TEST AND EVALUATION OF THE HELITORCH FOR THE IGNITION OF OIL SLICKS

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ABSTRACT

A field test and evaluation has been completed involving the use of gelled gasoline for the aerial ignition of oil under arctic conditions. This research has been conducted as the second phase of a much larger effort to identify or develop efficient, inexpensive aerial ignition concepts. All research has been conducted under the sponsorship of Alaska Clean Seas (an association of 14 oil companies with interest in Alaskan operations), with project administration handled by Shell Western E&P Inc. Results of several field tests under both temperate and Arctic conditions reveal that burning gelled gasoline can be released effectively from a helicopter-slung Helitorch and remain burning upon impact with water and/or oil. With release heights of 1 to 18 meters, burning gelled gasoline has been found to survive the splash effects upon impact and continue to burn for several minutes. Successful ignitions of fresh and weathered crude oil have been conducted with 2 1/2- to 12 1/2-mm thick oil layers on shallow water and ice, with air temperatures well below freezing, and with winds up to 29 km/h (18 mph). By varying the speed and height of the Helitorch, the distribution of burning globules at ground level can be selected involving a nearly continuous narrow swath of flame to one involving globules separated by a meter or more. Tests have been conducted with a number of nozzle configurations on the Helitorch creating ground-level distributions of burning globules with swath widths that vary from approximately 1 to 8 meters. Gelled gasoline, ignited and released from a Helitorch, appears to be an effective means of producing numerous oil ignition sources quickly, safely and at a cost of only pennies per ignition point.

BACKGROUND

This paper contains a summary of a much more extensive report prepared by Spiltec and administered by Shell Western E&P Inc. for Alaska Clean Seas (ACS). The original report, Refinement of Aerial Ignition Systems (Spiltec 1987), presents the results of one of several R&D efforts sponsored by ACS during 1986.

Various methods for the ignition of oil slicks were examined by Spiltec for Alaska Clean Seas during 1985 resulting in the publication: Survey And Analysis Of Air-Deployable Igniters (Spiltec, 1986). Five basic ignition systems were examined in the course of this project including the Canadian Environmental Protection Service (EPS) "PYROID" igniter, the Dome igniter (developed by Dome Petroleum Ltd.), laser ignition systems (under sponsorship of EPS), the Premo Aerial Ignition Device (manufactured by Premo Plastics Engineering Ltd.), and the Helitorch (manufactured by Simplex Manufacturing Co.). Each of these ignition systems represents a relatively unique approach for initiating the in-situ combustion of petroleum products.

Environment Canada. Arctic and Marine Oilspill Program (AMOP) Technical Seminar, 10th. Proceedings. June 9-11, 1987, Edmonton, Alberta, Canada, Environment Canada, Ottawa, Ontario, 243-265 pp, 1987.

The first two ignition systems (PYROID and Dome igniters) have had substantial exposure to actual field tests. These tests have resulted in several successful ignitions of floating oil slicks under a range of environmental conditions. These pyrotechnic devices, however, did have certain disadvantages in terms of safety, shelf-life, availability, speed of deployment and cost. The laser ignition concept, while still in the experimental stage, also showed several drawbacks associated with instability of beam-focussing from a helicopter, wind-effects during oil preheating, energy requirements, and cost.

These operational considerations and cost constraints became especially important as one examined the ignition requirements for a spill involving numerous isolated patches of oil. Should a major spill in the Arctic, for example, ever result in the uncontrolled movement of a continuous oil spill into a moving ice field, oil could conceivably surface as relatively small concentrations over an extensive region. In-situ burning could require the release of a very large number of individual ignition sources (S.L. Ross, 1981 and 1984). During such an event the cost to manufacture and deploy the igniters, as well as the speed and accuracy with which they could be distributed, would be of paramount concern.

As described in the above-referenced document (Spiltec, 1986), these operational and economic considerations highlighted the need to refine our understanding of existing aerial ignition concepts and equipment. The latter two ignition systems (Premo "AID" igniter and Helitorch*) seemed to have some of the most promising characteristics, even though they had never been used to initiate the combustion of an actual oil spill. Whether it be the use of a chemical starter (AID igniter) or the dropping of burning gelled gasoline (Helitorch), these approaches avoided the problems of finite inventories, limited shelf-life, time-consuming deployment, and high cost.

The research carried out during 1986, therefore, focussed on the feasibility of using the Premo AID igniter (or some similar configuration) and the Helitorch for the ignition of floating oil. After a few preliminary field tests it became apparent that the Helitorch offered considerable potential as an efficient aerial ignition device. Such tests also revealed that some major design changes would be needed in order to use the AID-like device. All further testing was then devoted exclusively to the Helitorch ignition system.

Igniter Performance Criteria

During the field-testing portion of this project, it was essential that igniter performance be based on the full range of actual oil spill "targets" that could be considered for in-situ burning. Such targets might be single large spills that are relatively thick and continuous (e.g., at a major tanker accident), or they might be a large number of isolated slicks such as those described above. If a major spill in the Arctic ever did occur, it is possible that during early breakup, oil-contaminated melt pools could result

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* The Helitorch is described in detail later in this paper. The Premo Aerial Ignition Device (AID) is a polystyrene spherical container about 1¼ inches in diameter with about 3 grams of potassium permanganate inside.

with irregular shapes ranging from typically 1 to 10 meters across. Some pools could be much larger, and spacings between pools could vary from a few meters to several hundred meters. The efficient ignition of such pools of oil could require a separate igniter for each pool thereby involving a very large number of individual ignition points.

In the above scenario, it would also be necessary to deliver the ignition sources to the "target" slicks with sufficient accuracy to impact most, if not all, of the spilled oil. The igniters would have to work reliably from altitudes that would ensure a reasonable degree of accuracy; they would have to survive falls onto ice and into shallow pools (including water); and they would have to operate effectively under relatively strong winds. Once in contact with an oil layer, the ignition source would need to provide sufficient heat to volatilize the oil nearby, and burn long enough and hot enough to create a self-sustaining flame over the surrounding oil. It is most desirable to have an ignition source that produces a "soft" flame; that is, one where there is a minimal disturbance of the surrounding oil. The use of gelled gasoline has considerable promise because such an ignition source can blend with and promote ignition of the surrounding oil. And, since the gelled gasoline is prepared as needed, there are no concerns regarding igniter shelf-life.

Another important criterion for effective and safe use is the need to avoid any open flame or sparks within the aircraft being used for deployment. The ignition source should be activated outside the aircraft so that any possibility of fire onboard is eliminated. And, if possible, all flammable materials should be carried outside the aircraft or at least be easily jettisoned in the event any equipment malfunctions or an emergency landing is necessary.

One final consideration involves the need to minimize and hopefully eliminate any debris following the use of an igniter. Unlike most ignition devices available to date, the Helitorch does not leave behind any structural components that could persist in the environment.

Objectives

The objectives during the Helitorch field trials (Figure 1) included an initial assessment of the survivability of burning gelled gasoline upon impact with water (Phase 1). Since burning globules from a conventional Helitorch configuration showed promise of survival, controlled low-level drop-tests were then conducted (Phase 2) to evaluate the importance of globule size, gelling-mix-to-fuel ratios, fuel type, and drop height. The influence of arctic conditions on globule/oil interactions, preheating times, ignition potential, and susceptibility to wind were also examined.

Objectives during Phase 3 involved the release of burning gelled gasoline (again under arctic conditions) from a Helitorch onto simulated melt pools with fresh and weathered crude oil. The results of these tests then led to the final field-test objectives (Phase 4) to determine the ground-level distributions of burning globules that could be achieved with different nozzle configurations at different release heights. Detailed descriptions of the environmental conditions and experimental procedures used during these four phases are contained in the final project report Refinement of Aerial Ignition Systems (Spiltec, 1987).

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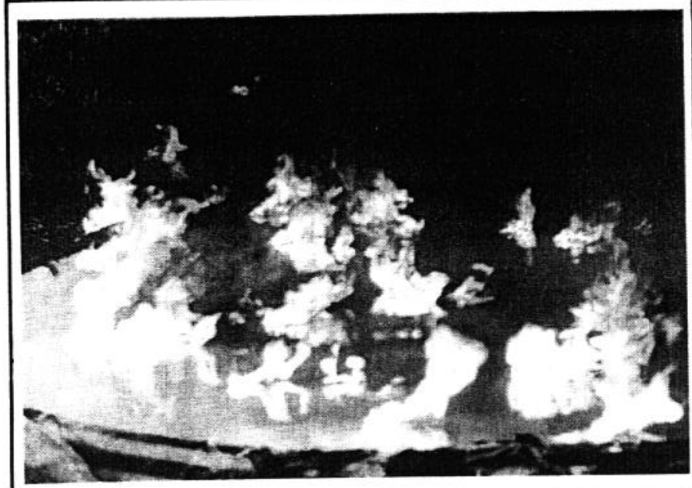
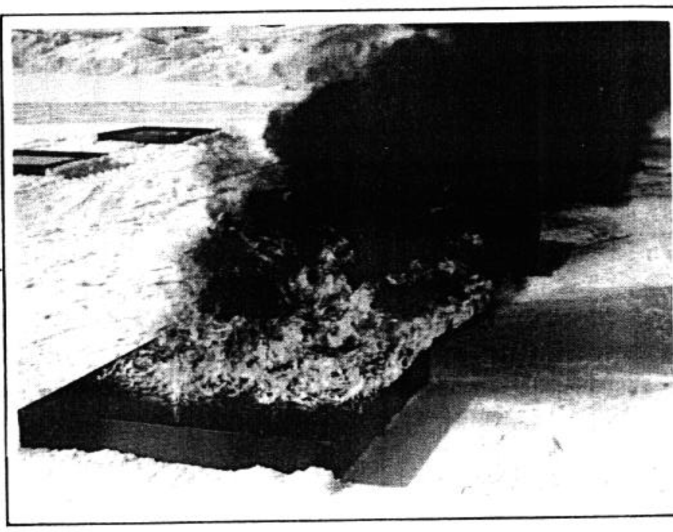


