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SPILL TECHNOLOGY

N E W S L E T T E R

ISSN 0381-4459

VOLUME 15 (1)
March 1990

The Performance of a Water Jet Barrier in a River

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Introduction

In June 1989, the Environmental Emergencies Technology Division (EETD) of Environment Canada performed tests with their water jet barrier on the St. Lawrence River in Prescott, Ontario. The purpose of the trial was to determine the barrier's ability to contain oil in a current and, if successful, to evaluate its effectiveness as an aid for the *in-situ* combustion of oil.

Since 1979, EETD has been performing tank and open water tests using water jet barrier prototypes. These trials have shown that this system could have significant advantages over conventional barriers. It has been proven superior for deflecting oil and there have been indications that it can also contain the oil in high currents and in wave conditions where other barriers would lose it.

Fireproof versions of conventional barriers make it possible to burn contained oil *in situ* and greatly reduce the amount of oil that has to be mechanically removed and disposed of. The main problem with burning oil *in situ* is that the incomplete combustion produces heavy black smoke that is not desirable, particularly in populated areas. Complete combustion will

occur if there is excess oxygen present within the burning area.

Using the water jet barrier for *in situ* burning could be a solution to the smoke problem. As the high pressure water jets spray towards the burning oil, the droplets of water entrain air which feeds the flame the oxygen needed for complete combustion and reduces smoke emissions.

Description of the Unit

One advantage of the current configuration of the water jet barrier is its ability to be manoeuvred or held in place by changing the pressures of each arms' opposing jets. Conventional barriers require either two vessels or a double mooring to hold them in position and are also unable to contain oil in currents greater than 0.4 m/s. It is hoped that the water jet barrier will contain oil in currents greater than 0.5 m/s.

The water jet barrier prototype is powered by a 550 Bhp diesel engine which runs a triplex water pump. The tether line to the barrier consists of four parallel hoses which spread into a v-shape at the barrier section. Each arm of the barrier is formed by two hoses with four evenly spaced sets of opposing jets. The nozzles are spaced approximately 2.4 m apart. The nozzles and fittings on the hose are mounted on circular floats which allows the nozzles to be raised 13 cm above the water. Because of the method in which the fittings are mounted on the floats, the optimum

15 Years!

This issue marks the beginning of the fifteenth year of this publication. We take this opportunity to thank all the contributors over the years and invite contributions for the future. The existence of the newsletter depends on receiving contributions from a broad spectrum of workers in the field.

The first article of this issue is by Monique Punt, who describes tests of a high-pressure containment boom in the St. Lawrence River. It was found that the boom showed potential, but the configuration chosen for these particular tests was not optimal. The second article is by Merv Fingas, one of the editors of the newsletter. This article is a summary of oil spill treating agent testing that has been conducted by Environment Canada and other agencies over the past five years.

Good reading!

Canada



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height of greater than 15 cm could not be achieved. Superceded floats from the previous prototype are used to support the tether line leading to the barrier.

The inner two sets of nozzles, at the apex of the barrier, are positioned perpendicular to the hose. The other six sets of nozzles are angled inward towards the apex at a 45° to the hose. Although the optimum nozzle angle has yet to be determined, 45° angled fittings were used during the river trial because they were the only fittings available.

The nozzle apertures are 0.33 cm in diameter with horizontal slots at the outlets which results in a fan-shaped water jet spray with a spread angle of 65°. The nozzles are adjusted so that the plane of the fan-shaped spray is horizontal with the flat top of the circular float. A schematic of the barrier system, as configured for the Prescott trial, is shown in Figure 1.

evaluation, the floats were changed to circular fiberglass floats having a flat top and bottom. This shape greatly reduced the drag and increased the stability of the barrier.

An optimization of the water jet barrier was performed in 1986 (Phillips *et al.*, 1987). The nozzle spacing, nozzle height, depression angle, water jet pressure, and nozzle type were studied to determine the configuration which yielded the greatest air velocity created by the jets. The optimum height was found to be between 15 and 30 cm. Variations between these two heights did not cause any significant change in the induced air velocities. It was confirmed that small deviations from a zero depression angle caused significant reduction in air velocities.

