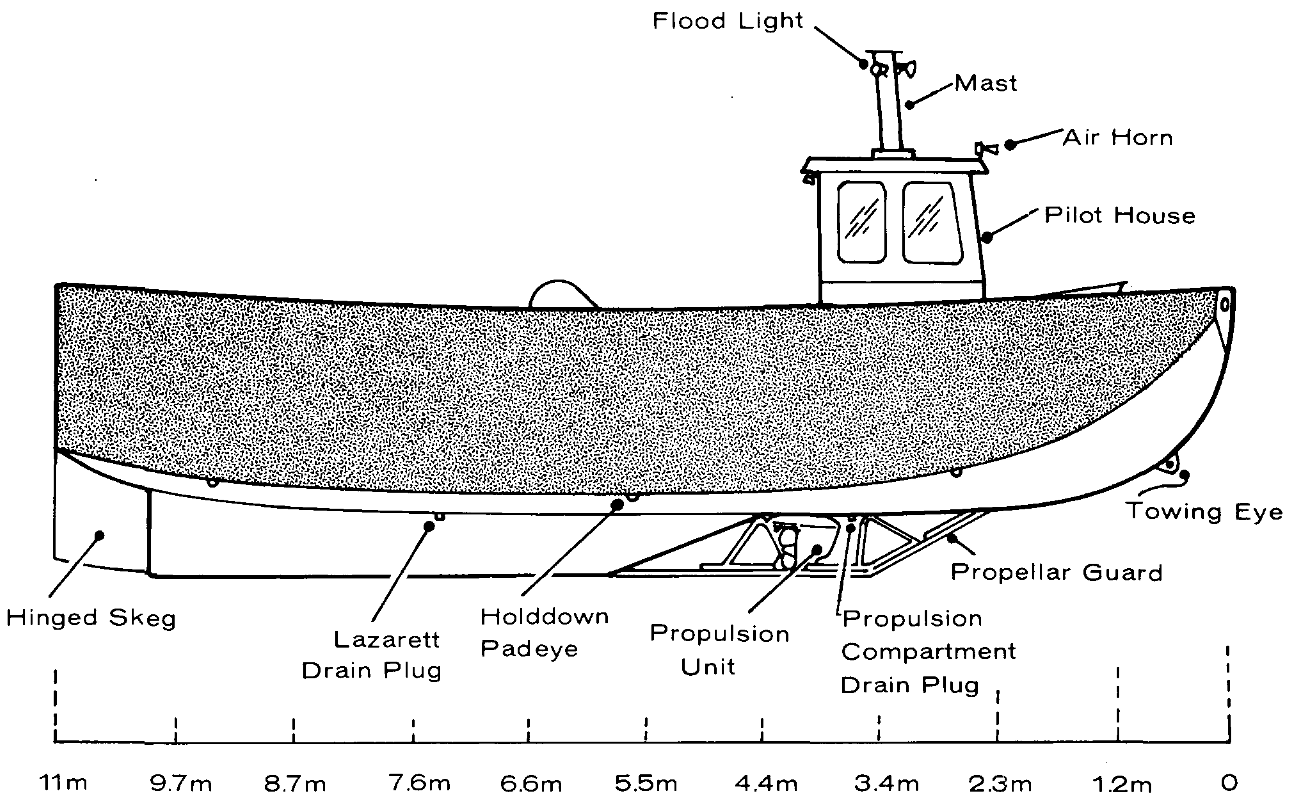


Fig.9 - MARCO SKIMMER—Outboard Profile

Equipment -

Oil Transfer Pumps	One 12.7 cm (5" Midland progressive cavity pump rated 12.6 ℓ/s (200 gpm) @ 41.3 kilopascals (60 psi); One Marco U101 10.2 cm (4") submersible trash pump rated 25.2 ℓ/s (400 gpm) @ 206.8 kilopascals (30 psi)
Fluid Power Supply	Marco 3-hole 1:1 geared hydraulic pump drive with 5 hydraulic pumps
Air Power Supply	Engine-driven .0035 m^3/s (7.5 CFM) air compressor
"Filterbelt" Module	Hydraulically driven .91 m (3 ft) wide belt unit; pneumatically actuated squeeze roller
"Filterbelt" (for light oils)	One .91 m x 9.04 m x 2.54 cm (36" x 29' 8" x 1") belt
"Bunkerbelt" (for heavy oils)	One .91 m x 9.04 m x .32 cm (36" x 29' 8" x 1/8") belt

3.2.3 Test Results and Discussion. In the case of the Marco V tests, there was a limited range of environmental conditions and, due to the time available, an insufficient variation of parameter range (such as vessel speed, belt speed, sea state, induction pump pressure) to allow for the construction of comprehensive plots of oil recovery performance. Although considerable scatter is evident in the data, this does not negate results - it simply requires that caution temper conclusions. A summary of the Marco V tests is presented in Table 2, which forms the basis for the plots presented. The figures for columns A, B and C were calculated from the test record in Appendix B. The emulsification factor was computed from the centrifuge results contained in Appendix C.

The oil recovery rate (ORR) as a function of vessel speed (Figure 10) and three other parameters suggest that best results are obtained at a speed between 1 and 1.5 knots and an induction pump pressure of 1,723 kilopascals (250 psi). A belt speed setting of 3 (66 cm/sec) was preferable to a belt speed setting of 2 (41 cm/sec). The three lowest ORR values at 1 knot were due to the installation of a new belt which was not saturated during those runs. The six upper values for the crude trials then are more indicative of the expected ORR for the Marco V. Even the highest value obtained (approx. 7 ℓ/min) is more than an order of magnitude less than the ORR claimed (Figure 11). The best ORR was obtained on August 25 with a mixture of diesel and Bunker C. Almost 25 ℓ/min was obtained at a belt speed setting of 2.5 (Figure 12). This is still considerably less than the advertised ORR of about 400 ℓ/min for this belt speed and oil viscosity. However, the manufacturer's figure is probably high since in 67 tests carried out at a belt speed setting of 3, Mason and Hanger (1977) obtained an average ORR of 105 ℓ/min with a standard deviation of 40 ℓ/min.