PHASE 1

Initial Warm-Water Drop Tests
With & Without Oil
March, 1986 Newberg, Oregon

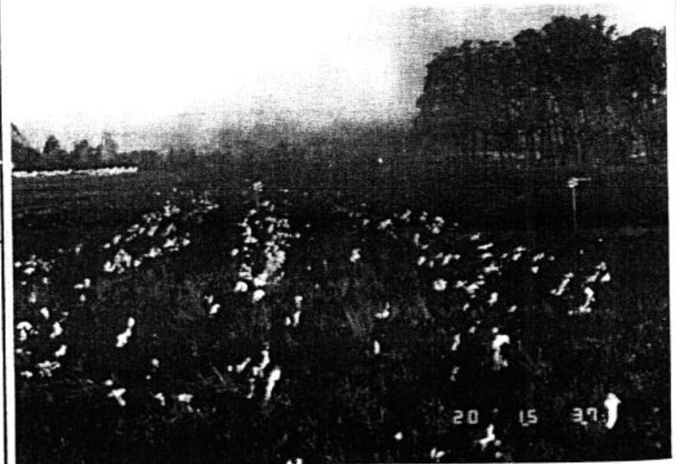


PHASE 2

Static, Cold-Weather, Ignition
Feasibility Tests With
Relatively Fresh Oil
April, 1986 Prudhoe Bay, Alaska

PHASE 3

Simulated Melt-Pool Ignition Tests
With Fresh and Weathered Oil
June, 1986 Prudhoe Bay, Alaska



PHASE 4

Surface Ignition Point
Distribution Tests With
Various Nozzle Configurations
And No Oil
October, 1986 Newberg, Oregon

FIGURE 1 PHASES OF HELITORCH R&D PROGRAM -1986

Physical Description of the Helitorch

The Helitorch (Figure 2) is a proven aerial ignition system commonly used by the U.S. Forest Service and Canadian Forestry Service for the burning of forest slash and for setting backfires during fire-control operations. It is a completely self-contained unit consisting of a fuel barrel, pump, and motor assembly slung beneath a helicopter and controlled with an electrical connection from the Helitorch to a panel in the cockpit. The fuel barrel can be filled with a gelled gasoline or gasoline-and-diesel mix which is then pumped upon demand to a positive-control shut-off valve and ignition tip. The gelled fuel mixture is ignited with electrically fired propane jets as it exits one or more nozzles protected by wind shields. The burning gelled fuel falls as a highly viscous stream and quickly breaks up into individual globules before impacting the ground.

In fighting forest fires, the Helitorch is normally operated at heights and speeds much greater than those desired for the ignition of oil slicks in the Arctic. Depending upon the actual nature of the slicks to be ignited, lower altitudes and airspeeds have been found to enhance the accuracy, burn-times, and distribution of the burning globules.

The Helitorch ignition system is manufactured by Simplex Manufacturing Co. in Portland, Oregon, and is approved by the Federal Aviation Administration (FAR Part 137). Users of the system in the United States are cautioned that certain federal regulations (46 CFR) require approval by the Office of Hazardous Materials Transportation (OHMT), U.S. Department of Transportation, for transporting fuel beneath a helicopter (e.g., sling-loaded Helitorch) and for transporting the fuel to support a gelling operation at a remote site. Exemptions from these requirements have been obtained for such operations as forest fire control; however, application for exemption involving oil spill control must be requested.

The Helitorch (Figure 2) can be carried by any helicopter with a cargo hook and a 24- to 28-volt power supply. When the single-point suspension cable system is used with helicopters carrying swivel cargo hooks (e.g., Bell 205, 212, 412), the Helitorch may experience certain degrees of freedom during flight that may alter its globule-distribution (or swath-generating) capabilities.

The weight of the Helitorch with a full 55-gallon (208-liter) drum is approximately 242 kilograms (534 pounds). As illustrated in Figure 2, the entire unit is connected to a helicopter with a support cable assembly that can be jettisoned quickly from the helicopter's cargo hook. The electrical cable has a quick-disconnect plug near the helicopter, allowing the plug to be pulled apart if the unit is released in an emergency.

Depending upon the helicopter used (i.e., with fixed or swivel cargo hook), the Helitorch support assembly may be rigged to include a self-releasing horizontal support arm or stabilizing bar to keep the Helitorch oriented properly. The stabilizing bar can be suspended at one end directly below the cargo hook, with the other end of the bar resting on one of the helicopter's skids. The Helitorch's support cable assembly is then connected directly to the stabilizing bar. This approach provides a stable two-point connection while permitting the Helitorch to be jettisoned if necessary. Both support systems (i.e., with and without the stabilizing bar) were used during the field trials described in this report.

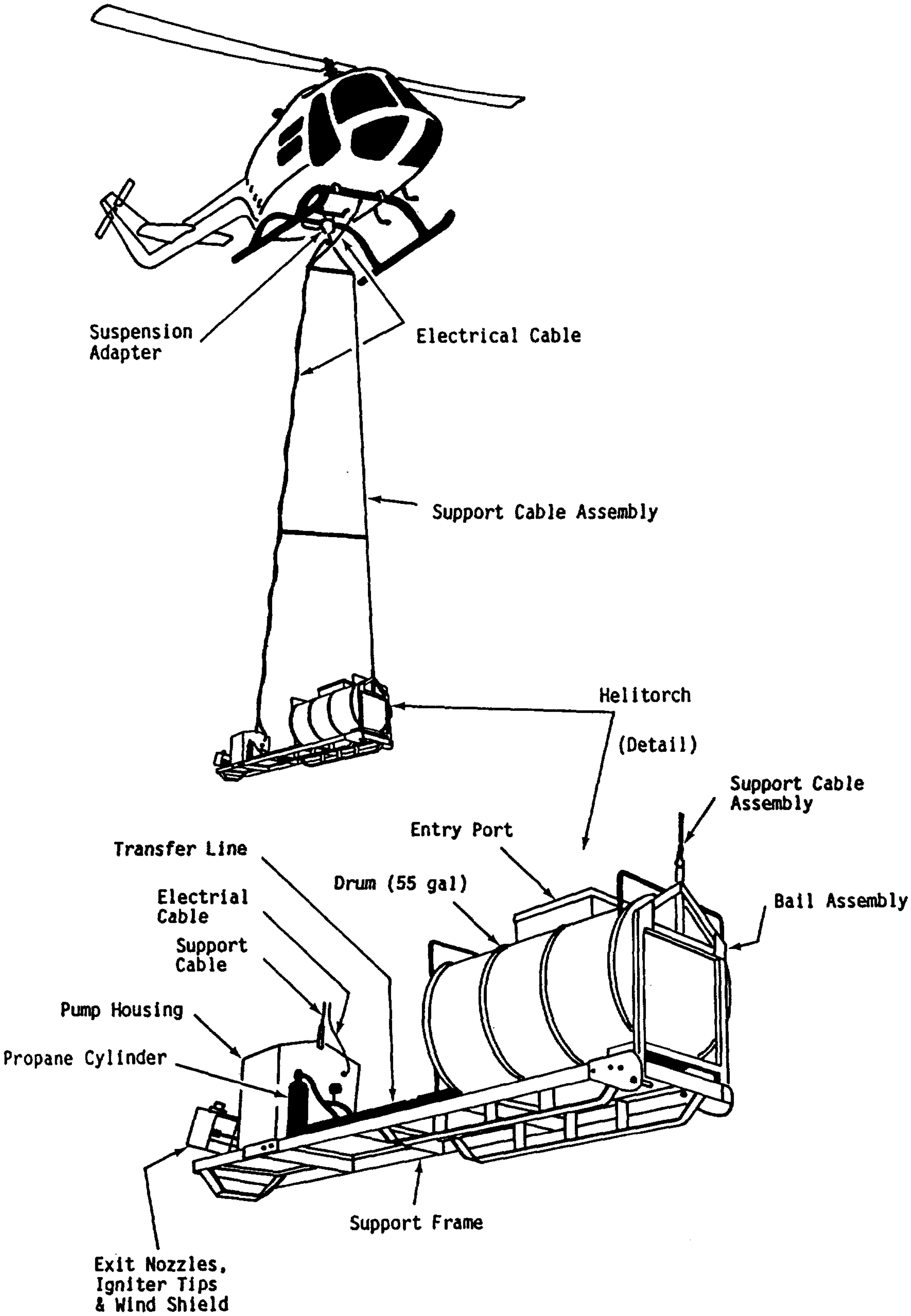


FIGURE 2 HELITORCH COMPONENTS AND SUPPORT SYSTEM

Throughout this project the gelling mix used to thicken the gasoline (or diesel in some cases) was SUREFIRE, a gelling agent available from Simplex, (Portland, Oregon) and from FIREFLEX MFG. LTD. (Langley, B.C.). SUREFIRE is a very fine powder which when mixed with liquid fuel produces a smooth, viscous gel. When typical ratios of 4 to 6 pounds of SUREFIRE to 55 gallons of fuel are used, (i.e., 9 to 13 grams/liter), adequate viscosities for Helitorch use can normally be achieved within a matter of minutes at room temperature. The gelling mix is poured through the entry port of the Helitorch fuel storage drum, which is equipped with a hand crank for mixing. Experiences gained in handling SUREFIRE at different ratios and under different temperatures during this project are presented below.