In the fall of 1988 a small tank trial was performed as a jointly funded project with the Minerals Management Service of the

During the tests the arm of the barrier was positioned so that it remained perpendicular to the dock. The wind velocity readings were taken by divers using a small anemometer. Distances were marked along the dock to determine the distance the divers were from the barrier. The divers centred themselves in front of each nozzle spray to take readings.

The velocity readings 9.1 m from the barrier where approximately 1.8 m/s at 3550 kPa, 2.2 m/s at 5300 kPa and 4.5 m/s at 7000 kPa. The readings were taken at a height of approximately 10 cm and 15 cm above the water surface. At a pressure greater than 7000 kPa the operator was not able to hold the barrier in position perpendicular to the dock.

Containment Trials

After the velocity tests were completed the barrier system was loaded onto the Coast Guard ship *Simcoe*. The ship was anchored into the current for the tests. The barrier was deployed from the well deck and was positioned up current using the power exerted by the outer water jets. Initially, the barrier arms were placed on a smaller boom deployment vessel so that the arms could be untangled on its deck instead of in the water. The barrier was dragged into the water using the ship's crane. The water jets were then started so that the barrier could be pushed from its down-stream position up into the current. Photo 1 (a,b,c) shows how the barrier was moved into position.

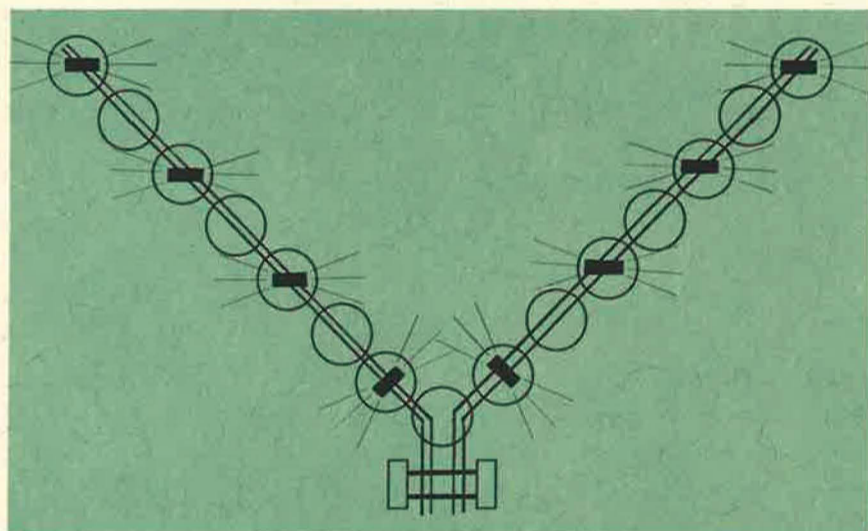


Figure 1 Water Jet Barrier as Configured for the Prescott Trial

Background

During a trial performed using the prototype water jet barrier in the MacKenzie River in August, 1984, a 120° arm angle was the maximum attainable in a 0.6 m/s current with power remaining to contain the oil (Laperrière, 1985). At this trial it was shown that the barrier could hold peat moss coated with vegetable oil when the arm angle was set at 120°.

At the MacKenzie River trial, the floats used to support the water nozzles and fittings consisted of two cylindrical boat fenders with a platform in between. The barrier was difficult to manoeuvre because of the high drag coefficient and lack of stability of these floats. Drag and stability tests were performed on these floats and on alternative float designs. Following this

U.S. Department of the Interior, to investigate the water jet barrier concept on burning oil (Comfort *et al.*, 1989). It was found that the jet's influence did in fact cause the oil to burn much more cleanly than without the jets. It remains to be seen whether the same effect would be achieved by the actual barrier in a true river situation.

Wind Velocity Tests

As a prelude to the actual containment tests one arm of the barrier was set up in the Coast Guard basin in Prescott to measure the wind velocity patterns created by the water jets. The wind velocity generated by the water jets creates the force which acts on the oil to contain it in the barrier and also provides the excess oxygen for combustion.

On the first day of testing, the measured current in the test area was approximately 0.5 m/s. It was decided that an attempt would be made to hold the barrier at an angle of 120° because at smaller angles a significant portion of the force created by the air jet velocity would be directed towards the apex. At an angle greater than 120° the oil would travel around the ends of the barrier.

Once the barrier was in the upstream position the arms were forced open by increasing the flow to the inner jets. At 3550 kPa the arm angle could be expanded to 120° but the barrier would veer away from the ship and the arm angle would begin to close because of the currents created around the bow of the ship. This meant that the barrier opening could not be centred directly into the current.