TABLE 2 SUMMARY OF MARCO CLASS V RESULTS - AUGUST 1977

Date August	Run No.	Test Oil	Belt Speed (m/s)	Forward Speed (m/s)	A Oil Spilled (ℓ)	B Liq. Coll. (ℓ)	C Oil Coll. (ℓ)	ORF C/A (%)	OCF C/B (%)	EF (%) Water	ORR (ℓ/min)	Comments
22	1	CR	0.66	1.04	-	-	-	-	-	41 B	-	No pressure to squeeze roller
23	1	CR	0.41	1.10	55	-	7	13	-	7 B	3.5	Overcast, rain, sea calm
	2	CR	0.66	1.01	16	76	5	31	7	7 B	5.0	Stationary cylinder bracket
	3	CR	0.66	0.64	77	143	43	56	30	3 B	10.8	Required gusset stiffner
	4	CR	0.66	0.58	50	199	23	46	12	1 B	2.3	Rain
	5	CR	0.66	0.61	32	64	-	-	-	No data	-	No EF to compute C; light swell, rain
24	1	CR	0.41	0.52	14	34	1	7	3	13 B	0.3	New belt and pad installed
	2	CR	0.41	0.55	18	39	2	11	5	4 B	0.5	Rain, light wind, sea calm
	3	CR	0.41	0.46	22	34	8	36	24	4 S	1.6	
	4	CR	0.66	0.55	17	219	16	94	7	28 S	5.2	10 cm to 40 cm wide slick to belt
		CR								9 B		
	5	CR	0.66	0.55	18	140	17	94	12	15 B	4.3	
	6	CR	0.66	0.44	20	172	16	80	9	34 S	4.0	Overcast, sea calm
	7	D	0.66	0.44	10	135	7	70	5	46 S	3.5	
	8	D	0.66	0.44	29	108	12	41	11	33 S	3.0	
	9	D	0.66	0.55	20	118	11	55	9	33 S	2.8	
										2 B		
	10	D	0.66	0.55	77	165	27	35	16	31 S	6.8	Valve on oil pump opened wider
										1 B		
25 AM	1	D+F	0.41	0.55	44	120	23	52	19	31 S	7.7	Rain, overcast, light wind
		D+F								1 B		
	2	D+F	0.66	0.58	34	49	13	38	27	2 S	4.3	
		D+F								2 B		
	3	D	0.54	0.58	64	157	37	58	24	21 S	9.3	
		D								1 B		
	4	D+B	0.54	0.55	86	160	69	80	43	27 S	34.5	Residual diesel in belt; sump overflowed, 2.5 cm oil lost
		D+B								19 B		
25 PM	5	B+D	0.54	0.55	18	103	15	83	15	23 S	7.5	
		B+D								17 B		
	6	B	0.54	0.55	14	96	21	150*	22	24 S	10.5	Scrapper blade removing much oil
										17 B		
	7	B	0.54	0.55	25	243	35	140*	14	19 S	11.7	

Note: Under EF, the letter following the percentage indicated whether the sample was taken from the sump (S) or the collection barrel (B)