SUMMARY OF FIELD TEST RESULTS

The results of field tests conducted during the four phases of this project have been synthesized and categorized as follows:

- Gelled Gasoline Performance on Water
- Ignition of Crude Oil with Gelled Gasoline
- Helitorch Operational Performance
- Nozzle Performance
- Preparation of Gelled Fuel

Based on the findings of this R & D effort, it can be concluded that the Helitorch does provide an effective tool for the aerial ignition of combustible oil accumulations even under arctic conditions. Key advantages of the Helitorch include improved safety, speed and efficiency during deployment; no shelf-life constraints; no post-use debris; and low cost.

Gelled Gasoline Performance On Water

(a) Burning gelled gasoline globules released from heights ranging from 1 meter to 18 meters remained burning after impact with water alone. Even without oil on the water's surface, splash effects were tolerable, and elongated "pancakes" of gelled burning fuel resulted.

(b) Burning globules released to an oil-free water surface produced floating "pancakes" with areas (if expressed as a circular mass) typically 13 to 18 centimeters in diameter. When the globules were released from the higher altitudes of 15 to 18 meters, the surface areas were reduced slightly due to globule breakup at times and due to the reduction of volume while burning and falling a greater distance.

(c) Controlled drop tests in Phase 2 revealed that for globule volumes between 1/4 cup (59.3 cc) and 2 cups (474 cc), the thicknesses and burn times are relatively insensitive to the volume of the globule.

(d) The accumulated experiences from all four phases of this project suggest that the average globule sizes produced by the Helitorch with its standard nozzle at heights of 18 meters or less will be between 60 and 120 cc. With gelling-mix-to-gasoline ratios of 5-1/2 to 11 pounds per 55 gallons of fuel (i.e., 12 to 24 grams/liter), such globules will likely achieve thicknesses of 0.5 to 0.8 centimeters on oil-free water surfaces. The resulting burn times are typically between 4 and 6 minutes.

Ignition Of Crude Oil With Gelled Gasoline

(a) Cook Inlet and Prudhoe Bay crude oils (2-1/2 to 12-1/2 millimeters thick) have been ignited successfully with gelled gasoline released from heights of from 0 to 8 meters (Figures 3 and 4). Field data suggest that such ignitions should also be successful at heights of from 8 to 18 meters or higher. Most of the actual ignition tests with a Helitorch were conducted with Prudhoe Bay crude oil weathered from 0 to 14 days, on shallow water and/or ice, and with air temperatures well below freezing.

(b) In most cases a single globule of burning gelled gasoline was sufficient to preheat and ignite the surrounding crude oil within 30 to 60 seconds following impact. During controlled experiments, it was found that burning globules or surface "pancakes" needed to be at least 4 to 5 centimeters in diameter to insure ignition under relatively calm conditions.

(c) The ignition of the fresh and weathered crude oil layers in Phase 2 was possible with winds of 10 to 15 mph (16 to 24 kilometers/hour); however, surface globules approximately 60 to 120 cc in volume (i.e., surface areas approximately 13 to 18 centimeters in diameter) were necessary to prevent a blowout of the flame. During several successful ignitions of crude oil layers in Phase 3, surface winds had reached speeds of 18 mph (29 kilometers/hour).

(d) Controlled drop tests in Phase 2 revealed that average "pancake" thicknesses of dropped globules were two to three times greater (i.e., 1 to 2 centimeters or more) with a surrounding oil layer than with oil-free water. Had such tests failed to ignite the surrounding oil (ignition typically occurring in 10 to 15 seconds under calm conditions), the thickened globules could have burned for periods in excess of 10 minutes.

(e) During the above-referenced controlled drop tests under calm conditions, there was no noticeable difference in the efficiency of igniting oil with various gelling-mix-to-fuel ratios. Nor was there any significant difference in ignition time with different globule volumes, as long as the surface area was more than 4 to 5 centimeters in diameter. This critical area represents a volume of about 0.05 cup (or 12 cc) for the average thicknesses experienced.

(f) The results of the oil-ignition tests suggest that for the oils and environmental conditions experienced during this project, the standard Helitorch configuration is capable of producing adequate ignition sources for crude oil weathered up to 2 weeks during spring conditions in the Arctic. Ignition tests were conducted under warm (18°C) and cold (-16°C) weather conditions, on water (with and without ice), and with winds from 0 to 18 mph (29 kilometers/hour).

Helitorch Operational Performance

(a) Minor modifications are needed to the electrical cable and connector on the Helitorch to prevent the connector from opening too easily during

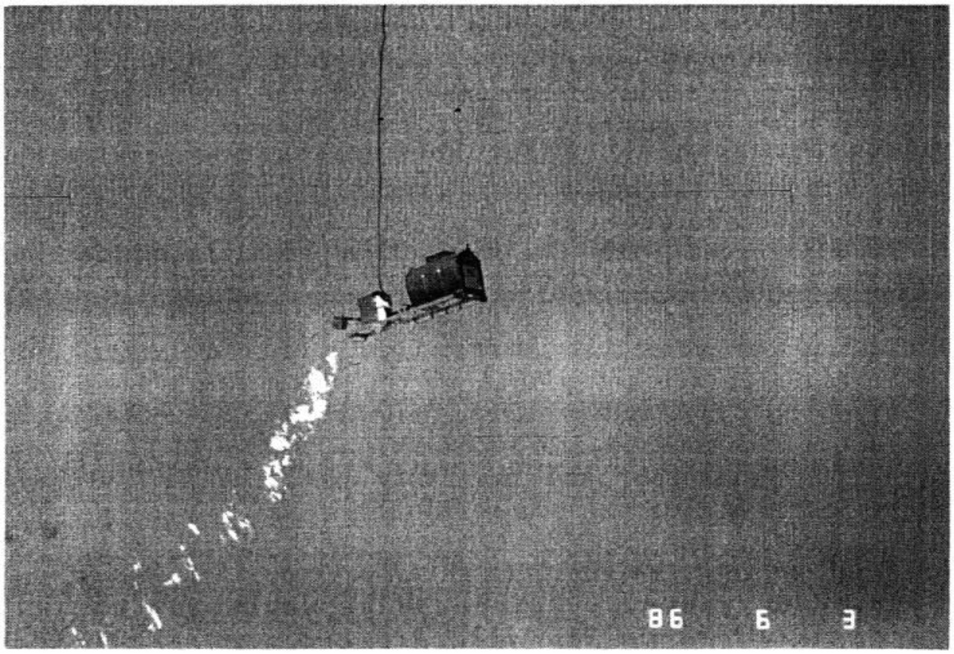


FIGURE 3 RELEASE OF BURNING GELLED GASOLINE FROM HELITORCH DURING SIMULATED MELT-POOL IGNITION TESTS

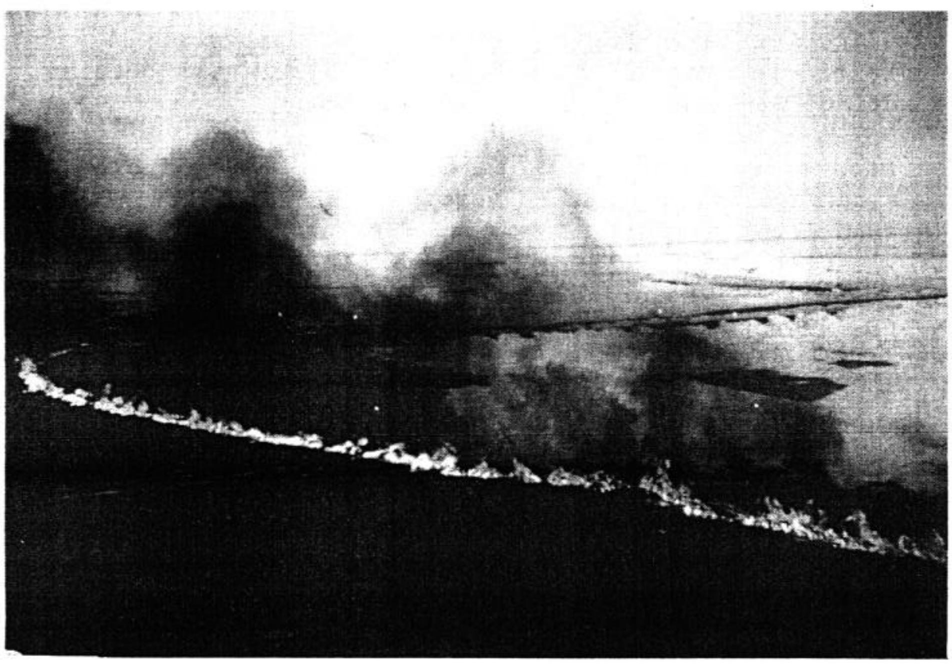


FIGURE 4 NEARLY CONTINUOUS PATH OF BURNING GELLED GASOLINE FOLLOWING SLOW, LOW-LEVEL PASS OF THE HELITORCH

flight. When the single-point suspension cable system is used with helicopters carrying swivel cargo hooks (e.g., Bell 205, 212 and 412), the resulting freedom of movement for the Helitorch can pull the connector open prematurely. This same freedom of movement can also allow the Helitorch to assume any number of orientations relative to the direction of flight, thereby presenting a problem should alternate nozzles be used to widen the swath width of the torch. These problems can be eliminated with the use of a stabilizing bar between the Helitorch's support cable assembly and the helicopter's landing skid.

(b) The Helitorch is relatively simple to operate, and very little instruction is required for the pilots of the helicopter to use it safely and effectively. Considerably more instruction is necessary for ground support and maintenance crews to mix and transfer gelled gasoline, to service the Helitorch, and to insure that the Helitorch is properly handled before and after each sortie.

