An Assessment Of Two Off-Shore Igniter Concepts

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Abstract

An international audience gathered to watch Oil Spill Response Limited conduct the first controlled in-situ burn (ISB) in the United Kingdom, in a location 40 miles offshore of Lowestoft, on June 12, 1996. Two burns were completed using a response-prepared ISB system. The first burn involved fresh crude oil and was ignited with a hand-held igniter using a standard gelled fuel mixture. The second burn involved an emulsified crude and was lit with a prototype emulsion breaking igniter deployed using the Helitorch. The trials were performed with the aim of determining operational practicalities under realistic conditions when responding to a weathered oil situation in an offshore location. The focus of this paper is on the assessment of the two igniter concepts tested during these trials.

1.0 Introduction

In 1993 Oil Spill Response Limited (OSRL) acquired in-situ burning equipment, including fire proof boom and a Helitorch, thus including In-Situ Burning (ISB) on the list of OSRL response options. By August 1994, the ISB package and the oil spill technicians were response prepared for an ISB call out. The next requirement was to evaluate the practical assessment of OSRL capabilities.

In July 1995 OSRL initiated a project to test the ISB strategy as realistically as possible. The oil would be released ahead of, and not into the boom. The oil would be weathered according to an achievable response time arrival expectation. 'Vessels of Opportunity' would be used to deploy the boom, and the trials would be performed according to the ambient weather conditions (upper limit permitting). OSRL wanted an end user's assessment of the hardware and the strategy. Questions to be answered included: Would emulsions ignite and burn using an emulsion breaking igniter deployed from a Helitorch? Would hand-held igniters work? Would the boom hold up? Could a multinational team aboard 'vessels of opportunity' overcome language and deployment challenges? Would worker safety be compromised? and overall, would ISB stake a claim as a credible response strategy? OSRL in the role of practitioners, intended to highlight the constraints in using ISB as a response strategy.

This paper presents an overview of the trials in terms of the overall objectives, operations, and burn performance. The focus of the paper is on the ignition techniques used in these trials. A comprehensive presentation of these burn trials can be found in Thornborough, (1997).

2.0 Objectives

The aim of these burn trials was to ascertain the practicality of employing ISB as a viable international response option. The specific objectives of the trials were to:

1. Challenge the recognised limits of the window of opportunity for ISB.

Environment Canada. Arctic and Marine Oilspill Program (AMOP) Technical Seminar, 20th. Volume 2. Proceedings. June 11-13, 1997, Alberta, Canada, Environment Canada, Ottawa, Ontario, 795-808 pp, 1997.

2. Appraise the deployment, performance and handling of the 3M/ American Marine fire boom system.
3. Assess the performance of a custom-designed hand-held igniter.
4. Evaluate the practical performance of a prototype Helitorch-deployable, emulsion-breaking igniter.
5. Contribute to the scientific knowledge of burning oils, related to air emissions and properties of the burn residue.

3.0 Operational Overview

3.1 Location

The trials were conducted in the North Sea in a licensed operating box measuring 25 square miles, which lay 40 nautical miles North East off the coast of Lowestoft, UK. The exact rendezvous position was 52^0 50' N, 002^0 55' E.

3.2 Response Time

The actual response time to arrive on location once redundant time, and non ISB equipment movements had been discounted, was 12 hours. This assumed 1-hour trailer loading at OSRL, 6-hours road transport to Lowestoft, 1-hour vessel loading, and 4-hours passage to location.

3.3 Oil Type

The oil type released was 'Larkwhistle Farm' (SG 0.8376), which is produced from an inland reservoir near to the OSRL base at Southampton. To produce a weathered oil simulating conditions encountered upon an achievable response time, the oil was artificially evaporated, then emulsified before release at sea.