The barrier was also operated at pressures of 5300 kPa, but it was very difficult to manoeuvre at this pressure and the floats on the barrier arms tended to flip easily. When the arm angle did reach 120° the arms began to close much faster than at 3550 kPa.

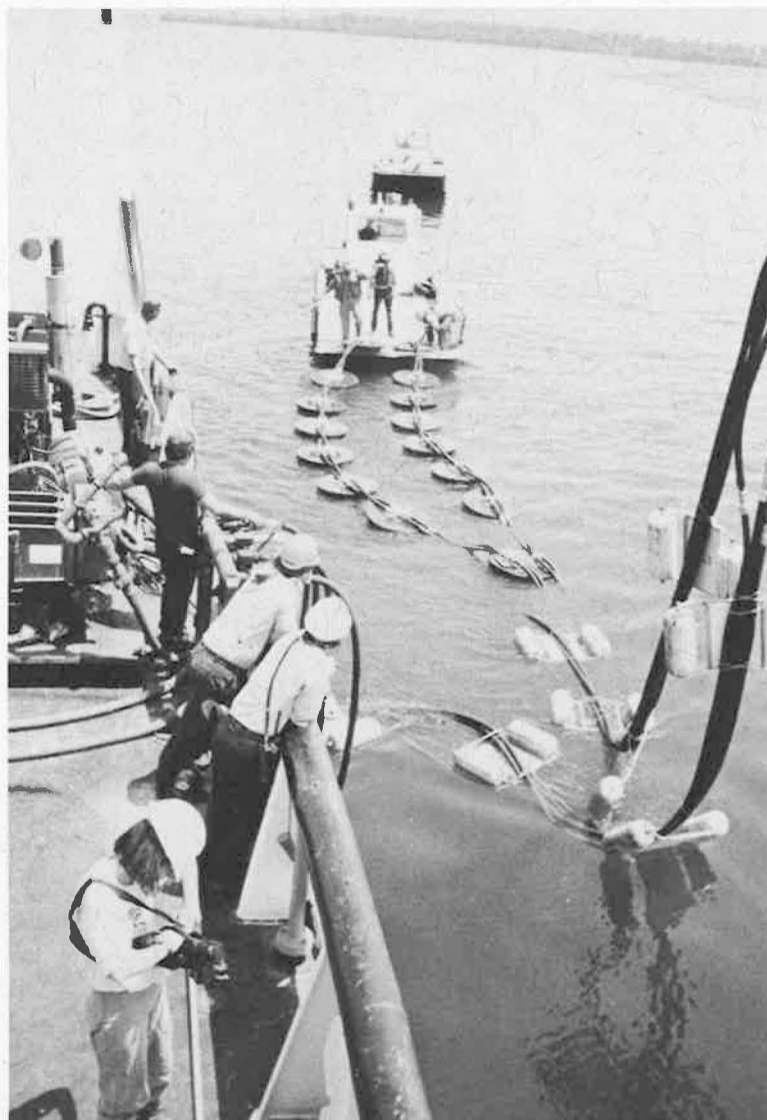
Even though problems were encountered in maintaining a large barrier arm angle, a biodegradable, dyed Canola oil was spilled into the barrier using a pressure of 3550 kPa. Twenty-three litres of Canola were released from a small vessel upstream of the barrier as soon the arm angle reached approximately 120°. Initially, the oil was held in the barrier for about 10 seconds but, as expected, the Canola began to slip through the apex as the arm angle decreased. Photo 2 (a,b,c) depicts the loss of the oil with the decreasing arm angle.

Later the same day, Canola oil was also spilled into the barrier at a water jet pressure of 5300 kPa. The oil was pushed through the apex almost instantaneously because of the rapid decrease in the arm angle and the increased pressure.

On the following day 14 m of hose was added to the existing 15 m of tether line. The line was added in an attempt to position the barrier far enough ahead of the ship, as opposed to directly beside it, so that the current around the ship would not affect the barrier.

The current had increased to 0.75 m/s on the day the extra tether line was added. When the water jets were activated, it was more difficult to move the barrier upstream into position than during the previous day. Because of drag of the extra line and the increased current, it was not possible to position the barrier much further away from the ship. Again, Canola oil was spilled into the barrier and the same results were observed as without the extra line.