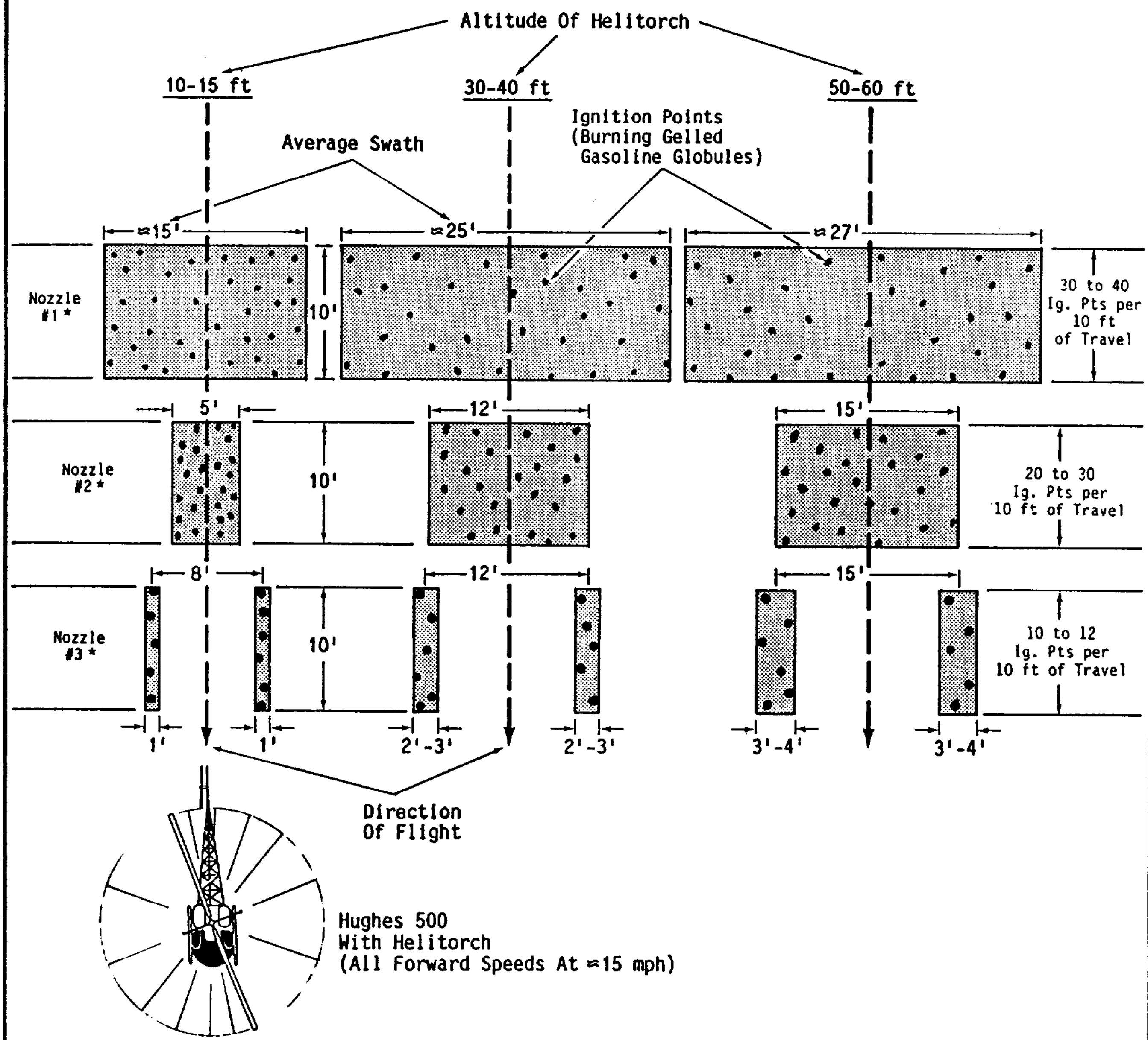
(c) When target slicks are small (1 meter or less in diameter), accuracy is difficult to achieve. This is particularly true with larger helicopters such as the Bell 212. Improved accuracy should result with a) smaller helicopters, b) helicopters with good downward visibility, c) a two-point suspension assembly to arrest rotation of the Helitorch unit, and d) pilots experienced with the equipment.

(d) Experience has shown that the Helitorch should be flown at altitudes of 3 and 8 meters and with speeds in excess of 15 mph (24 kilometers/hour). 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 blowout of smaller globules on the surface when the helicopter is flying at low speeds. Speeds of 24 kilometers/hour or more are recommended to prevent the blowout of burning globules on the surface with the helicopter's downwash.

(e) When used at altitudes of 3 to 8 meters, the Helitorch with standard nozzle configuration produced burning globules that fell within a swath at ground level that was less than 1 meter wide. When it was flown at approximately 24 kilometers/hour over the ground, individual globules would usually be separated by less than 1/2 meter. If the system is flown at slower speeds and higher altitudes (to prevent the blowout of surface flame), a nearly continuous line of burning gel can be produced at ground level. Greater swaths can be achieved with different nozzle configurations, as described below.

Nozzle Performance

(a) It is possible to remove the standard Simplex Solid Stream nozzle (orifice = 7/16 inch or approximately 1.11 centimeters), which at recommended altitudes (for igniting oil slicks) produces a narrow swath of burning gelled globules typically between 1/4 cup (60 cc) and 1/2 cup (120 cc) in volume. Three multiple nozzle configurations were tested in Phase 4 (Figure 5) resulting in a variety of globule distributions and swaths ranging from 5 to 27 feet (i.e., approximately 1-1/2 to 8.2 meters).



*Nozzle Configuration 1: Six VeeJet Solid Stream nozzles (three nozzles mounted on each of two triple spray manifold assemblies); manifolds positioned so that nozzles, with 15° between each nozzle, cover a full 75°. Nozzle orifice = 3/16 inch.

*Nozzle Configuration 2: Two TeeJet Off-Center OC150 (flat spray) nozzles mounted with 30° between nozzles. Nozzle orifice = 3/8 inch.

*Nozzle Configuration 3: Two Simplex Solid Stream nozzles mounted with 30° between nozzles. Nozzle orifice = 7/16 inch.

FIGURE 5 SWATH WIDTHS AND IMPACT POINT DISTRIBUTIONS FOR THREE DIFFERENT NOZZLE CONFIGURATIONS AND THREE RELEASE ALTITUDES

(b) Nozzle Configuration 1 (six VeeJet Solid Stream nozzles - Figures 6 and 7), operating from altitudes of 30 to 60 feet (9 to 18 meters), resulted in uniformly dispersed globules typically 3 to 4 feet (approximately 1 meter) apart over a swath of 25 to 27 feet (about 8 meters). From elevations of 10 to 15 feet (3 to 4-1/2 meters), the globules were a little less than 1 meter apart, within an average swath of 4-1/2 meters. Globules with an average volume of 0.05 cup (or approximately 12 cc) were produced leaving about 30 to 40 separate ignition points per 10 feet (3 meters) of travel when the system was flown at 15 mph (24 kilometers/hour). Such ignition sources are comparable to the smallest globules found to be successful in igniting cold, fairly fresh crude oil with light wind.

(c) Nozzle Configuration 2 (two VeeJet off-center nozzles) produced swaths of from 5 to 15 feet (1-1/2 to 4-1/2 meters) for altitudes of 10 to 60 feet (3 to 18 meters), with uniformly distributed globules approximately 1 to 2 feet apart (about 1/2 meter or less). Average globule sizes were approximately 0.072 cup (or about 17 cc). Again, such ignition sources are at the lower range of acceptable sizes for igniting cold, fairly fresh crude oil under light wind conditions.

(d) Nozzle Configuration 3 (two Simplex Solid Stream nozzles) resulted in the formation of two separate swaths separated by distances of 8 to 15 feet (2.4 to 4.5 meters), depending upon the Helitorch's height (10 to 60 feet, or 3 to 18 meters). Each of the swaths comprising a pair (made by a single pass) was between 1 and 4 feet wide (0.3 to 1.2 meters), again increasing with the altitude up to 60 feet (18 meters). Average globule sizes of about 0.18 cup (or about 43 cc) were produced, with approximately 10 to 12 ignition points per 10 feet (3 meters) of travel when the globules were released at 15 mph (24 kilometers/hour). This volume is well within the range of acceptable sizes for igniting cold, fresh and weathered crude oils even under light to moderate winds.

Preparation Of Gelled Fuel

(a) SUREFIRE gelling mix was used as the thickening agent throughout this project. SUREFIRE was found to be effective in producing adequately thickened fuel (gasoline or diesel) within a matter of a few minutes following contact with the fuel during all indoor mixing operations (16°C to 18°C). Mixture ratios varied from 5-1/2 pounds of gelling mix per 55 gallons of fuel to 18-1/3 pounds per 55 gallons (i.e., 12 grams/liter to 40 grams/liter). The higher ratios were used simply to expose any differences in globule spreading and ignition processes associated with greater viscosities in the gelled medium. It was found that there is very little advantage (from an ignition standpoint) in using higher gelling mix ratios; however, the higher ratios could reduce the gelling time at very cold fuel temperatures.

