INCENDIARY DEVICE FOR OIL SLICK IGNITION

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INTRODUCTION

The design and development of two incendiary devices intended to be dropped from aircraft to ignite confined oil slicks on Arctic melt pools and other remote water surfaces have been described by Twardawa and Couture (1980).

The operational considerations and assumptions that formed the basis for the design criteria have also been reported (Meikle, 1981).

The purpose of this paper is to:

1. summarize the results of the Arctic field testing of both designs;
2. explain the choice of design for commercial production;
3. describe a design change incorporated;
4. report the results of field tests of the production version; and
5. outline the further testing to be done to complete the project.

Environment Canada. Arctic and Marine Oilspill Program (AMOP) Technical Seminar, 4th. Proceedings. June 16-18, 1981, Edmonton, Alberta, Canada, Environment Canada, Ottawa, Ontario, 499-513 pp, 1981.

ARCTIC FIELD TEST

The ability of both the canister-shaped device and the sandwich configuration to ignite oil within the specified limiting conditions was established previously by laboratory tests that provided the required degree of control over the key factors. Physical aspects of the design (mechanical and structural) were satisfactorily demonstrated both by controlled drops from a fixed tower and by actual drops into water from a helicopter flying at the design altitudes and airspeeds.

Before a choice could be made between the two contending designs, it remained to establish their functional reliability and compare operational performance under field conditions. While that could probably have been adequately accomplished elsewhere under conditions approximating those expected to prevail in the area for which the devices were primarily intended (Arctic melt pools), an element of uncertainty would undoubtedly have remained. It was, therefore, decided to take advantage of the opportunity afforded to test the devices under actual Arctic conditions in conjunction with the Oil and Gas Under Sea Ice experiment sponsored by Dome Petroleum Limited (Dickens and Buist, 1980).

A total of thirty prototypes (twenty canisters and ten of the sandwich design as shown in Figures 1 and 2), were manufactured by the Defence Research Establishment Valcartier (DREV) and shipped to the test site off McKinley Bay, NWT. By the time the devices could be assembled, the over-ice sections of the Mackenzie highway were no longer in use. Therefore, to effect delivery in time for the expected appearance of the spring melt pools and comply with the regulations pertaining to the transportation of such devices, it was necessary to send them by road to Whitehorse in the Yukon and charter an aircraft for the remaining distance.