CR = Crude
D = Diesel
B = Bunker
F = Fluorescence Dye

*Anomalous result (more oil collected than spilled); see text for explanation

+ 1 metre/second = 1.942 knots

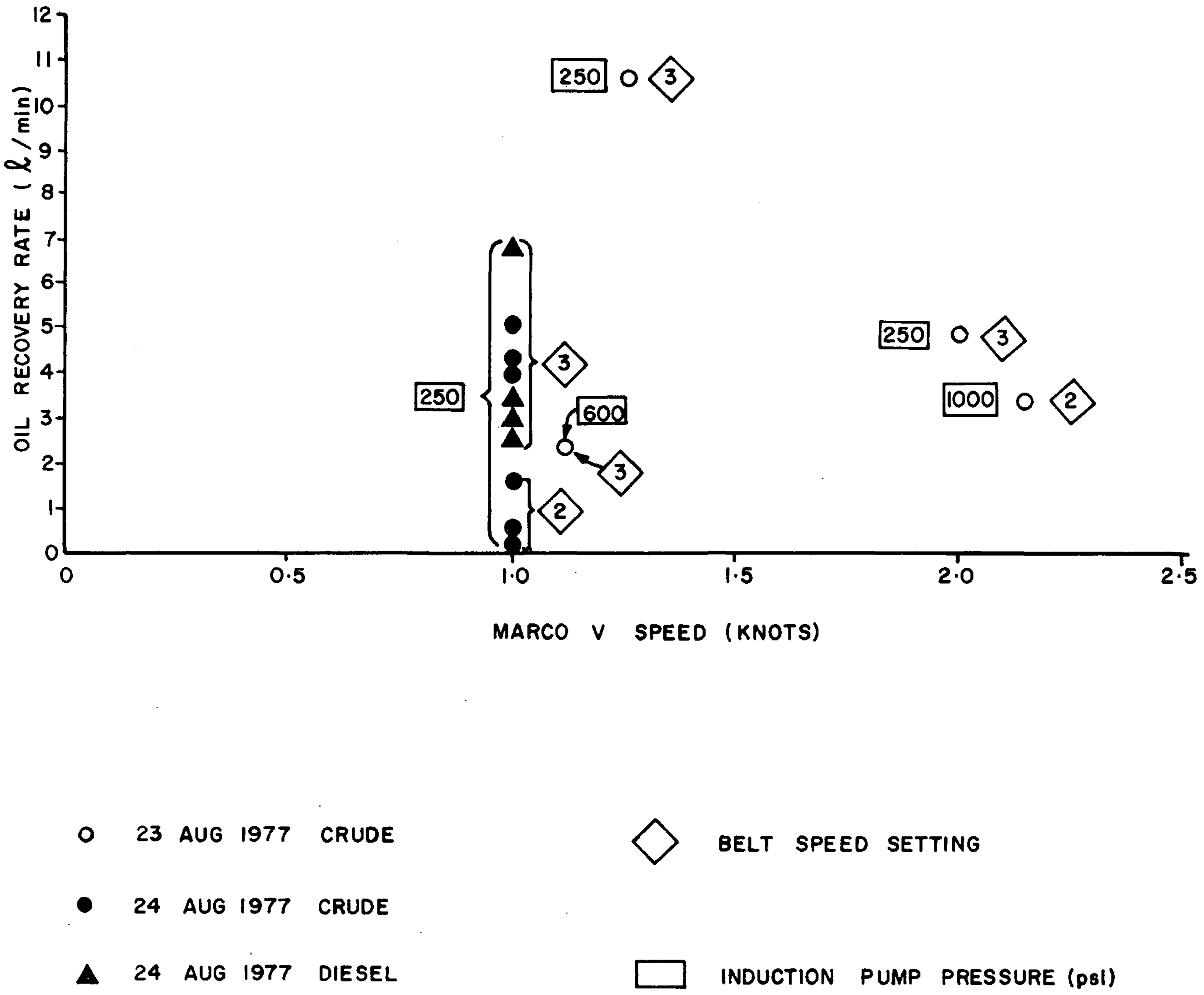


Fig.10 - Oil Recovery Rate versus MARCO CLASS $\underline{V}$ Speed

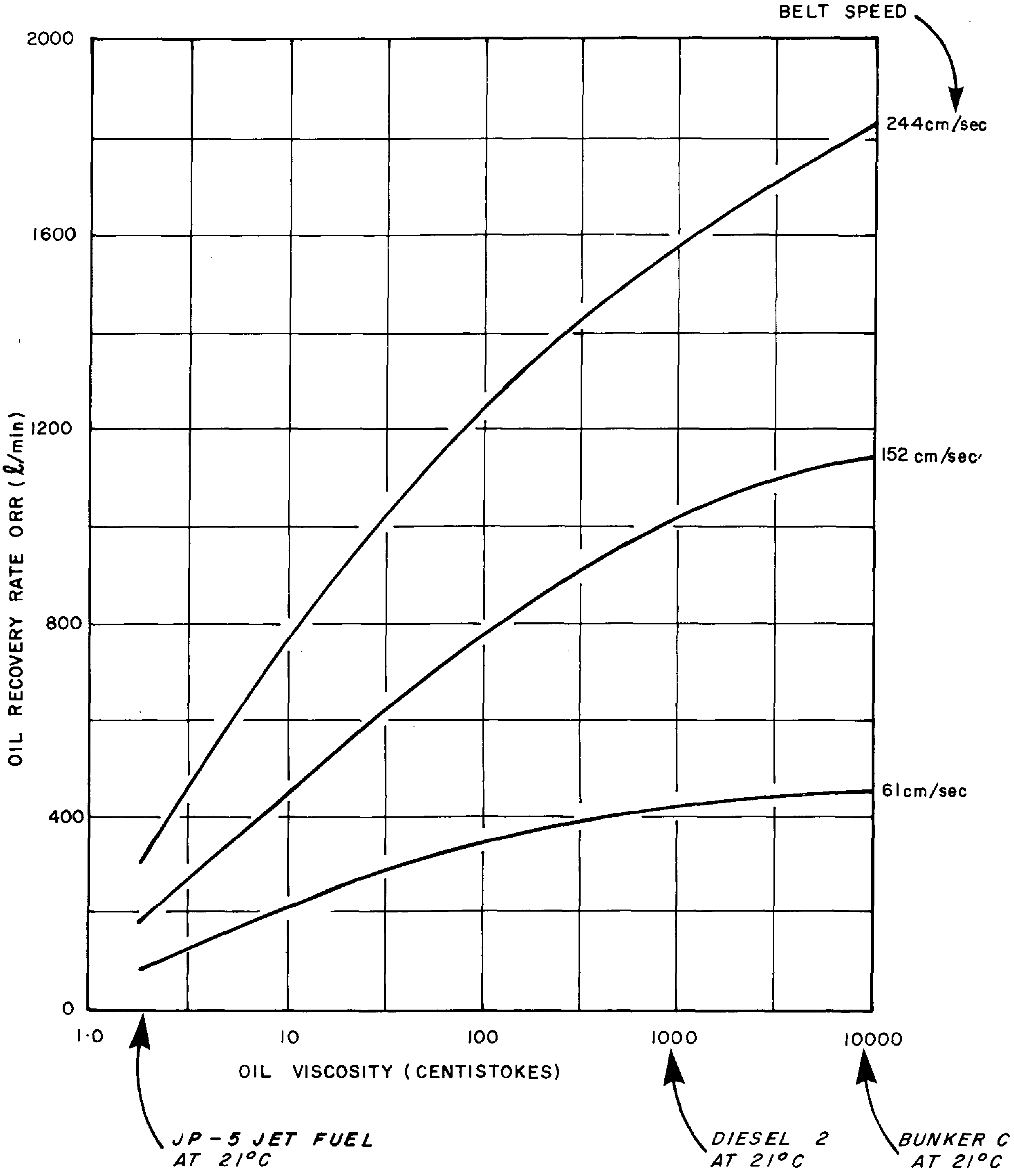
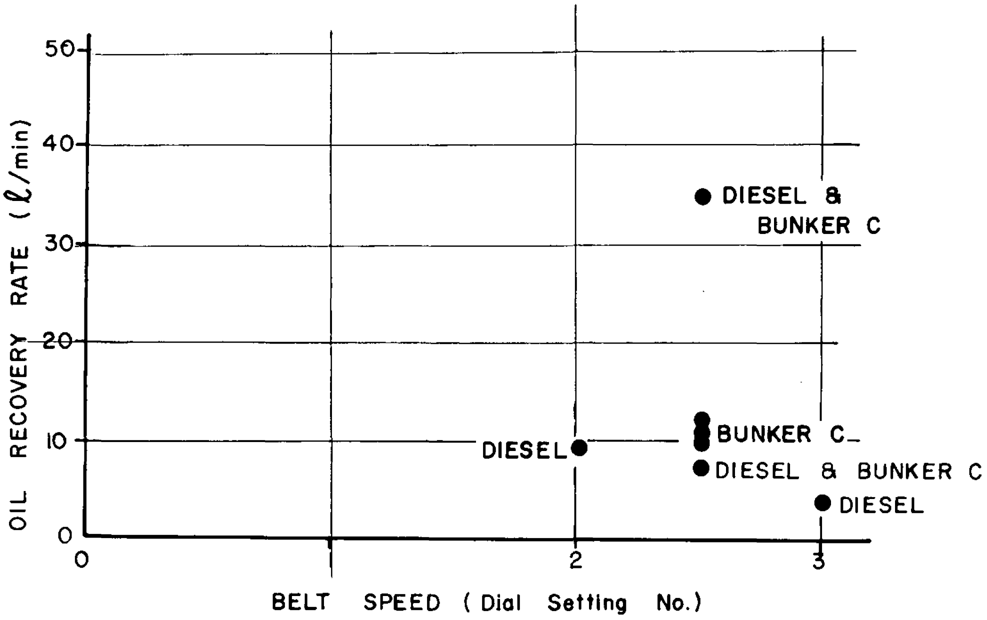