This particular oil contained a demulsifer at 100 ppm injected by the oil production as part of a standard operating procedure designed to prevent emulsions from forming. Pre-trials tests carried out to determine the weathering characteristics of the test oil in terms evaporation and emulsification indicated that the maximum uptake ability of the oil was high (over 86%). Emulsions formed with 15% and 27% evaporated oil were stable in the short term (0.25 hrs), but in the long term (24 hrs), the emulsion formed with 15% evaporated oil lost 45% of the incorporated water, whereas the more evaporated fraction remained stable.

3.4 Oil Volume

Licence was given for a total release of 60,000 litres of oil.

3.5 The Fire Boom

OSRL provided 750 feet of first-generation 30", 3M fire boom, stored in a 30' purpose-built ISO container which had been fitted with a fast curtain track rail system. The boom is suspended in three aisles, ready for launch. American Marine Inc. donated a further 50' of latest specification fire boom.

3.6 Ignition Systems

One Simplex, 30 US Gallon Helitorch (Model 5400), delivered to North Denes heliport, and three Simplex hand-held igniters stored aboard the main deployment vessel.

3.7 Back Up Systems

The first contingency system on stand-by to recover unburned oil, was a heavy oil rotating drum skimmer system' (WP - 130), loaded aboard the oil release vessel. The second contingency system, on stand-by to recover unburned oil, was the fixed wing, aerial dispersant application of Corexit 9500.

3.8 Logistic Support

The air and sea logistics assembled to support the operation are shown in Table 1.

3.9 The Programme

The trials program beganon June 11th and finished on June 12th, 1996. One boom trial and two burns were completed (see Table 2).

Table 1. Logistics

Platform	Type
Spotter Aircraft	Air Atlantique Cessna 404
Spray Aircraft	Air Atlantique DC3 (Dakota)
Helitorch Aircraft	Bond Sikorsky S76A
Primary Vessel	French Navy Supply Vessel 'Alcyon'
Tow End Vessel	Harbour Tug 'Anglian Man'
Oil Release Vessel	Supply Vessel 'Eilean Dubh E'

Table 2. ISB Trials Program

Date	Trial	Objective
11/6/96	Boom	Released 160 litres of green fluoroscene dye, to act as a realistic marker, which the vessels crews could use to rehearse boom handling skills.
12/6/96	Burn 1	Released 15,000 litres of fresh crude oil for containment, and applied a hand held ignition system filled with a standard gel mix.
12/6/96	Burn 2	Released 18,000 litres of crude oil emulsion, weathered to a response time expectation of 12 hours, and applied the Helitorch filled with an emulsion breaking ignition mix.

4.0 Burn Performance

One of the primary objectives of these trials was to challenge the recognised limits of the ISB operating envelope. Generally, it has been found that wind speed and direction have a positive effect on flame spreading, particularly in broken ice. However, excessive winds also can make ignition and sustained burning difficult. This effect is dependant on the oil type and conditions. The presence of waves can prevent the ignition of marginally-ignitable oils and stable emulsions, due to the temporary thinning of the slick at the crest of the swell. The following guidelines and limitations concerning the requirements for conducting a burn at sea have been established (Anon. 1995):

Minimum slick thickness:
- 2 to 3 mm for fresh crude oil
- 3 to 5 mm for diesel and weathered crude oil.
- 5 to 10 mm for Bunker C and emulsified oil.

Sate of the oil:
- Evaporation loss less than 30% for most crude oils.
- Emulsion water content of less than 25%.
- For water-in-oil emulsions containing greater than 25% water, an emulsion breaker may be needed to obtain ignition.

Weather conditions:
- Wind speeds of less than 10 to 12 m/s (20 knots).
- Waves of less than 1 m for non emulsified oils, less for emulsions.
- Current velocities of less than 0.4 m/s, (3/4 knots).

These trials were performed under exacting conditions: the weather was poor, the exercise location was an unsheltered open sea environment, and the operations team had to settle for vessels of opportunity. According to the guidelines presented above, the minimum slick thickness and the state of the oil were within the limits of the ISB operating envelope, however, the environmental conditions under which these burns were carried out, (Table 3), approached or exceeded the upper limit of the optimal environmental conditions under which in-situ burning is considered feasible.