The burning trials were cancelled because of the inability to position the barrier in a configuration conducive to containing oil.



a.

Photo 1 Manoeuvring the Barrier Into Position



b.



c.

Recommendations

Before abandoning the concept of the water jet barrier as a containment device for burning oil, the system should be re-examined to determine if the several observed deficiencies can be corrected. The floatation system for the barrier and the tether line could be redesigned to prevent the barrier's circular floats from flipping and reduce the drag on the tether line. Other suggested modifications include raising the nozzles higher above the water, designing a method of keeping the nozzles level with the water and using a rigid pipe system attached to the ship in lieu of a floating hose system.

Conclusions

With the existing design, the water jet barrier could not be held in a position which would allow it to contain oil in a current greater than 0.5 m/s. It is believed that water jet barrier concept is still feasible for containing and aiding in the combustion of oil, but the configuration of the system must be changed.

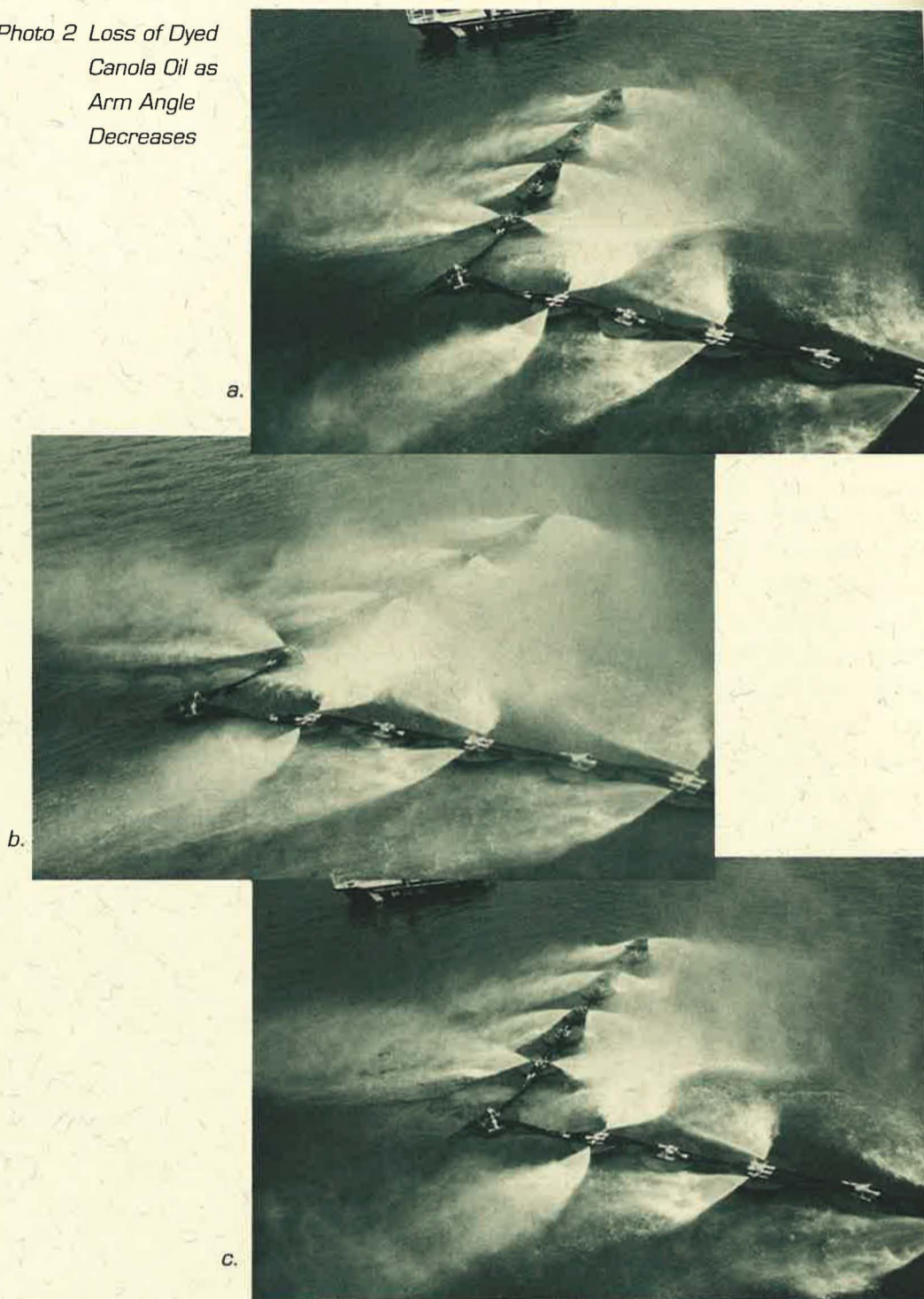
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Photo 2 Loss of Dyed
Canola Oil as
Arm Angle
Decreases