Fig.11 - Oil Recovery Rate for 0.91 m (3ft) Wide Belt for MARCO CLASS V
(Manufacturer's Literature)



25 AUGUST 1977

INDUCTION PUMP PRESSURE OF 250 psi

Fig.12 - Oil Recovery Rate versus Belt Speed Setting

During the trials concern was expressed that less than optimum performance would be achieved with the Marco V because of the limited amounts of oil deployed. In an attempt to test the validity of this concern, a plot of ORR, the oil recovery factor (ORF) and the oil collection factor (OCF) were plotted as a function of oil spilled (Figure 12). With the exception of five large ORF values (>50%) between 10 and 20 ℓ of oil spilled, there is a weakly defined trend indicating improving performance with increasing amounts of oil spilled.

Initially during the trials (August 22-24) oil samples were taken from the collection barrels. Since additional emulsification can be expected due to the action of the SPATE pump which takes the collected oil-water mix from the Marco sump to the collection barrels, a series of dual samples from sump and barrel were collected during the August 25 trials. A histogram of the emulsification factor (EF) was constructed with a class interval of 4% (Figure 14) which clearly shows that there is a systematic difference in the EF's of the two sampling methods. The sump samples have a greater proportion of water. This is believed to be due to the difficulty of collecting sump samples without including water. Regardless of the cause, the method of collecting samples is important and for consistency in future tests, a standardized sampling method should be devised.

Two cases demonstrate some of the problems involved in measuring the relative amounts of oil and liquid collected. The initial measurement of the oil collected immediately at the completion of Run 4 on August 24 indicated that more oil had been collected than spilled. A relatively large volume of liquid (219 ℓ) had been collected and appreciable emulsification had occurred (EF = 28%). Approximately four hours later, the measurement of oil collected was repeated and a much thinner oil layer was found. The difference in volume collected amounted to 10 ℓ. Measurements taken after each of the last two runs with Bunker C (August 25, Runs 6 and 7) also indicated more oil collected than spilled (ORF >100%). In this case Bunker adhering to the belt from previous runs was squeezed and scraped into the collection system during these runs. Even after the emulsification factor correction was made, the anomalous results remained, but can probably be best explained in terms of the migration of lighter ends residual in the belt which were drawn off along with the Bunker test medium.

3.2.4 Comments on Design and Performance. The head end of the filter belt was found to be fabricated of many types of dissimilar metals, some not suitable for a marine atmosphere. The pulley drive chain was plain steel, as were several other components. The aluminum block components were pitted and not marine aluminum or anodized.

The rigid cylinder supports require gusset stiffeners to eliminate bending of brackets under pressure. The fibreglass safety covers over the working components are secured on the aluminum head assembly with slotted round-head screws which are very difficult to remove. The screwdriver slots do not allow sufficient torque to be placed on the screws which bind into the aluminum. Cap screws for this purpose would be preferable.