The performance of the burns was assessed from several vantages: (a) UK government patrol remote-sensing aircraft obtained video footage, (b) an invited contractor filmed the event, and (c) on a military-specification thermal imaging camera. At sea level, remote photographic evidence was recorded from all the platforms. The observers, who worked closest to the boom apex, consisted of representatives from OSRL, CEDRE, American Marine, and Spiltec and they operated from an inflatable, belonging to the "Alcyon". During burn periods, the inflatable was stationed astern of the towing vessels, to witness the burn from as close a point as possible. The consensus opinion of this team has been used to analyse the performance of the burns.

A burn rate figure of 0.07 U.S. gallons/ minute/ foot^2 (2.85 litres/ minute/ metre^2), which has been used on several controlled burns with fresh oil, was used to calculate the amount of oil burned within a nominal oil containment area, adjudged to be 1/4 (116 to 162 m^2) of the nominal burn area.

Table 3. Environmental conditions during the burn trials

Weather conditions	Burn #1	Burn #2
Sea state (Beaufort scale)	4 to 5	4
Wave height (m)	2.0 to 2.5	2.0
Wind velocity (m/s)	10 to 12	10
Current velocity (m/s)	1.8	1.8
Deployment direction	down current	down current
Relative wind direction	green (starboard) 120°	green (starboard) 120°

4.1 Burn # 1

Burn 1 involved the release of 15,000 litres of fresh oil close to the opening of the boom. The igniter used for this burn was the custom-designed hand-held igniter. The "intense burn" lasted 13 minutes. A "reduced burn" then continued for 6 minutes, during which the average area of the burn was approximately half of the intense burn. The flame heights appeared to be about 50 to 80 feet (15 to 25 m) in height during the intense part of the burn.

Upon completion of the burn, approximately 160 litres of residue remained; 80 litres floating which was 2m^2 in area and 4 cm thick, with a similar quantity coating the boom. The fraction of residue remaining constituted 2% to 3% of the amount burned. The amount burned was in the order of 36% to 50% of the amount released. The total amount of oil burnt was estimated to be between 5,300 to 7,400 litres.

4.2 Burn # 2

Burn two involved the release of 18,000 litres of emulsified oil (see Figure 2) which had been evaporated by 14% and emulsified to a 25% by volume water content. Ignition was achieved using the emulsion breaking igniter deployed form the Helitorch. The "intense burn" lasted 18 minutes. A "reduced burn" then continued 8 minutes, during which the average area of the reduced burn was approximately half of the intense burn.

Upon completion of the burn, approximately 320 litres of thick-taffy like, residue remained. The fraction of residue remaining constituted 3% to 4% of the amount burned. The amount burned was in the order of 54% to 75% of the amount released. The total amount of oil burned was estimated to be between 7,280 to 10,160 litres.

5.0 Assessment Of The Performance Of Two Igniter Concepts

Two types of igniters were tested during these trials: a hand held igniter consisting of gelled gasoline, and a Helitorch-deployable, emulsion-breaking igniter

(EBI). Both were based on the concept of using burning gelled fuel floating on the oil slick surface as the ignition source.

5.1 Custom-Designed Hand-Held Igniter

A simple ignition concept was tested in a demonstration of in-situ burning as an effective and efficient cleanup method following the Exxon Valdez spill (Allen 1991). A small plastic bag containing gelled gasoline was ignited, thrown into the water upwind from the contained oil, and allowed to drift into the slick. This resulted in the successful ignition and burning of the contained oil.