Evaluation of Oil Spill Treating Agents

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Introduction

A large number of chemical agents for treating oil spills have been promoted in the past 20 years. During the seventeen years of the life of the Environmental Emergencies Technology Division over 100 dispersants have been tested for

toxicity and/or effectiveness. Only eight products still remain on the accepted list and only about 15 products are still being produced. The compendium on oil spill treating agents prepared for the American Petroleum Institute in 1972 lists 69 dispersants and 43 beach cleanup agents, most of which are also dispersants.¹ Only two of these are current commercial products, but both are produced in different formulations. Over 50 biodegradation agents, including bacterial mixtures, enzymes, or fertilizers have been proposed and only five of these, all very recent inventions, remain on the market. Ten sinking agents have been

examined with none remaining commercial. The American Petroleum Institute (API) compendium lists 18 sinking agents, none of which remain on the market, primarily because they are banned in Canada, the United States, and most other countries. Elastol, one recovery aid of the several proposed, still remains. Ten emulsion breakers and preventers have been on the market. None are commercially available at this time. Over 100 surface washing agents have been sold in the North American market. About 12 of these are still commercially available. A number of agents which have been sold for various purposes, but do not fit into the above

categories, include those that help trace or detect an oil slick, those which are combinations of the categories previously described, and those very vague items that are claimed to make oil disappear, become nontoxic, etc. It is estimated that over 100 agents of this category have been offered at one time or another on the North American market. The total number of agents proposed worldwide is estimated to be 600, of which only about 200 were ever tested in the lab or field, even in a limited way. It is also estimated that only about 35 agents are commercially available at this time. The bustle of activity in this field has left the potential buyer confused and sceptical of treating agents.

Effectiveness remains to be the major problem with most treating agents. Effectiveness is generally a function of molecular size and type. Crude and refined oil products have a wide range of molecular sizes and composition including whole categories of materials like asphaltenes, alkanes, aromatics, and resins. What is often effective for a small molecular asphaltene is ineffective on a large molecular asphaltene. What is effective on an aromatic compound may not be effective on a polar compound. Additionally, the composition of crude oils varies widely. This leaves little scope for a universally-applicable and effective spill control chemical.

Testing of spill-treating agents has involved two facets at Environment Canada, the first being testing for toxicity and other forms of environmental acceptability, and the second being effectiveness testing. A number of projects have been initiated to develop tests and to complete testing of most spill treating agents currently being sold.

Gelling or Solidification Agents

Gelling agents are those agents which change oil from liquid to solid. Also known as solidification agents, these agents often consist of polymerization catalysts and cross-linking agents. Agents which are actually sorbents are not considered to be gelling agents. Three gelling agents have been tested by Environment Canada and others in recent years:

1. a BP (British Petroleum) product which consisted of deodorized kerosene and a cross-linking agent;
2. a Japanese product consisting of an amine which forms a polymer; and

3. a solidification agent proposed by Professor Bannister of the University of Lowell, an agent which used liquefied carbon dioxide and an activating agent.

During tests conducted in the laboratory, all three agents functioned, but large amounts were required to effectively solidify the oil. Under some situations the oil became a semi-solid, which does not aid recovery. The BP agent worked better than the other agents and was tested on a larger scale by the Canadian Coast Guard and the Canadian oil industry. In the large-scale tests even more agent was required to solidify the oil, in fact up to 40% of the actual volume of the oil itself. This is double the laboratory requirement. Both requirements were deemed to be far in excess of what was actually practical in the event of a real spill. Because of the large amount of agent required, gelling agents have not been historically used nor stocked for use by spill responders.