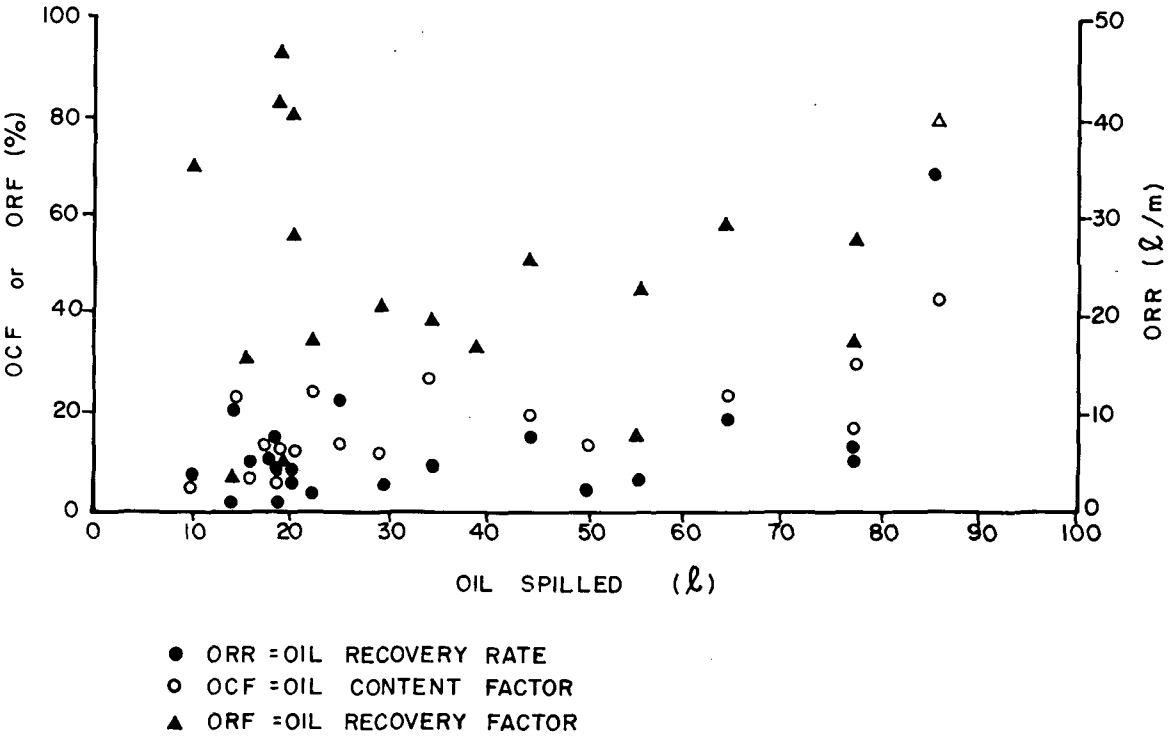


Fig.13 - Oil Recovery Factors versus Amount of Oil Spilled

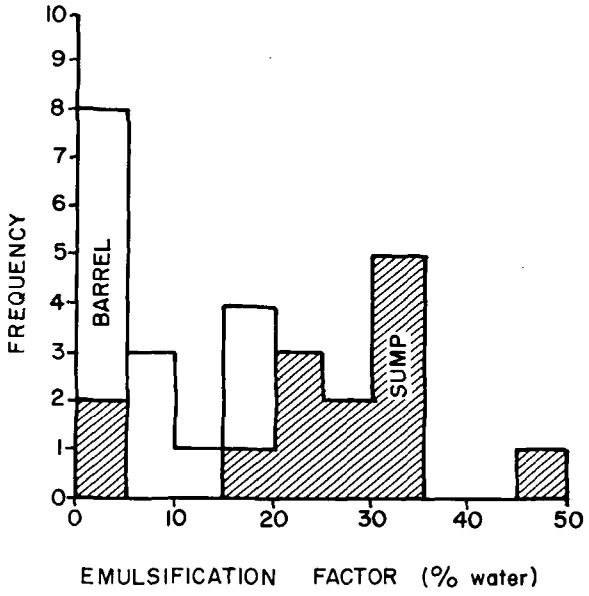


Fig.14 - Histogram of Emulsification Factor as Determined from Barrel and Sump Samples

Hardly any oil was recovered during the first few test spills because the pistons, which compressed the squeezer arm, were not functioning due to internal corrosion. As this malfunction was not obvious, only a trained operator would have noticed it. The problem clearly demonstrated that the Marco V is a device which requires an experienced crew for operation and maintenance.

The filter belt was well designed. An alligator clip seam aided the installation of a new nylon belt. Pads were installed on this belt in less than 30 minutes due, in large part, to the use of Velcro fasteners. The raising and lowering of the module and the variation of the belt speed were carried out smoothly and easily.

As mentioned in Section 2.2.2, an aluminum cross support on the filter-belt module had broken welds when the skimmer was received; rewelding was necessary.

The engine noise was excessive although the engine was covered with a sound-absorbing box. The majority of the noise emanated from the exhaust stack; a more efficient exhaust silencer would reduce the noise to an acceptable (health) level.

While the unit was in self-propulsion or in tow, the hull was stable in the water. A threaded nipple on the diesel engine compressor system was received broken and repaired on site. The phenolic retaining blocks locking the door skegs in the "open" position proved to be inadequate, shifting with any vibration at sea and thereby allowing the skegs to open and close without control. The skegs had to be secured in the "open" position.

In common with all oil recovery devices, the decks of the vehicle became treachrously slippery as the operation proceeded. Either the type of decking used in the area of the belt squeezer should be incorporated throughout the whole vehicle, or precut plywood sheets should be used on the side decks and the crew required to wear caulk boots. The plywood deckings could be disposed of at the end of each operating day or when worn out.

The design of vessel layout was satisfactory and, with the exception of the choice of metals in the pinch roller cylinder, the Marco Class V was well constructed. The controls and maneuverability of this skimmer were also satisfactory. Redesign of the prows of the hulls could be considered for improved skimming performance at higher speeds.

APPENDIX A

ENVIRONMENTAL SETTING

APPENDIX A ENVIRONMENTAL SETTING

1 GENERAL

The trials were carried out near and in Esquimalt Harbour, which comprises for the most part a Department of National Defence naval base near Victoria, British Columbia (Figure 15). Deployment and operations were staged at D-jetty on the Colwood site of the harbour.

During familiarization trials, skimmers, booms and tugs were operated within the harbour. During actual test runs (oil spilled) equipment was operated just outside the entrance to the harbour.

Clear skies, hot weather and calm seas prevailed during the first week of testing. Considerably cooler weather with some rain occurred during the second week. Sea conditions featured a slight chop (10-20 cm) and a slight swell (30 cm, 4 sec period) during one day. Weather information during specific trials is contained in Appendix B.

Sea surface temperatures (SST) inside the harbour were about 14°C. Outside the SST fell to about 10°C. The gradient occurred across the entrance to the harbour. Air temperatures ranged from 12 to 22°C.

Some kelp (primarily macrocystis) and wood debris, although not widely distributed, were commonly encountered.

1.1 Equipment

To be made operative, the Super Seahawk required auxiliary equipment. Oil containment booms were attached to the skimmer with the skimmer forming the apex of a "V". Each boom was pulled by a single tug.