The hand-held igniter developed by Spiltec, and tested during these burn trials, was a more sophisticated version of this concept. This custom-designed igniter, shown in Figure 1, consists of a polyethylene "Nalgene" bottle filled with 1 L gasoline gelled with 0.01 kg of Sure Fire Fuel Thickener (aluminium soap). Buoyancy is provided by means of two polystyrene foam rings place around the bottle. A standard 6-inch marine hand-held distress flare is attached to the outside of the bottle and provides the ignition source for the gelled gasoline. This device is operated by lighting the flare and throwing the igniter ahead of the oil slick. The flare burns through the plastic bottle, igniting the gelled gasoline, which is then release onto the slick as the bottle melts away.

The gelled fuel used was a standard mix and consisted of 1 L of gasoline mixed with 0.01 kg of "Sure Fire Fuel Thickener" (aluminium soap). This igniter was used during the first burn with fresh crude oil. The igniter was cast into the boom opening from an inflatable boat positioned upwind of the boom. The results were that the igniter drifted directly into the apex, with the flare burning for 60 seconds. The flame penetrated the plastic jar and lit the gel. The oil caught fire shortly afterwards.

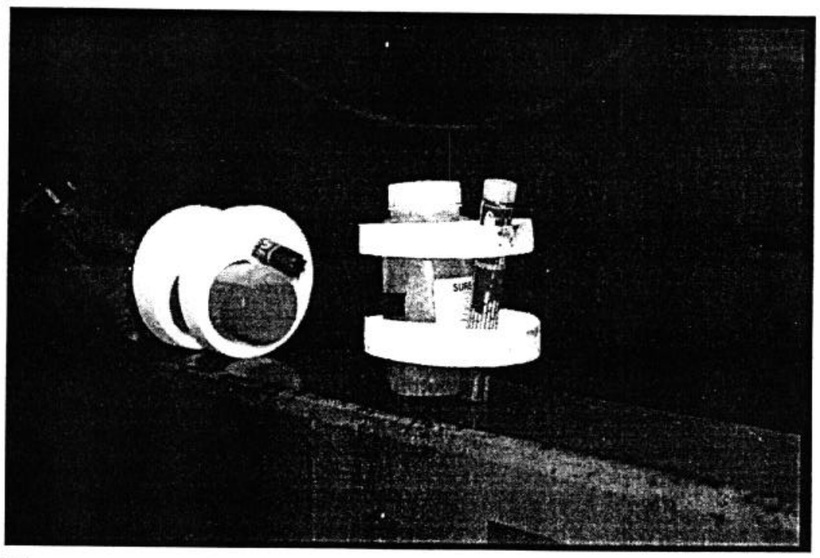

Figure 1. Hand-held igniters

5.2 Helitorch-Deployable Emulsion Breaking Igniter Concept

One of the objectives of these trials was to evaluate the practical performance of emulsion-breaking ignition technology using the Helitorch. EBI research and development studies had been performed by SINTEF during the early 90's, and the results looked promising. This prototype igniter had been tested on a small scale, but not in a fully operational manner. OSRL elected to adopt this innovative approach to burning emulsions and sent all the necessary ingredients to SINTEF for laboratory testing.

5.2.1 Background

The EBI is a Helitorch-deployable igniter, specifically designed for the ignition of emulsified oils. Much of the research leading to the development of this concept was carried out under a research programme aimed at studying the feasibility of in-situ burning as a response method for spills in broken ice, initiated by NOFO (Norwegian Clean Seas) as part of a wider NOFO programme; "Oil spill contingency in Northern and Arctic waters" (ONA). Early on in this programme, it was concluded that the ignition and burning of water-in-oil emulsions was more difficult and involved a more complex process than burning fresh or evaporated oils. Existing ignition methods, such as gelled gasoline, known to be effective with unemulsified oils, were found to be increasingly less effective with increasing emulsion water content (Spiltec, 1987: Bech et al., 1992). Alternative ignition sources were investigated and it was decided to improve upon the Helitorch technology, as this concept was deemed most suitable for oil in ice applications (NOFO's main area of interest where burning is concerned). Suggested improvements to this concept were to replace the gasoline and diesel with fuels which burn at a higher temperature (e.g., crude oil) and to use performance-enhancing additives such as emulsion breaker, combustion-promoters and foam-educing agents (Bech et al.,1993). Initial experiments were carried out with various crude oils as the fuel. However, due to the wide range in properties of crude oils, formulation of the igniter could differ significantly in terms of the additives. To minimise this variation, readily available fuels with relatively constant properties, such as bunker C, diesel and gasoline were selected for these studies.