A standard test was developed to assess new solidifiers. The test consists of adding solidifier to an oil with continuous stirring until the oil becomes solid. The test is repeatable within 5%, even with different laboratory personnel. Results of testing some solidifiers is given in Table 1. Values are given as the weight percent required to solidify an oil completely. Elastol is an oil recovery enhancer, not a solidifier, but was included for comparison.

Recovery Aids and Demoussifiers

A number of agents have been sold throughout the years for assisting in the recovery of spilled oil. None have been widely known or promoted except for Elastol. Earlier agents were not well tested nor were they sophisticated. One product was shredded peat moss which was

claimed to improve the recovery efficiency of sorbent-surface devices. None of these earlier agents offered enough promise to warrant extensive testing.

Some agents were also developed for breaking up or preventing emulsion formation. Most of these were hydrophilic surfactants, that is surfactants with a strong tendency to make oil-in-water emulsions. Such surfactants have the ability to reserve the water-in-oil emulsion to two separate phases. The problem with a hydrophilic surfactant is that it is more soluble in water than in oil and will quickly leave the system if there is sufficient water. Obviously such products cannot be successfully used on open water. This problem was avoided in some recent products by using a less water-soluble surfactant and accepting the resulting decrease in effectiveness. One recent product, "Demoussifier", developed by Environment Canada does not use surfactant in the normal sense of the word. This product does not suffer the limitations previously noted.

Two commercial products, Exxon Breaxit and the Shell product LA 1834, and a surfactant, sodium dioctyl sulphosuccinate were evaluated in one study.² All three products functioned in a limited way, but only the Shell product prevented the formation of emulsions over a wide range of oils and conditions. The Shell product and the Exxon product are not commercially available, but have been obtainable in small quantities for testing.

The United States Minerals Management Service and Environment Canada joined forces to evaluate two new and promising treating agents, Elastol, a recovery-enhancement agent, and Demoussifier, an emulsion breaker and preventer. Results of the extensive testing on these products

TABLE 1 SOLIDIFIER TEST RESULTS

Product Name	Percentage Required for Solidification (%)
RAWFLEX	16
Elastol	26 (note, this product is a recovery enhancer, not a solidifier)
Oil Bond 100	33
Oil Sponge	36
Petro Lock	44
Molten Wax	109
Powdered Wax	278

have been widely published.³⁻⁸

Elastol is a nontoxic powder and renders oil visco-elastic making it adhesive to oil spill recovery surfaces. Demoussifier is a mixture of long-chain polymers which again has no measurable toxicity to humans or aquatic life. This product was developed at Environment Canada's River Road Environmental Technology Centre and functions both to break emulsions and prevent their formation. The laboratory work on Elastol involved several different tests. The effect on a suite of different oils was determined by measuring the time to initiate change and the degree of elasticity formed. All oils display visco-elastic properties when treated with doses of 600 to 6000 ppm Elastol. In general, more viscous oils tend to attain a higher degree of elasticity than non-viscous oils, but do so over a longer period of time. Under low mixing energy conditions, oils exhibit some degree of elasticity within 15 minutes of Elastol application. A high degree of elasticity is not displayed until one hour after treatment. Less viscous oils take less time to reach maximum elasticity and viscous oils more time. At higher mixing energies, maximum elasticity is reached in much less time. Elastol causes a minor reduction in the rate of oil evaporation, but not significant enough to reduce its flash point. The addition of Elastol either has no effect or an inhibiting effect on the formation of water-in-oil emulsions. Testing with the Demoussifier showed the Elastol has no effect on its operation and that both products could be used together.

Both Elastol and Demoussifier were tested on a large scale using the Esso test tank in Calgary, Alberta. Funding for this part of the program was provided by the U.S. Minerals Management Service, Environment Canada, and Esso Resources. In the large-scale tests, two slicks were put out simultaneously in parallel booms. This permitted the simultaneous testing of a control and a treated slick under identical conditions. The first two days were devoted to testing the demoussifier. The demoussifier prevented the formation of water-in-oil emulsions on both slicks and did so at treatment ratios as low as 1:2000 (500 ppm). Elastol was tested on the final two days. In the first of these tests, Elastol was added to a test crude oil at 4000 ppm and the test slick was released several hours later when the oil was highly elastic. Although not thick enough to burn, the high elasticity increased the recovery rate by a

rotating disk skimmer. On the fourth day of testing, crude oil was treated with 2000 ppm of Elastol and recovered with a skimmer. The recovery rate was again high and exceeded the capacity of the skimmer's pump to remove it.