The LOCHINVAR, an 18.9 m (62 ft) oceanographic vessel (RCN diving class) served as the coordinating vessel for the sea operations.

The Marco Class V was self-contained during field trials, but was towed to and from test areas by tug.

Loading and unloading of skimmers, oil drums, pump etc. was carried out by a variety of portable cranes operated by DND personnel. With the exception of the LOCHINVAR, all sea support was supplied by DND through the Queens Harbourmaster.

1.2 Temperature Measurements

Separate thermometers were used for air and sea surface temperatures: an electronic thermometer (quartz sensor) and a telethermometer (thermistor sensor) respectively. A calibration check with a precision thermometer showed that the electronic thermometer tended to read low (Table 3).

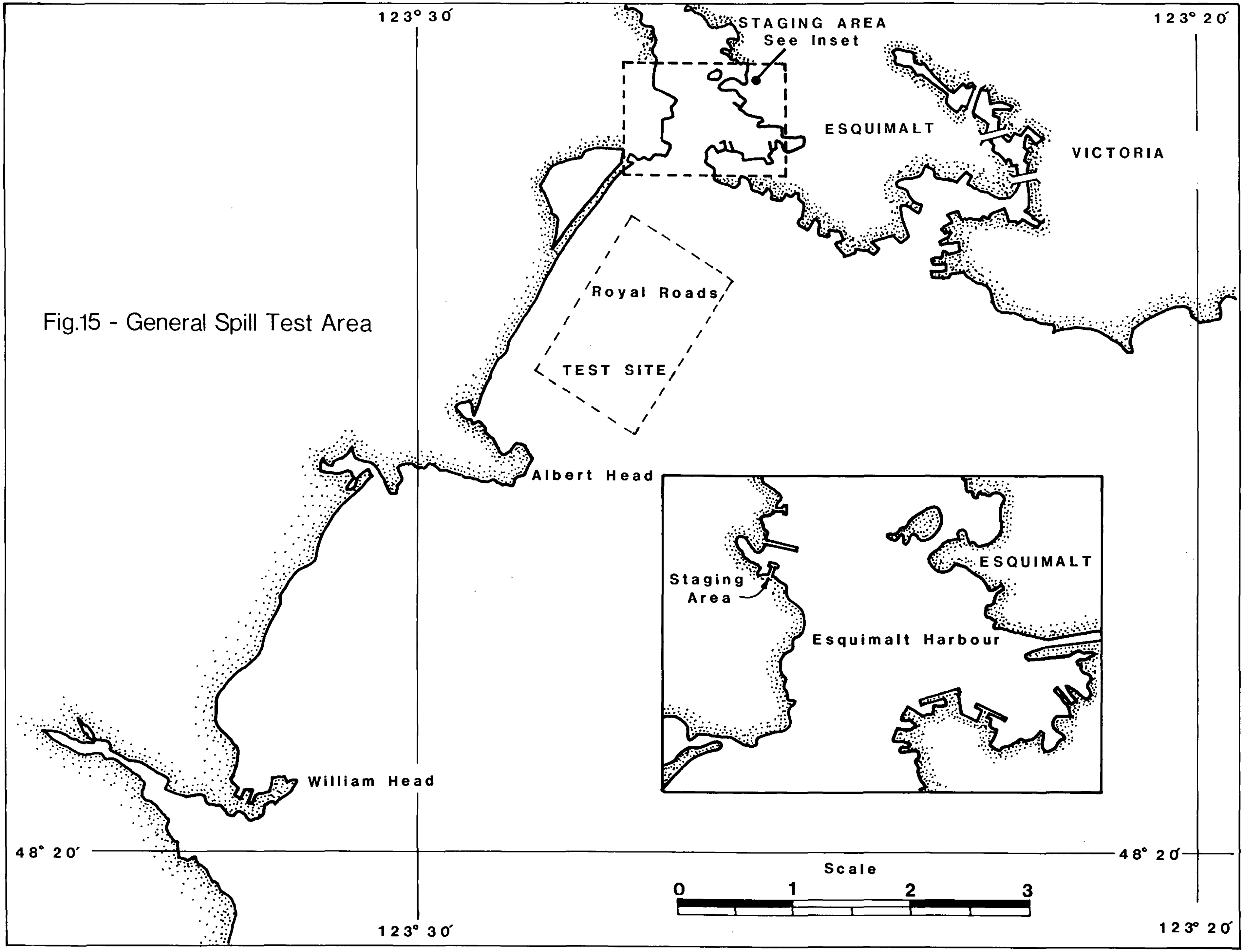


Fig.15 - General Spill Test Area

TABLE 3 THREE-POINT CALIBRATION CHECK OF THERMOMETERS USED

Precision Thermometer	8°C	20°C	38°C
Electronic Thermometer	8°C	18.5°C	37.5°C
Telethermometer	8.5°C	20°C	38°C

APPENDIX B

TEST DATA - MARCO CLASS V

APPENDIX B TEST DATA - MARCO CLASS V

I RAW DATA RECORD

22 August 1977

Run No.	Test Time	Test Medium	Vessel Speed (m/s)	Vessel Speed (kts)	Air Temp. (°C)	H_2O Temp. (°C)	Belt Speed*	Ind. Pump Press (psi)	Liquid Collected (cm)	Oil Collected (cm)	Oil Spilled (cm)	Remarks
1	1:40 5 min 27 sec	Crude	1.04	2	18.5	10	No. 3	1500	-	-	86.4	No oil pickup

- No pressure to squeeze roller
- Pneumatic cylinders on squeeze rollers are inoperative
- Much use of dissimilar metals for head end of boom mechanism
- Aluminum not marine grade (anodized) and is pitted
- Chains are plain steel and rusted
- Some parts galv. steel and others plain steel and rusted
- Fibreglass covers over head end mechanism held on by S.S. screws into aluminum - very difficult to remove