The experimental work carried out on the emulsion breaking igniter concept lead to the development of a Helitorch-deployable igniter capable of igniting 50% water-in-oil emulsions of 25% evaporated Statfjord crude oil (Guénette and Sveum, 1995). The main findings from this work, concerning the ignition of emulsified crude oils were:

- Ignition of stable emulsions was not possible without an emulsion breaker.
- The optimal igniter fuel contained a range of light, medium, and heavy ends of crude oil. The light ends were required to enable quick ignition of the igniter fuel as it leaves the Helitorch nozzle, while the heavy ends provided the heat input required for the ignition of emulsions. The full range of oil components were required to maintain continuous burning of the igniter.
- Crude oil, and the mixed fuels, did not gel as firmly as gasoline. A marked decrease in the viscosity and gel firmness of the fuel was observed when emulsion breaker was added to the fuel prior to gelling. Considerably higher

concentrations of gelling agent were required to achieve the similar gelling properties as a gelled gasoline.

- Continuous stirring of the fuel following the addition of the gelling agent was found to increase the rate of gelling and the viscosity of the gelled fuel and, also, was essential in producing an evenly gelled fuel.
- The igniter had to be deployed upwind and directly onto the emulsion slick for ignition to occur. Igniters deployed upwind from the slick, and allowed to drift into the emulsion, did not result in ignition. Igniters had to be deployed closer together in high winds due to limited lateral flame spreading over stable emulsions.

This prototype igniter was tested in the field using a modified Helitorch deployed from a crane on a boat, under relatively calm environmental conditions. Following the promising results from these tests, it was recommended that the EBI be tested under more realistic operational and environmental conditions in order to fully assess the capability of this technique. The OSRL in-situ burn trials provided that opportunity. These trials marked the first time that this igniter was used at sea and deployed from a helicopter.

5.2.1 Pre-trial tests

Prior to the field trials, laboratory burns were conducted to test the EBI with emulsions of Larkwhistle Farm crude representative of oil conditions which could feasibly be encountered at sea after periods of up to 24 hours. As this was a prototype igniter, which had not been previously tested with any oil other than Statfjord crude, tests were conducted with the oil selected for the offshore trials to ascertain the effectiveness of the igniter.

A dozen test burns were carried out in 1 m^2 metal pans at the SINTEF Norwegian Fire Laboratory inside the fire test hall (Figure 2) to test the igniter with emulsions of Larkwhistle Farm crude at various degrees of evaporation and emulsification. The effectiveness of gelled gasoline, the usual fuel used with the Helitorch, was also assessed. The number of igniters was varied in these tests, with each igniter consisting of a fuel volume of approximately 200 ml (approximately the size of the gelled fuel globules when released from the Helitorch). The test pans contained sea water topped with a layer of 5 to 10 mm of the test oil. The igniters were placed onto the slick surface and ignited using a propane torch. The effectiveness of the igniters was evaluated in terms of ignition time, defined as the time required for flames to spread over the entire slick area (1m^2). Aa a general guideline regarding the ignition of spilled crude oil is that once 1 m^2 of the slick is ignited, the burn is considered underway (Buist et al, 1994).

Results from these test burns indicated that fresh and evaporated Larkwhistle Farm crude oil could be readily ignited using gelled gasoline. Emulsions made with 15% evaporated crude and containing 25% water also could be ignited with gelled gasoline. However, ignition and flame spreading was quicker when the EBI was used. Increasing the water content of this fraction resulted in a substantial increase in the time required for ignition. Ignition and flame spreading was more difficult with emulsions of oil evaporated to 27% and containing between 40 and 60% water. No ignition was possible with gelled gasoline and several EBI igniters were required to ignite these emulsions, compared to just one in the tests with the less weathered oil.