(b) SUREFIRE was used with gasoline that had been left outside at ambient air temperatures of -18°C to -12°C. During these gelling operations it was observed that weights of approximately 14 to 18 pounds per 55 gallons (30 to 40 grams/liter) of fuel were needed in order to achieve

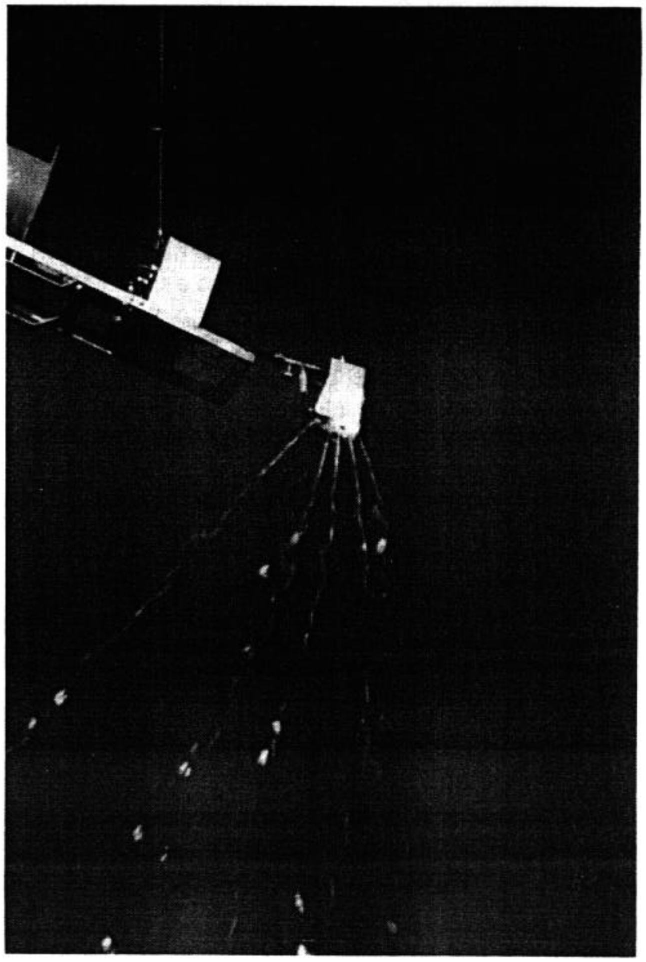


FIGURE 6

RELEASE OF BURNING GELLED GASOLINE FROM HELITORCH WITH NOZZLE CONFIGURATION 1. NOTE THAT ONE OF SIX NOZZLES IS PLUGGED DURING THIS PASS.

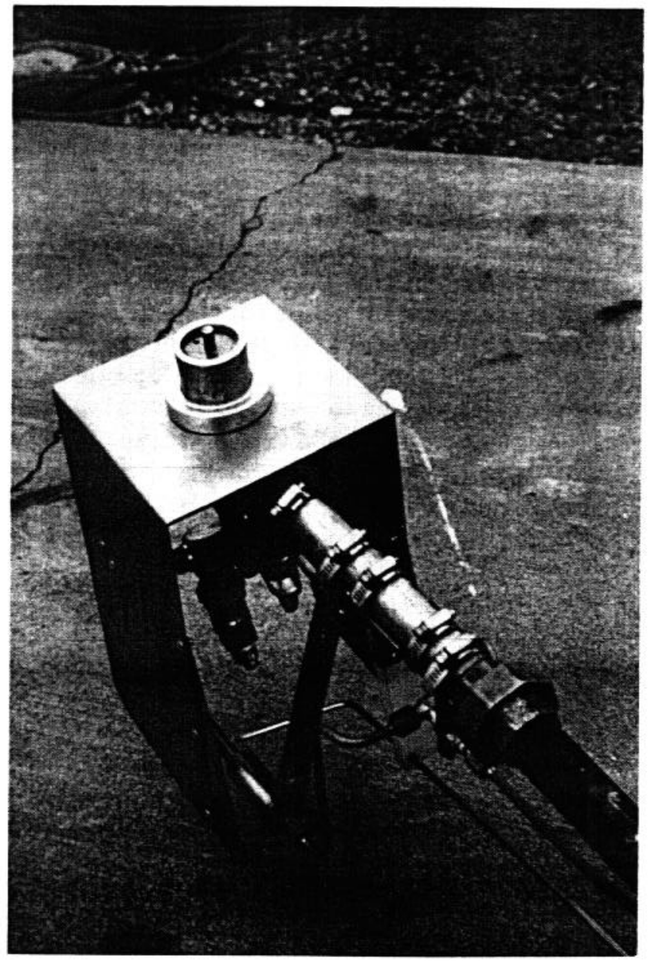


FIGURE 7

SIX VEEJET SOLID STREAM NOZZLES (CONFIGURATION 1) MOUNTED WITHIN STANDARD HELITORCH WIND-SHIELD ASSEMBLY. NOTE PROPANE EMISSION TUBE AND ELECTRICAL IGNITION TIP BELOW THE VEEJET NOZZLES.

adequate "torching" viscosities within 15 to 20 minutes. Using 11 pounds per 55 gallons (24 grams/liter), adequate viscosity was achieved within 30 to 40 minutes; and with 7-1/3 pounds per 55 gallons (16 grams/liter), a usable mixture required well over an hour.

(c) During all cold-weather tests (Phases 2 and 3), it was found that fuels gelled at room temperature retained their thickened properties without any noticeable change even after several hours of exposure to temperatures well below freezing.

(d) During all gelling operations it is essential that the thickening agent be applied at a moderate rate to a fuel that is free of water. As little as 2% water in the gasoline can seriously degrade the gelling process. A proper rate and mode of dispersion is needed to ensure a uniform distribution within the fuel, while completing the injection of powder prior to any noticeable thickening. Improper mixing, particularly with the higher mixture ratios, will result in the formation of stable lumps that can plug nozzles.

OPERATIONAL CONSIDERATIONS

The Helitorch has been shown to be an effective means of deploying ignition sources from the air onto floating oil. Burning gelled gasoline globules from the Helitorch can be applied as a narrow band with a swath width of a few feet or less, or they can be applied in a "broadcast" mode with swaths of nearly 30 feet (8 to 9 meters). Although not tested during this project, it is conceivable that much greater swaths could be achieved with a single helicopter using two or more Helitorches, higher pump rates, and/or a modified discharge and ignition assembly.

Depending upon the nature of the oil concentrations to be ignited, the Helitorch can be used to deliver a continuous stream of ignition sources, or it can be turned off and on for short bursts of burning fuel. Several examples of each type of application are illustrated in the following section.

It should be recognized that independent of the application mode, the Helitorch is operated with a positive-displacement pump producing a flow of approximately 15 gpm (56.8 liters/min). When operated with a 55-gallon-capacity holding drum (208 liters), the Helitorch can therefore provide a total application time of about 3 minutes and 40 seconds. The drum would then have to be refilled with gelled fuel or replaced with another drum already filled. The Helitorch is rigged so that an empty drum can be removed from the support frame and replaced with a full backup drum quickly and safely.

The distance over the ground, areal coverage, and number of ignition points that can be achieved during an application time of 3-2/3 minutes is dependent on a number of variables, including the speed and altitude of the Helitorch as well as the nozzle configuration used. The nozzle configuration will determine the number and size of ignition points created, which together with the speed and altitude of the Helitorch will determine the distribution of burning globules at ground level.

Using the fixed pump rate of 15 gpm (56.8 liters/min) and 55 gallons (208 liters)/drum, the resulting 3-2/3 minutes for application per drum can be used with any Helitorch speed (over the ground) to determine the distance achievable during continuous application. For example, at a speed of 15 mph (24 kilometers/hour) the distance (D) that can be achieved with a single drum and continuous application would be:

$$D = 15 \text{ mi/hour} \times 3.67 \text{ min/drum} \times 1 \text{ hr/60 min}$$
$$= 0.92 \text{ mi/drum (or approximately 1-1/2 kilometers/drum of gelled fuel)}$$

When the Helitorch is operated with nozzles that produce various swaths and distribution patterns, one might want to know the coverage rate at which the Helitorch can distribute such globules. A common expression for the areal coverage rate ($\dot{A}$) of any application system is:

$$\dot{A} \text{ (acres/min)} = \text{speed (kt)} \times \text{swath (ft)} \div 430$$
or
$$\dot{A} \text{ (acres/min)} = \text{speed (mph)} \times \text{swath (ft)} \div 494.5$$

If, for example, the Helitorch were to be operated at approximately 15 mph (24 kilometers/hour) with a nozzle configuration and altitude that resulted in a swath of 15 feet (4-1/2 meters), the Helitorch would cover the ground at about 1/2 acre per minute (0.18 hectares/min). That is:

$$\dot{A} = 15 \times 15 \div 494.5 = 0.45 \text{ acre/min (0.18 hectares/min)}$$

The total area (T.A.) covered with a single drum under these conditions would therefore be:

$$T.A. = 0.45 \text{ acre/min} \times 3.67 \text{ min/drum}$$
$$= 1.66 \text{ acres/drum (0.67 hectares/drum)}$$

This area represents the size of the zone within which burning globules would be deposited. The area of oil concentration that might ultimately be ignited, of course, could be considerably greater depending upon the size and distribution of the original pools of oil.

Some additional calculations may be of interest recognizing that various nozzle configurations produced fairly consistent numbers of ignition points (Figure 5). For example, Nozzle Configuration 2 typically produced 20 to 30 ignition points per 10 feet (3 meters) of travel when flown at 15 mph (24 kilometers/hour). If the Helitorch were then flown at an altitude of 50 to 60 feet (15-18 meters), these 20 to 30 globules per 10 feet (3 meters) of travel would be distributed over a swath of about 15 feet (4-1/2 meters). If the helicopter were to double its speed to 30 mph (48 kilometers) and then to 60 mph (96 kilometers/hour), the resulting concentrations would correspondingly drop from an average of 25 ignition points per 10 feet (3 meters) of travel to 12 and 6 ignition points per 10 feet (3 meters) respectively. Table 1 shows how each of the above parameters would vary for a single Helitorch flown at 15, 30, and 60 mph with swaths of 5, 15, and 25 feet. (Conversions for metric units are provided at the bottom of the table.)