Pump speed = 200 ℓ/5 min 27 sec = 36.7 ℓ/min

23 August 1977

Run No.	Test Time	Test Medium	Vessel Speed (m/s)	Vessel Speed (kts)	Air Temp. (°C)	H_2O Temp. (°C)	Belt Speed*	Ind. Pump Press (psi)	Liquid Collected (cm)	Oil Collected (cm)	Oil Spilled (cm)	Remarks
	A.M.											
1	2 min 10:18	Crude	1.10	2.13	13.5	10	No. 2	1000	-	3.8	28.6	Overcast, rain, sea calm
2	1 min 10:36	Crude	1.01	2	14	10	No. 3	250	39.4	2.7	8.3	Stationary cylinder bracket req. gusset stiffner
	P.M.											
3	4 min 2:12	Crude	0.64	1.24	12.5	11	No. 3	250	73.7	23.1	40.0	
4	10 min 2:36	Crude	0.58	1.12	12.5	11	No. 3	600	102.9	11.7	26.0	Rain
5	3 min 3:09	Crude	0.61	1.2	12.5	11	No. 3	600	33.0	4.1	16.5	Splash plate raised above water surface; rain, light swell

*BELT SPEED:

No. 2 = 21.6 sec/rev = 1.34 FPS = 0.41 m/s
No. 3 = 13.5 sec/rev = 2.15 FPS = 0.66 m/s
No. 4 = 8.2 sec/rev = 3.54 FPS = 1.08 m/s
No. 5 = 5.5 sec/rev = 5.27 FPS = 1.61 m/s

24 August 1977

Run No.	Test Time	Test Medium	Vessel Speed (m/s)	Vessel Speed (kts)	Air Temp. (°C)	H_2O Temp. (°C)	Belt Speed*	Ind. Pump Press (psi)	Liquid Collected (cm)	Oil Collected (cm)	Oil Spilled (cm)	Remarks
	A.M.											
1	3 min	Crude	0.52	1	12	11	No. 2	250	17.8	0.4	7.0	New belt & pads installed; new belt had improved metal splicing system for joining belt; 30 min req. to change belt; pads attached to belt with velcro strip
2	4 min 10:17	Crude	0.55	1	12	11	No. 2	250	20.3	1.1	9.5	Raining, sea a calm, light wind
3	5 min	Crude	0.48	1	12	11	No. 2	250	17.8	4.4	11.4	5-15" wide slick to belt
4	5 min	Crude	0.55	1	13	11	No. 3	250	113.0	18.4	8.9	
5	4 min	Crude	0.55	1	13	11	No. 3	250	72.4	10.2	9.5	
	P.M.											
6	4 min 1:50	Crude	0.44	0.9	13	11.5	No. 3	250	88.9	12.6	10.2	Overcast, sea calm
7	2 min 2:31	Diesel Clear	0.44	0.9	13	11.5	No. 3	250	69.9	6.6	5.1	
8	4 min 2:40	Diesel Clear	0.44	0.9	13.3	11.5	No. 3	250	55.9	8.9	15.2	
9	4 min 2:52	Diesel Clear	0.55	1	13.3	11.5	No. 3	250	61.0	8.1	10.2	
10	4 min	Diesel Clear	0.55	1	13.3	11.5	No. 3	250	81.1	20.3	39.6	Valve on oil pump open wider

P.M. runs total liquid collected = 262 cm (measured August 25, 1977 A.M.)
P.M. runs total oil collected = 29 cm (measured August 25, 1977 A.M.)
Run No. 9 liquid collected = 77.5 cm (measured August 25, 1977 A.M., some liquid bailed out)
Run No. 9 oil collected = 12.4 cm (measured August 25, 1977 A.M.)

*BELT SPEED:

No. 2 = 21.6 sec/rev = 1.34 FPS = 0.41 m/s
No. 3 = 13.5 sec/rev = 2.15 FPS = 0.66 m/s
No. 4 = 8.2 sec/rev = 3.54 FPS = 1.08 m/s
No. 5 = 5.5 sec/rev = 5.27 FPS = 1.61 m/s

I RAW DATA RECORD (Cont'd)

25 August 1977

Run No.	Test Time	Test Medium	Vessel Speed (m/s)	Vessel Speed (kts)	Air Temp. (°C)	H_2O Temp. (°C)	Belt Speed*	Ind. Pump Press (psi)	Liquid Collected (cm)	Oil Collected (cm)	Oil Spilled (cm)	Remarks
	A.M.											
1	3 min 9:25	Diesel Fluoresene in meth.	0.55	1	11.8	11.1	No. 2	250	62.2	17.1	22.9	Rain, overcast, light wind
1-B	9:37	No oil	0.55	1	11.8	11.1	No. 2	0	-	-	-	Ind. pump turn-off flow to belt not positive w/o ind. pump
2	3 min 9:50	Diesel & Fluor.	0.58	1.1	12.6	11.3	No. 3	250	25.4	6.9	17.8	
3	4 min 10:05	Diesel	0.58	1.1	12.6	11.3	No. 2.5	250	81.3	24.1	33.0	
4	2 min	Diesel Bunker	0.55	1	12.6	11.3	No. 2.5	250	81.3	49.1	44.5	Residual diesel in belt; sump overflowed, 1" oil lost
	P.M.											
5	2 min 1:15	Bunker C & + 8" Diesel	0.55	1	14.2	11.1	No. 2.5	250	53.3	10.2	9.5	
6	2 min 1:25	Bunker C	0.55	1	14.2	11.1	No. 2.5	250	49.5	14.0	5.7	Scrapper blade removing much oil
7	3 min 1:31	Bunker C	0.55	1	14.2	11.1	No. 2.5	250	125.7	22.2	12.7	
8	1:50	Diesel Clear		1	14.2	11.1	No. 2.5	250	-	-	-	Belt pads removed in less than 3 min

* BELT SPEED:

No. 2 = 21.6 sec/rev = 1.34 FPS = 0.41 m/s
No. 3 = 13.5 sec/rev = 2.15 FPS = 0.66 m/s
No. 4 = 8.2 sec/rev = 3.54 FPS = 1.08 m/s
No. 5 = 5.5 sec/rev = 5.27 FPS = 1.61 m/s

2 CHARACTERISTICS OF OIL USED

Crude	Peace River Stream
API Gravity	41.0
Sulfur	0.3%

Fuel Oil	Bunker C
API Gravity	15.2
Flash	93.3°C
BS & W	0.1%
Viscosity	70 SSF @ 50°C

Diesel	
API Gravity	34
Flash	-56.7°C
Pour Point	-20.6°C
Cetane Index	44.5

Distillation	
IBP	148.9°C
10%	197.8
20%	215.6
50%	254.4
80%	292.2
90%	302.2
EP	348.9

APPENDIX C

OIL-WATER CONTENT ANALYSIS

APPENDIX C OIL-WATER CONTENT ANALYSIS

Because of slight delays in getting the analyses (ASTM D96-98) underway, it was necessary to store the samples temporarily at 4°C. Prior to testing, therefore, all samples were heated to room temperature (20°C) then vigorously agitated on an "Elerbach" shaker for at least 10 minutes prior to transfer to 50 ml centrifuge tubes. Before this transfer, 25.0 mls of benzene were dispensed into each tube. The tubes were then shaken well to facilitate mixing of the sample and benzene. Following this the tubes were immersed in a water bath (49 ± 1°C) for 10 minutes and when removed, inverted to again mix the benzene with the sample. The contents of each tube were then transferred to 50 ml round-bottom glass centrifuge tubes and spun for 10 minutes at a relative centrifugal force of 700.

After these tubes were removed, the oil-water interface was marked on the outside with a fine grease pen. Two 50 ml tubes were used for each sample and two readings taken.

After the first centrifuging and marking of the oil-water interface, the tube contents were then transferred back to the tapered, graduated centrifuge tubes. Using a small, distilled water bottle, water was added to the glass tubes up to the pencil line. This water was then decanted into one of the graduated tubes and the reading taken. This constituted the initial reading and the process was simply repeated by pouring the benzene-oil sample back into the glass tubes and spinning for a further 10 minutes. Once again the oil-water interface was marked, samples transferred back to the graduated tubes and final readings taken.

PERCENT WATER IN OIL SAMPLES

Test No.	Sample Aug.	Run No.	Initial Reading (ml) A	B	Final Reading (ml) A	B	Water Content (%)
1	24	9-sump	14	16	15	18	33
2	24	9-barrel	1	1	1	1	2.0
3	24	10-sump	13	14	15	16	31
4	24	10-barrel	0.5	0.5	0.5	0.5	1.0
5	25	1-sump	13	14	15	16	31
6	25	1-barrel	0.5	0.5	0.5	0.5	1.0
7	24	3-sump	9	12	9	12	21
8	25	3-barrel	0.5	0.5	0.5	0.5	1.0
9	25	4-sump	13.5	13.5	13.5	13.5	27.0
10	25	4-barrel	9.5	9.5	9.5	9.5	19.0
11	25	2-sump	1.0	1.5	1.0	1.5	2.5
12	25	2-barrel	1.0	1.0	1.0	1.0	2.0
13	25	6-sump	12.0	12.0	12.0	12.5	24.5
14	25	6-barrel	7.5	8.0	8.5	8.5	17.0
15	24	4-sump	13.5	14.0	13.5	14.5	28.0
16	24	4-barrel	4.0	5.5	4.0	5.5	9.5
17	24	8-sump	15.5	16.5	16.5	16.5	33
18	25	5-barrel	8.5	9.0	8.5	9.0	17.5
19	24	3-sump	3.0	3.5	3.0	3.5	6.5
20	24	5-barrel	7.5	7.5	7.5	7.5	15.0
21	24	6-sump	13.5	20.0	14.0	20.0	34.0
22	24	7-sump	22.0	23.0	22.5	24.0	46.5
23	24	1-barrel	6.5	6.0	6.5	6.5	13.0
24	24	2-barrel	1.25	1.0	2.0	2.0	4.0
25	25	5-sump	11.5	11.5	12.0	11.5	23.5

PERCENT WATER IN OIL SAMPLES (Cont'd)

	Sample		Initial Reading (ml)		Final Reading (ml)		
Test No.	Aug.	Run No.	A	B	A	B	Water Content (%)
26	25	7-sump	9.0	9.5	9.0	10.0	19
27		3	20.5	21.0	21.0	21.0	42.0
28		4	14.5	14.5	14.5	14.5	29.0
29	23	1 and 2	3.5	3.5	3.5	3.5	7.0
30		5	20.0	20.0	20.0	20.5	40.5
31	23	4	<0.25	<0.25	0.25	0.25	0.5
32	23	3	1.0	1.0	1.5	1.25	2.75
33		1-Crude	19.0	21.0	19.0	22.0	41.0
			Replicate Tests (ml)				
	24	4-barrel	3.0	3.5	3.5	3.5	7.0
	24	9-sump	13.0	11.0	13.0	11.0	24.0
	25	1-sump	14.0	14.0	14.5	14.0	28.5
	24	6-sump	19.0	17.0	16.0	19.5	35.5
	25	5-barrel	9.5	9.5	10.0	9.0	19.0
	25	4-sump	14.0	13.5	14.0	14.0	28.0
	25	3-barrel	0.5	0.5	0.75	0.75	1.50
		3	21.0	21.0	22.0	22.0	44.0
	24	2-barrel	1.5	1.5	2.0	2.0	4.0

Sample number is shown as "date - run number". Two readings each were recorded in an initial and final analytical procedure described on the preceding page

Centrifuge - diameter of swing = 26 cm (10.25 in)

Rpm = 265 700/10.25 = 2,190 rpm