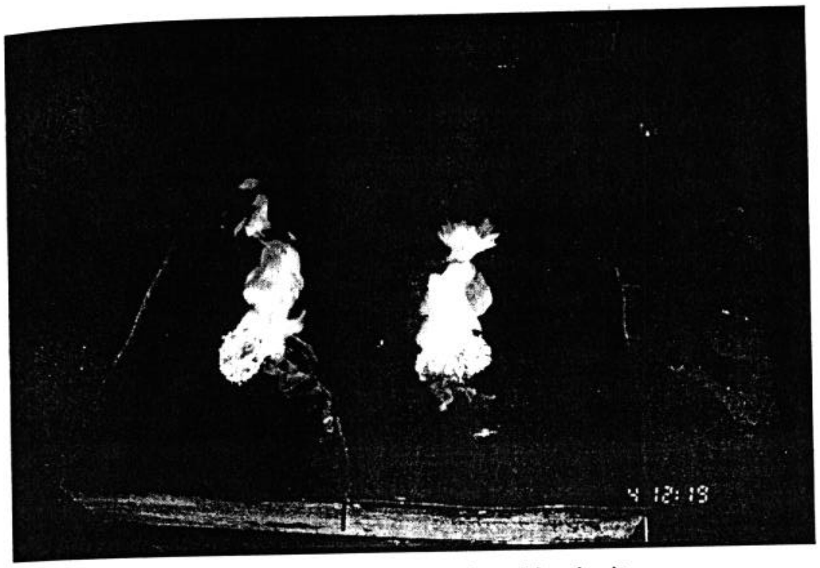

Figure 2. Laboratory testing of emulsion breaking igniters

Given that the Larkwhistle Farm crude used in these test contained a demulsifier, it was not surprising that the less weathered oil could be ignited with the gelled gasoline. As indicated in the emulsion formation tests, although the maximum water uptake ability of this oil was high, this oil does not form very stable emulsions until the oil has been evaporated to approximately 25% (vol.).

The igniter formulation given in Table 4, which proved effective in the laboratory tests, was recommended for the off-shore trials. The bunker C and diesel components of the igniter fuel, as recommended following the laboratory test, were replaced with an intermediate fuel of similar properties, as this was the most readily available heavy fuel at the OSRL base at the time of the trials.

Table 4. Emulsion Breaking Ignition Formulation

Item No.	Ingredients	Ratios (approximate)
1	Intermediate Fuel 30 (IF 30) Comprises 39% Gasoil and 61% IF 380	39%
2	Gasoline	57%
3	Alcopol 60	4%
4	Sure Fire	15% by Weight of Items 1+ 2+ 3

5.2.3 Off-Shore Burn Trials

Some preparations had to be implemented prior to this trial. OSRL purchased a Simplex Helitorch, Model 5400, 30 US gallon capacity which had FAA type approval, but this did not accredit it for UK use. Before the unit could be used on these trials, OSRL had to earn Civil Aviation Authority (CAA) approval. The air worthiness licence to carry and deploy the system, underslung by a Bond Sikorsky S76A, was only granted after a flight test, a Helitorch firing test, and a subsequent modification program, had been performed and inspected. The licence process lasted 6 months to obtain and was restricted to the specific unit tested, and to use of Bond Helicopters Limited as the carrier. Other carriers could apply to operate the system, but they would have had to apply to the CAA for a supplement to their Rotorcraft Flight Manual detailing the installation inspection routine. The modifications carried out by OSRL to address the deficiencies identified by the CAA are shown in Table 5.