Use of the Helitorch in a "broadcast" mode over an extensive region would require a carefully planned application program involving the potential for many staging areas. With application times of less than 4 minutes

TABLE 1

HELITORCH PERFORMANCE APPROXIMATIONS FOR SELECTED VALUES OF SWATH AND GROUND SPEED DURING CONTINUOUS OPERATION

(Single Helitorch with fixed pump rate of 15 gpm)

	Swath = 5 ft			Swath = 15 ft			Swath = 25 ft		
	Speed			Speed			Speed		
	15mph	30mph	60mph	15mph	30mph	60mph	15mph	30mph	60mph
Areal Coverage Rate $\dot{A}$ (acres/min)	0.15	0.30	0.61	0.45	0.91	1.82	0.76	1.52	3.03
Application Time T (min/drum)	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67
Total Area* Covered T.A. (acres/drum)	0.55	1.11	2.24	1.65	3.34	6.68	2.79	5.58	11.12
Distance Covered D (miles/drum)	0.92	1.84	3.68	0.92	1.84	3.68	0.92	1.84	3.68
Ignition Points per 10' of Travel (Avg. #/10')	≈25	≈12	≈6	≈25	≈12	≈6	≈25	≈12	≈6

* T.A. = $\dot{A}$ x T [Because of rounded-off values for $\dot{A}$ and T, T.A. values do not reflect exact multiples for speed and swath comparisons. (Example: when comparing T.A. for 15-ft swath @ 60 mph with T.A. for 5-ft swath @ 60 mph, T.A. (15') is not exactly 3 times T.A. (5').]

1 acre = 0.4047 hectare
1 foot = 0.3048 meter
1 mph = 1.6093 kilometers/hour
1 gpm = 3.785 liters/minute

per drum, it may be necessary to provide gel-preparation and reloading sites, as well as helicopter refueling stations, at a number of locations as close as possible to the region being treated. During open water, it may be possible to use a barge as such a staging platform. Depending upon the width and length of the oiled zone, "D" values of only a few miles (5 to 6 kilometers) or less per drum suggest that staging sites also be separated by comparable distances if possible. Such logistical considerations will be addressed in the following section for a hypothetical region of contamination approximately 100 miles (161 kilometers) in length.

One final consideration relates to the cost to conduct an in-situ burning operation with the Helitorch. The cost for the helicopter will obviously represent a substantial portion of the overall expense, running from hundreds to thousands of dollars per hour depending upon the type of helicopter used.

Deployment costs will also vary with the company and location from which the aircraft is obtained. Other costs, however, can be anticipated such as the purchase price of the Helitorch (approximately $5,000 U.S. as of January, 1987) and the price for gelling agent (approximately $4.00 U.S./lb for SUREFIRE as of January, 1987).

Using current gasoline prices, an estimate can be made of the application cost (less helicopter and ground support expenses). As discussed in detail in the original report (Spiltec, 1987), one could achieve a nearly continuous path of burning gelled gasoline (with more than 12,000 ignition points) for approximately $50 U.S. per kilometer (less than $100 U.S./mile). With Nozzle Configuration 3, producing the largest but least number of ignition points, the cost still remains on the order of a penny per ignition point.

POTENTIAL SCENARIOS

Figures 8 through 13 are provided as examples of spill situations during which a Helitorch could be used to support an approved in-situ burning program. While other scenarios can be envisioned, those illustrated here are representative of ones which could conceivably take place in Alaska and other cold-weather regions. Two scenarios are provided for solid (decaying) ice conditions, two are given for broken ice conditions, and two are also provided for open water environments (one as an open lead). Figure 12 could apply to temperate and tropical areas as well.

In the spill scenario illustrated in Figure 8, the Helitorch could be especially effective in covering an extensive area of isolated patches of oil. As discussed earlier, this kind of spill scenario could occur during the early melt period in the Arctic. Oil from a massive spill could have been released during breakup or during the winter months into moving broken ice or beneath moving solid ice. A response of this magnitude involving tens to hundreds of miles of oiled ice in a relatively narrow swath would require careful logistical planning involving:

- Helicopter and Helitorch nozzle selection,
- Ground speed and altitude required for efficient ignition,
- Number and location of staging areas for gelled fuel and helicopter fuel,

DECAYING ICE

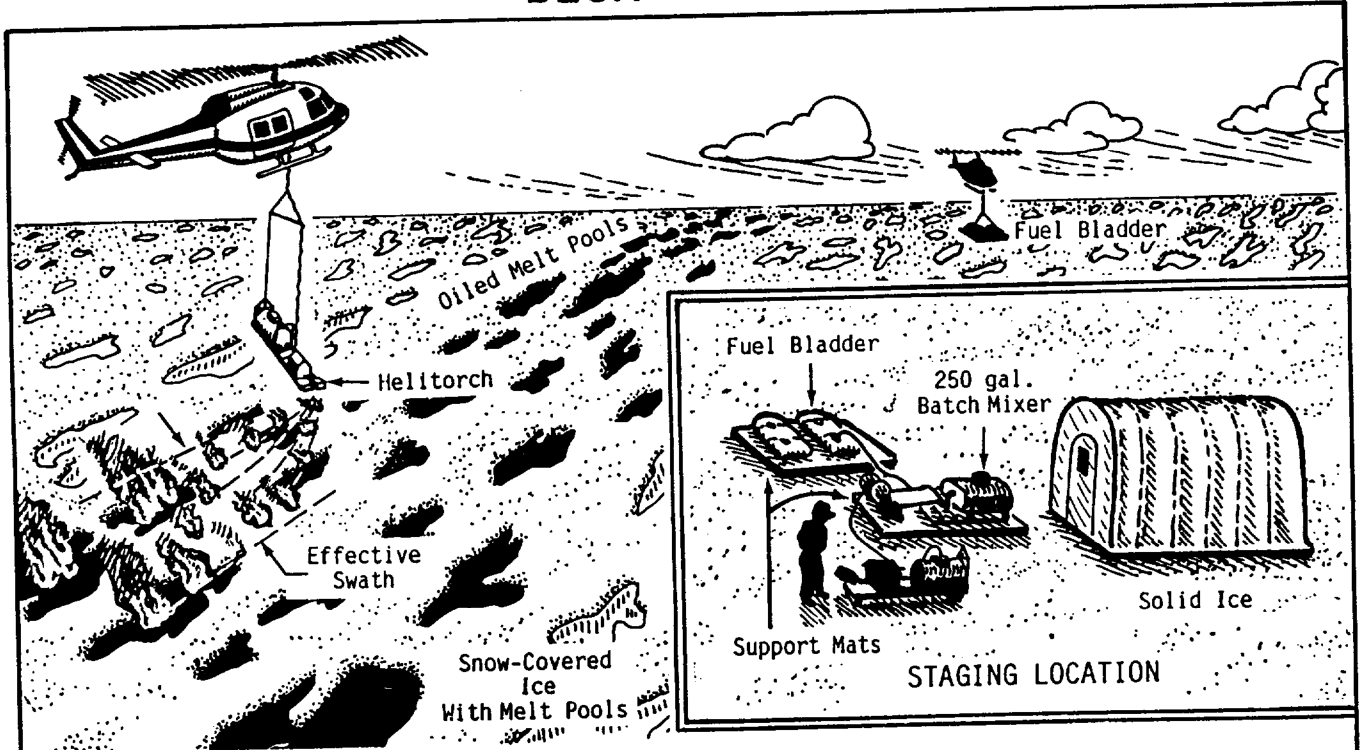


FIGURE 8 APPLICATION OF BURNING GASOLINE FROM A HELITORCH OVER A CONTINUOUS ZONE OF OILED MELT POOLS (BROADCAST MODE)