The tank-scale tests showed that there were no scaling effects for either the Elastol or the Demoussifier. Both products worked well for the intended purpose. Elastol increased the visco-elasticity of the oil and greatly increased the skimmer recovery rate. Elastol, however, did not reduce the spreading or increase the thickness of the slick sufficiently to allow *in situ* burning. Demoussifier prevented the formation of water-in-oil emulsion and also broke emulsion already formed. Although demoussifier causes the oil to be less adhesive and lowers the recovery rate of skimmers, the two products can be applied together to achieve positive results.

The two products were then tested on a large scale offshore. The sponsors of this test included; U.S. Minerals Management Service, Environment Canada, Esso Resources, and the Canadian Coast Guard. The field trial was conducted 80 km offshore from Nova Scotia. Five slicks of five-barrels each were laid for each of the products and each product was tested both pre-mixed and by application-at-sea, to confirm that application effects were not a factor.

The Demoussifier trials were performed by laying down a five-barrel oil slick, treating it with the product at the specified ratio, taking samples at subsequent intervals and measuring the water content and the viscosity. One slick was left untreated and then treated at the 240-minute interval to test Demoussifier's ability to break emulsion at sea. A large reduction in viscosity (105 000 to 22 600 cSt) occurred over the 30-minute period between samples, showing that the product worked well to break the emulsion. The product continued to work well over the five-hour test period to prevent the formation of emulsions.

The Elastol tests were performed in an analogous manner to those for Demoussifier, with one control slick laid and one slick being pretreated to test the effect of at-sea treatment. The slicks were sampled periodically and both viscosity and elasticity were measured immediately on

board ship. The elasticity of the treated slicks was significantly higher than that of the untreated slicks and corresponded to that experienced in the laboratory. In fact, it actually exceeded laboratory results at higher doses. This un-expected result is probably because of the better mixing achieved in the field.

Surface Washing Agents

The most common and most suggested treating agents are those containing surfactants as the major ingredient. These agents have been divided into two groups, dispersants and surface washing agents. Dispersants are those agents which have approximately the same solubility in water and oil and will cause the oil to be dispersed into the water in fine droplets. Surface washing agents are those agents which remove oil from solid surfaces (such as beaches) by a mechanism known as "detergency". As it turns out, the mechanism of dispersancy and detergency are quite different and testing has found that a product that is a good surface washing agent is a poor dispersant and vice versa.

A test for surface washing agents was developed by Environment Canada and a number of commercial products have been tested using this protocol.⁹ The test measures how much oil is removed from a standard test surface when the surface washing agent is allowed to soak into the oil and then water is used to rinse off the oil. Table 2 shows the results of these tests with a seawater rinse and the results of an aquatic toxicity test (lethal concentration to Rainbow Trout over four days in mg/L, larger values indicate less toxicity) and a dispersant effectiveness test (swirling flask test, values represent percent oil put into the water column) for the same products. The latter data points were included to show the opposite nature of dispersant and surface-washing effectiveness. Some products display neither property. Only one product tested, Corexit 9580 is relatively effective as a surface washing agent and has low toxicity.

Dispersants

Dispersants are the biggest class of oil spill treating agents and have perhaps generated the greatest number of studies and amount of discussion since the birth of the oil spill countermeasures

TABLE 2 SURFACE WASHING AGENT TEST RESULTS

Agent	Percent Oil Removed (%)	Toxicity* (mg/L)	Dispersant Effectiveness* *
Corexit 9580	42	>5600	0
Citrikleen XPC	36	34	2
Corexit 7664	27	850	2
BP 1100 WD	21	120	6
Palmolive dish soap	16	13	9
Breaker 4	13	340	0
Nokomis 3	13	110	0
Sunlight dish soap	12	13	9
Citrikleen 1855	12	55	0
Con-Lei	12	70	0
Mr. Clean	6	30	0
Corexit CRX-8	5	20	48
Corexit 9527	3	108	41
Biosolve	2	9	0
Lestoil	1	51	0
Enersperse 700	1	50	56

* Lethal concentration to Rainbow Trout over four days.
** Percent of oil put into the water column.