Table 5. Helitorch Modifications Ordered By CAA

Mod. No.	Description
1	Drum vent flame retarder (already incorporated by OSRL at initial inspection)
2	Drum retention straps - two 500 Kg ratchet tensioned cargo straps to secure the drum to the frame
3	Lower strop attachment fittings - articulated linkages to alleviate cable kinking
4	Propane cylinder securing brackets - fail safe clamping arrangement
5	HT lead re-routing and clipping - separation from propane and petroleum gel pipes and p-clipping to base

A trial run with the Helitorch and the recommended igniter formulation was conducted at the OSRL base prior to departure for Lowestoft to ensure that the fuel would be deployed as expected during the sea trials. A small batch (approx. 20 L) of the igniter was prepared in the Helitorch and the gelled fuel released from a height of approximately 5 m into a metal pan. The Helitorch appeared to be functioning properly, releasing a stream of burning gelled fuel which broke up into globules before hitting the pan. The fuel remained ignited throughout the fall and continued burning after landing in the pan.

As noted above, a significant increase in gelling powder is required to produce the necessary gel properties for this emulsion-breaking igniter, as compared with a standard formulation. This is caused, in part, by the heavy fuel used in the formulation, but is mainly due to the addition of the demulsifier. Based on the requirements for the 30 US gallon model Helitorch, the difference is 1.135 kg for a gasoline gel as compared with 12 - 15 kg for this EBI gel. This extra dosing requires very careful mixing to avoid a lumpy gel. The EBI recipe was deployed using the Helitorch.

The significant increase in gelling powder required by the EBI mix over the standard mix, meant that great care had to be taken in adding the powder to the fuel. Unfortunately mistakes were made. These included: not using fresh powder (it was 2 years old), not sieving the powder; not making up the mix in a batch method (it was made in one go); and rushing the mix (a communication problem). These factors resulted in a gel of uneven consistency. Inspection of the Helitorch upon completion of the trials revealed that the EBI mixture had clogged the feed pipe to the nozzle. A semi-solid plug of gelled fuel was later removed at the OSRL workshops.

The Helitorch was deployed under a Bond S76A helicopter. A stand-alone, 28-volt DC feed battery was fitted in the aircraft, and was used to power the electrical actions. Airborne, the Helitorch hung in line with the aircraft, with the nozzle facing to the rear. Initially, the aircraft flew a dummy circuit so that the observers in other aircraft and vessels could see the equipment and so that the aircrew could observe the arrangement of vessels and boom. The helicopter then flew by the vessels at 35 knots/170 feet for a full test run. It was apparent that the ignited gel fuel was extinguished prior to hitting the sea surface. A further test run was flown at 120 feet and 25 to 30 knots. Ignited oil did reach the sea surface but extinguished immediately. At 60 to 70 feet and 20 to 25 knots, burning gelled oil reached the surface. Four attempts were made to ignite emulsified crude oil contained within the fire boom. The fourth attempt was successful (Figure 3).

Although the burn started after the fourth pass, the consensus opinion by most observers was that the fire had, in fact, started on pass three, when an orange burst was seen to emanate from the oil, only to be quelled by the downwash from the propeller blades. It is believed that a smoulder fire had started after pass number three which just needed time to take hold, only manifesting itself once the aircraft had made its fourth and final pass.