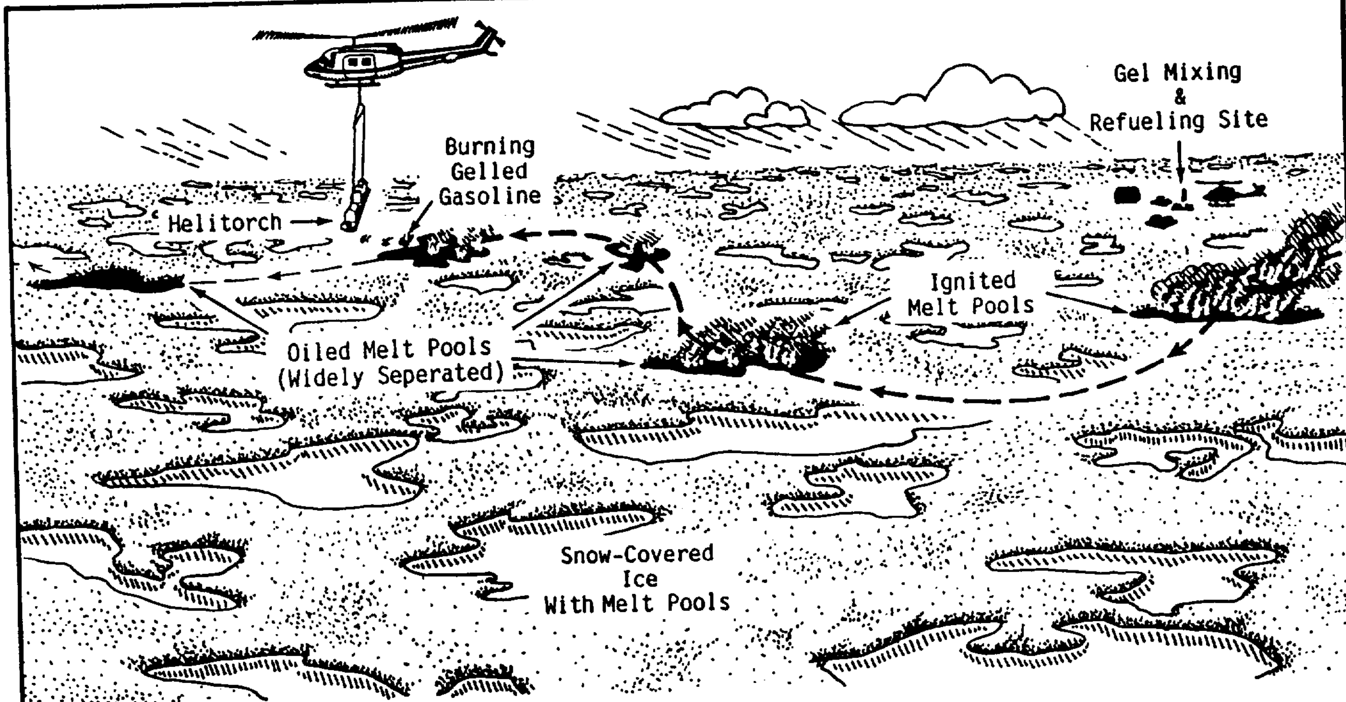


FIGURE 9 APPLICATION OF GELLED GASOLINE WITH A HELITORCH OVER INDIVIDUALLY-TARGETED MELT POOLS WITH OIL (SINGLE-TARGET MODE)