industry twenty years ago with the TORREY CANYON incident. Discussion is as lively today, and there still exists a polarization between dispersant proponents and opponents. Little has changed in the way of documentation. There is still no undisputed documentation on large-scale experiments or use, to show that dispersants are effective or not. Similarly, no large-scale biological experiments have convinced all environmentalists that the use of dispersants is safe in all conditions, although the evidence is becoming increasingly clear that dispersants cause little ecological damage above that caused by un-treated oil and that they could in fact minimize ecological damage if they were effective.^{10,11}

Field tests of oil spill dispersants have not been successful. Over the past 12 years, 107 test spills have been laid out to test the effectiveness of oil spill dispersants.¹² A number of smaller tests or other tests which were not documented have taken place but are not discussed here. Of the 107 slicks documented, 23 were controls used to establish a comparison. Percentage effectiveness is reported in 25 spills and the average for these is 30%. Values range from 0 to 100%. Most experimenters have not assigned effectiveness values because effectiveness values are difficult to assign.

The test results show clearly that dispersants are not highly effective, even under highly controlled experimental situations. Of greater concern, however, is the methodology used to estimate effectiveness. Some experimenters simply estimated effectiveness, but most based their measure on integrations of water column concentrations relative to surface slick dimensions. This is not a correct means of performing the measure because the underwater concentrations have little positional relationship to the surface slick. Underwater dynamics of the ocean are very different than surface dynamics. Extreme cases of the positional variances between surface and sub-surface slicks have been illustrated by Brown and Goodman in controlled tank testing.¹³ Their work has shown that the underwater plumes move in highly random fashion with respect to the surface slick and even two trials conducted on the same day and in the same tank location will not have similar movement patterns. Furthermore, all of the experimenters who used underwater concentrations to estimate field effectiveness also used the method of dividing the water into different compartments and averaging concentrations. Mathematically this is not appropriate and can result in effectiveness values that are much larger and range from twice to ten times greater than the actual values. Underwater esti-

mates of oil spill dispersant effectiveness are highly inaccurate and misleading because of these factors. Surface measures are also inadequate at this time but may be possible with the development of new remote sensors.¹⁴

In summary, field trials of dispersant effectiveness have not shown any quantitative or qualitative proof of high (>50%) dispersant effectiveness. Analytical means do not exist to accurately quantify dispersant effectiveness in field trial situations.

A number of laboratory studies have been performed to compare the test results from different apparatus and procedures. A review of these results shows that there is poor correlation in effectiveness results between the various test methods.¹⁵ A recent study by the author has shown that lack of correlation is primarily a function of settling time allowed between the time that the energy is no longer applied and the time that the water sample is taken from the apparatus.¹⁶ Another important factor is that of the oil-to-water ratio in the apparatus. When the settling time and oil-to-water ratio are adjusted to realistic values, test results from most apparatus are similar. Results from more energetic dispersant effectiveness tests are higher but when corrected for natural dispersion, these results are nearly identical to those from less energetic apparatus. Given that essentially identical results can now be obtained from virtually any laboratory test, a simple, repeatable, and fast test can be chosen to make determinations of the dispersant effectiveness. One test developed by Environment Canada called the "swirling flask" test meets these criteria and has been used to test many combinations of oil/dispersant effectiveness.¹⁶ Some of these test results are given in Table 3.

The trends that are notable in these data are that weathered oils disperse poorly, and heavy oils are very difficult to disperse.

Concluding Remarks

Testing of spill treating agents shows that there are distinct differences in their efficiencies and effectiveness with different oils. The testing of effectiveness along with toxicity is an important screening tool for selecting treating agents.

TABLE 3 DISPERSANT EFFECTIVENESS RESULTS

Percent Effectiveness With Dispersant (%)

Oil	Corexit 9527	Corexit CRX-8	Enersperse 700	Dasic Slickgone
Alberta	33	45	51	24
Arabian light	17	9	22	33
Bent Horn	17	20	20	35
Bunker C	1	2	2	1
California heavy	1	1	1	1
Hibernia	6	6	10	14
Hibernia weathered	4	3	8	7
Lago Medio	5	5	13	15
Norman Wells	26	43	51	26
Prudhoe Bay	7	7	10	14
Prudhoe Bay (weathered)	4	4	8	10
South Louisiana	31	36	48	42
Synthetic crude	63	16	61	25
Transmountain	8	8	28	27
Used Motor oil	33	31	36	29

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