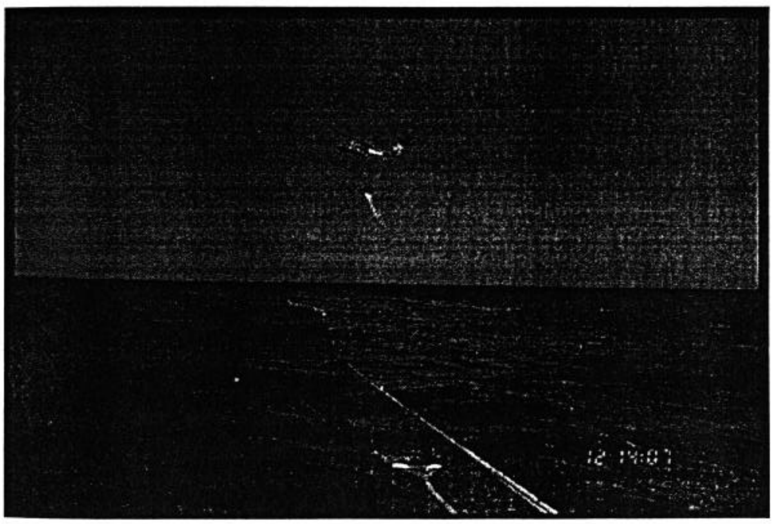

Figure 3. Deployment of the emulsion-breaking igniter

One important aspect of this igniter test was the deployment of this igniter formulation under realistic conditions. In earlier meso-scale field tests, the maximum height from which the igniters were deployed was approximately 2 to 3 m, and the prevailing wind conditions were very calm compared to these sea trials. The fuel mixture used in the emulsion breaking igniter is not as flammable as gelled gasoline. There was, therefore, some uncertainty as to whether the ignited globules of the EBI fuel would remain burning when released from higher altitudes. Compared to the meso-scale tests, the time between release of burning fuel from the Helitorch and contact with the oil slick would be longer and the depth to which the igniters would plunge below the sea surface would be greater. There were also concerns related to the effect of the downwash from the propeller blades.

These problems were encountered during the trials, as outlined above. The conclusions provided by the helicopter pilot were that slow speed, not exceeding 25 knots, would appear to be essential to avoid the gelled fuel breaking up into too fine a flow. A minimum height of 60 to 70 feet is recommended for S76 helicopter. Very slow airspeed, or the hover, should be avoided, as rotor downwash affect the performance of the Helitorch by causing blow-out of burning globules.

This is consistent with previous experiments with the Helitorch, where speeds of greater than 15 m/hr were recommended (Allen, 1987). Previous tests have shown that the Helitorch should be flown at altitude of 8 to 23 m (26 to 75 feet) and with speeds of 40 to 50 km/hr (Allen, 1987). The suggested altitude range is to provide accuracy during the release, to reduce the loss of gelled fuel while burning in the air, and to prevent the blow-out of smaller globules on the surface by the downwash of the helicopter.

6.0 Summary And Conclusions

These trials were not designed as an experiment. OSRL knew that fresh oil burned and had no desire to validate any previous scientific research, other than to advance any findings. OSRL hoped to learn the practical considerations attached to the ISB strategy. OSRL put this aim to the test using a response-prepared fire boom system, deployed in an offshore location, using "vessels of opportunity", and released weathered oil. Along with some unpredictable weather, all the elements were present which constitute a real event.

The results were encouraging: oil aged by 12 hours with a 25% water content burned down to a 3 - 4% residue; the fire boom survived two burns intact; the hand held ignition systems worked; and, the Helitorch lit emulsified oil using EBI. The trials were not without their problems and adjustments had to be made, but the trials met the objectives.

In summary, these trials demonstrated that burning can be successfully carried out under conditions approaching recognised limits for these techniques, particularly in terms of the environmental conditions. Oil was ignited and continued to burn with wind speeds up to 15 m/s.

These trials provided an excellent opportunity to evaluate two igniter concepts; the hand-held igniter; and, an emulsion breaking igniter, under realistic operational and environmental conditions. These off-shore burn trials marked the first time that the Emulsion Breaking Igniter was deployed from a Helitorch slung beneath a helicopter, and was in fact the first-full scale testing of this igniter concept.

The simplicity of the logistics required for use of a hand-held igniters which would favour the use of this approach over the Helitorch method for fresh or lightly weathered. More heavily weathered oils (i.e., stable emulsions) would require the use of an emulsion-breaking type igniter or the application of an emulsion breaker to the slick prior to deployment of the gelled gasoline igniter. Aerial deployment of igniters offers the advantage of allowing more accurate positioning of the igniters onto the oil slick, which is an important consideration when dealing with stable emulsions requiring many ignition point sources, or oil spills in broken ice where the oil coverage can be patchy.

7.0 Acknowledgements

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