BROKEN ICE

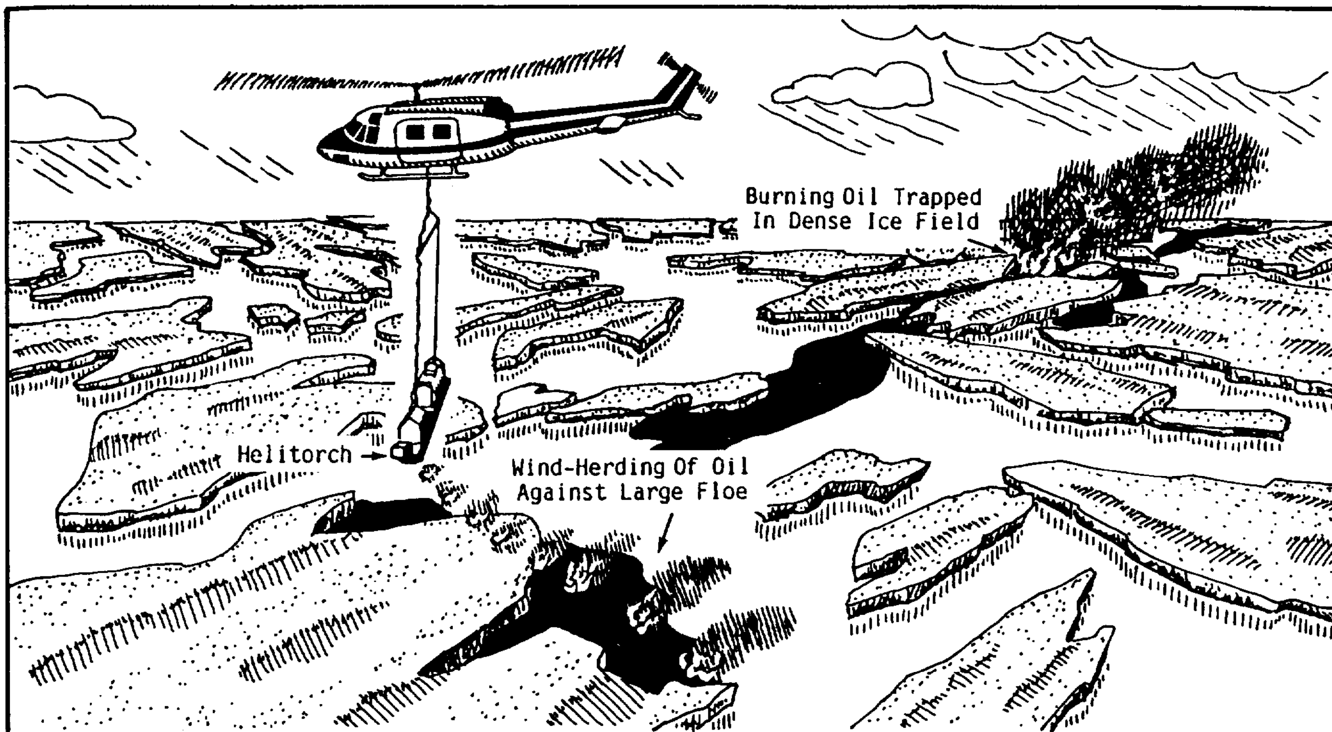


FIGURE 10 USE OF A HELITORCH OVER POOLS OF FLOATING OIL TRAPPED WITHIN OR AGAINST MOVING ICE FLOES

FIGURE 11 USE OF A HELITORCH OVER OIL AND ICE TRAPPED ALONG A SHORELINE

OPEN WATER

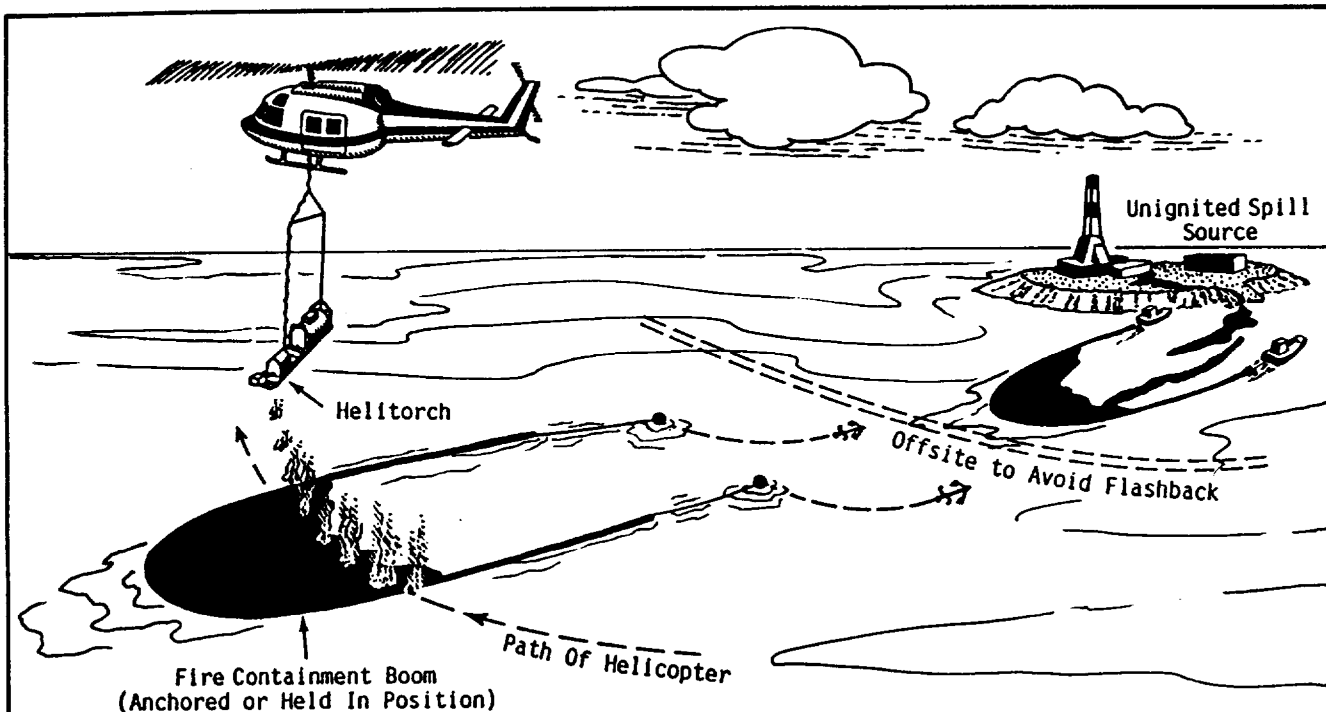


FIGURE 12 USE OF A HELITORCH IN IGNITING AND POSSIBLY RE-IGNITING OIL TRAPPED IN FIRE CONTAINMENT BOOM

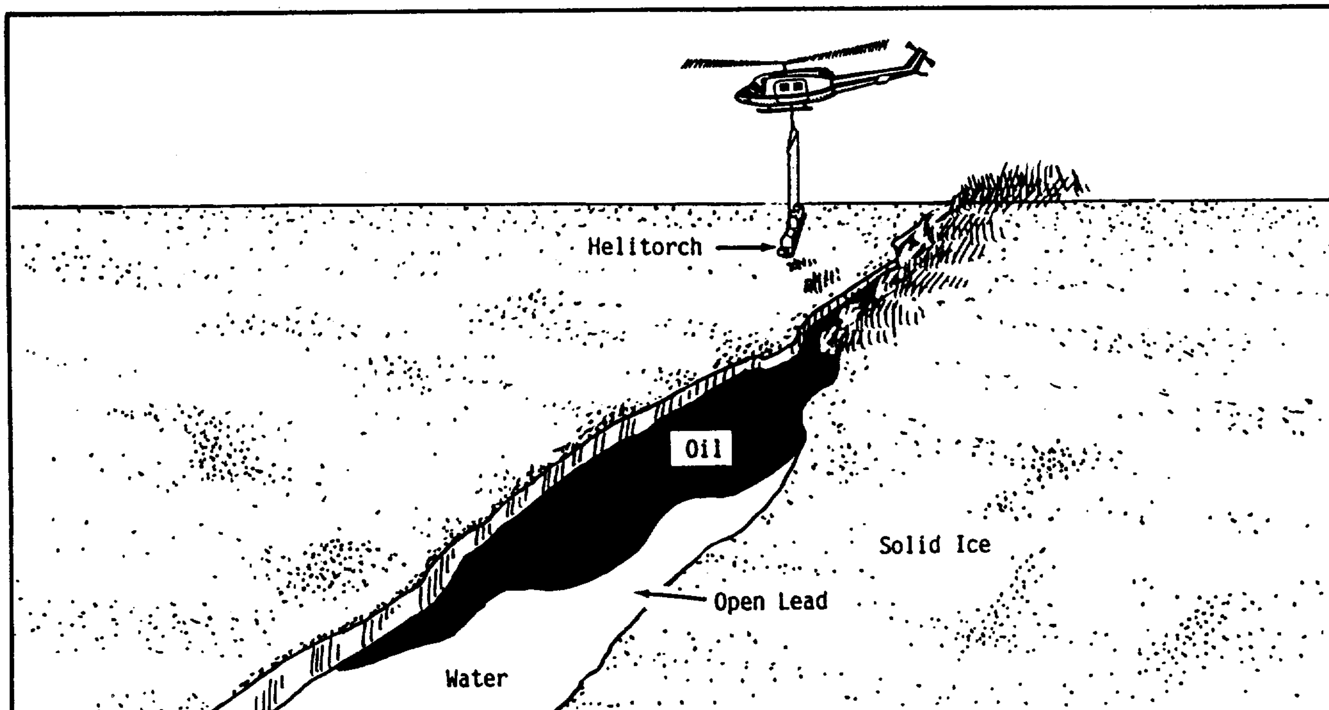


FIGURE 13 USE OF A HELITORCH IN IGNITING OIL TRAPPED IN AN OPEN LEAD

- Volume of fuel for helicopter and gelling operations at each staging site, etc.

These choices would depend on the actual location and extent of the oiled ice, the nature of the oil and ice, and the feasibility of staging personnel and equipment on the ice. Ideally, one would attempt to locate staging sites as close as possible to the oiled zone in order to minimize transit times following the depletion of each gelled payload. If safe and practical to do so, such locations would be positioned so that each sortie with a full Helitorch could begin or end very near each staging site.

These and other staging considerations can best be explained with the use of a hypothetical spill scenario. Assume, for example, that a response as depicted in Figure 8 is to be carried out using the assumptions provided below. (Normally, weeks to months would be available for such planning and staging preparations.)

- Length of oiled ice zone = 100 miles (161 kilometers).

- Width of oiled ice zone is approximately 50 to 60 feet (15 to 18 meters).

- A nozzle configuration comparable to Nozzle 2 in this report is used providing an effective swath of approximately 15 feet (4-1/2 meters) when flown at an altitude of 50 to 60 feet (15 to 18 meters).

- The Helitorch is flown with an estimated ground speed of 30 mph (48 kilometers/hour), thereby providing an estimated 12 ignition points per 10 feet (3 meters) of travel.

Using the above assumptions and data generated in the previous section, a single Helitorch could be flown continuously (without reloading) a distance of 1.84 miles (2.96 kilometers) in this scenario and cover about 9/10 acre (0.37 hectare) per minute. With an effective swath width of 15 feet (4-1/2 meters), it will be assumed that 4 passes will be required to cover the full area of oiled ice, which is 50 to 60 feet (15 to 18 meters) wide.

In Figure 14, such application distances per drum are illustrated along with one suggested mode of staging fuel and transiting to/from the oiled ice zone. The distance between staging sites using this method would be about 3.7 miles (5.95 kilometers). This mode would minimize overall transit time and allow the helicopter to conduct its longest transits with an empty Helitorch. Should conditions such as the wind require application in the same direction during each run, four of the eight longest transits would be conducted with a full load. This should not increase the overall time significantly.

If this staging mode was used along the entire 100 miles (161 kilometers), it would be necessary to stock fuel at 27 locations (i.e., 100 miles ÷ 3.7 miles per site). Each site would need at least 8 drums of gelled fuel, requiring approximately 216 drums to stock all 27 locations.

An estimate of the time to complete each grouping of 8 runs (or sorties) covering 3.7 miles (5.95 kilometers) of the oiled zone can be made as follows:

Application time	= 3.67 min/drum x 8 passes = <u>29.4</u> minutes
Long-transit time (assuming avg. transit speed of 80 mph)	= (2 mi/run x 8 runs)÷(80 mi/hr x 1 hr/60 min)
	= <u>12</u> minutes
Time for turns, relocation, take-offs and landings	= <u>12</u> minutes (assume equal to long-transit time)
Time for refueling	= approx. <u>15</u> minutes for every hour of flight time (in this case, 1 fuel stop per staging site)
Time for reloading gelled fuel	= <u>24</u> minutes (assume 3 minutes per change of drum)

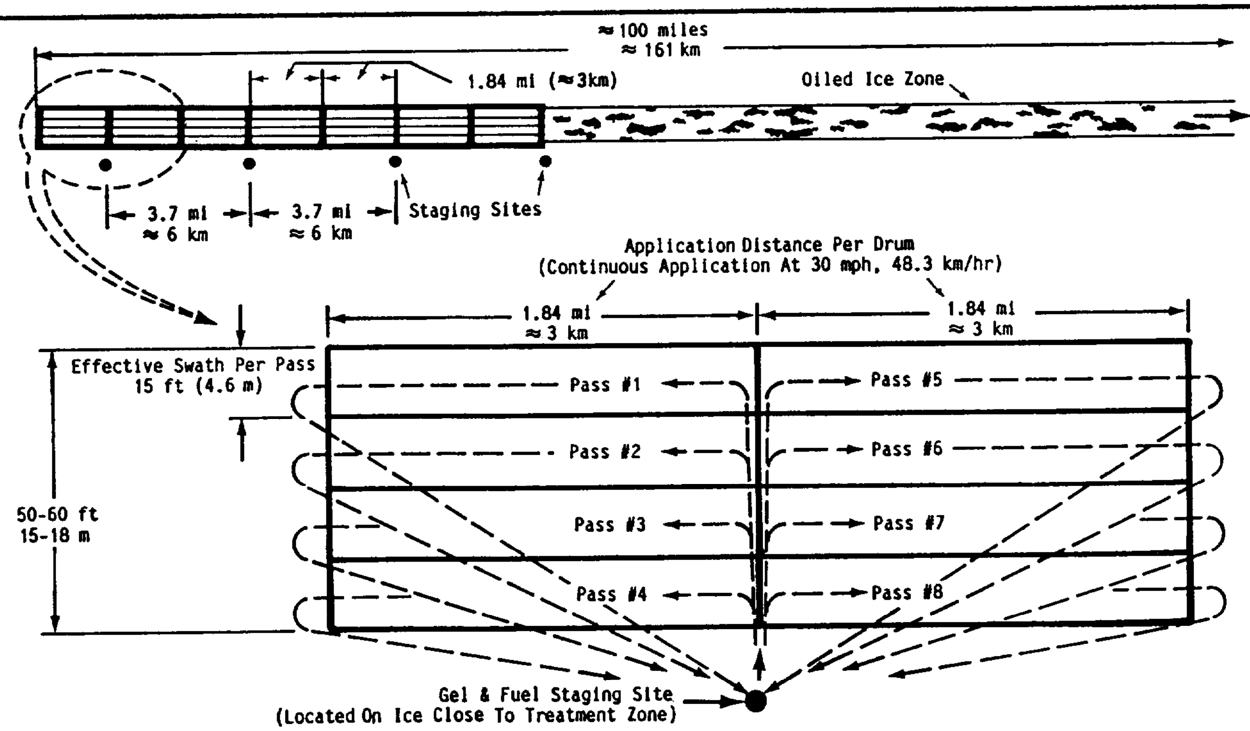


FIGURE 14 SAMPLE LOCATION OF STAGING SITES FOR CONTINUOUS TREATMENT OF A 100 MILE LONG OILED ICE ZONE WITH A HELITORCH

These rough estimates add up to 92.4 minutes per staging location (or per 3.7 miles along the 100-mile oiled zone). The total time to complete the entire 100 miles (161 kilometers) with a single Helitorch would therefore be about:

$$27 \times 92.4 \text{ minutes} = 2{,}495 \text{ minutes or } \underline{\text{nearly 42 hours}}.$$

The cost (U.S. dollars) for the gelled gasoline (assuming $1/gal gasoline, $4/lb of gel mix and 5.5 lb mix/drum) would be about $77/drum x 216 drums, or $16,632. Added to this cost would be all costs for the helicopter, for ground personnel, and for equipment.

If each staging site in the previous scenario is located at 7.4-mile (11.9-kilometer) intervals, the number of staging sites can be reduced from 27 to 13 or 14 over the entire 100-mile (161-kilometer) drop-zone. The same amount of gelling agent would be required (216 drums); however, each site would need to have 16 drums of gelled fuel and enough helicopter fuel for potentially two refuelings per site. With this mode of operation, the additional transit time (and corresponding turn and relocation time) could add as much as 7 hours, bringing the total application time to about 49 hours.

An operation of this nature would very likely be accomplished during the spring when there are nearly 24 hours of usable light each day. If the size and location of the oiled ice zone are monitored before the spring thaw, an operation could be planned with the optimum number and location of staging areas for that response. Additional helicopters and Helitorches could be used along with batch mixing equipment to reduce the total response time to less than a day.

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