FIGURE 1 PROTOTYPE CANISTER DEVICE

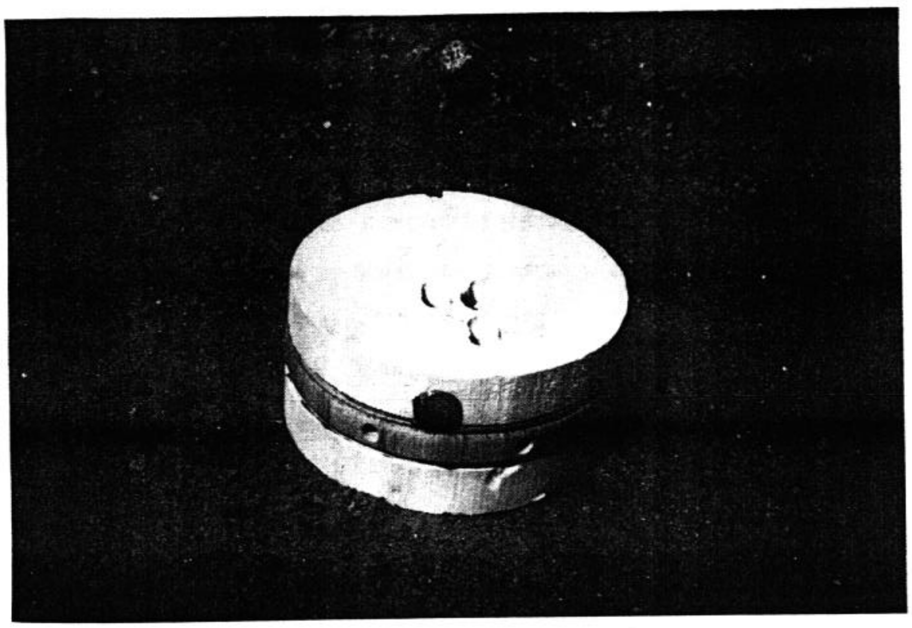

FIGURE 2 PROTOTYPE SANDWICH DEVICE

Functional Reliability

For the purposes of this assessment "functional reliability" concerns only the functioning of the ignition train and the generation of the intended flame; it does not take into account the accuracy of delivery or the ignitability of the target material.

a) Canister Model

Fourteen devices were dropped from altitudes ranging from 5 to 10 metres at forward airspeeds of 2 to 5 knots. Two of them misfired completely (no flame generated) and a third fired but failed structurally and only burned for about 45 seconds (the dome separated shortly after ignition occurred). The remaining six were placed in slicks by hand instead of being dropped from the air and, of these, one misfired. The overall functional reliability for the prototypes was, therefore, 80% (slightly under 79% if only those that were air-dropped are considered). Delay time averaged 20 seconds, easily satisfying the minimum 15 seconds sought. The average burn time for those that activated properly was only 93 seconds or 77.5% of the 2 minute minimum specified. Disregarding the shorter-than- desired burn time (which was sufficient for the type of oil encountered in this case), the overall functional reliability of the canister prototype easily exceeded the minimum 75% that was specified.

b) Sandwich Configuration

All of the 20 prototype devices ignited and generated the expected heat pattern. Delay times and burn times were not recorded for any of them, but those that encountered oil achieved slick ignition. Functional reliability of this design was, therefore, superior to that of the canister design and also exceeded the specified requirements.

Operational Performance

"Operational performance", in the context of the Arctic trials, included adequacy of handling arrangements, delivery accuracy, and ignition of oil slicks on melt pools.

Both designs satisfied the handling requirements in that they were transported, stored, embarked, activated and launched without disclosing any design deficiencies.

The trials confirmed that incendiary devices such as those developed by DREV can be dropped from a helicopter with sufficient accuracy without launching and sighting aids. Targets with an estimated area of only 4 m^2 were hit from an altitude of 5 m while transiting at speeds of 2 to 5 knots. Inert drops at 30 knots from 15 m confirmed that structural requirements had been satisfied.

The canister, despite its cylindrical shape, did not roll after impact, but it was never able to free-float in the intended upright attitude because the depth of water was always less than the 10 cm specified by the designer. Despite the attendant adverse affect on performance, the device still readily achieved self-sustained burning of the oil providing its position in the pool was suitable for the prevailing wind conditions.

One fact determined from the series of burns done during the experiment was that the flame would only propagate upwind if the wind-speed did not exceed 10 km/h. For higher windspeeds, the incendiary device must, therefore, be placed in the upwind part of the pool.

The sandwich configuration was able to float freely in the prevalent depths of water and also confirmed its ability to produce self-sustained burning of the oil. However, a major problem was disclosed in that the disc-shaped sandwich tended to roll excessively after impact, degrading deployment accuracy to the extent that only 3 "hits" were obtained; that is, only 3 came to rest in their intended target pools of oil.

PRODUCTION CHOICE

The sandwich configuration was chosen as the one to be brought to the stage of being approved for commercial production in Canada. Although the canister arrangement with its heat deflecting dome would probably be able to ignite slightly more-weathered oil than the sandwich, a major re-design would have had to be undertaken to make it able to float in the shallower-than-expected melt pools found to prevail. On the other hand, only a minor change was expected to cure the post-impact rolling problem experienced with the sandwich, and the required modification could be made without delaying the availability of the finished product.

It was, therefore, decided that the small increase in capability that might be possible with the canister model did not justify the additional cost and the further delay that would be involved.

MODIFIED SANDWICH DESCRIPTION

The basic design was retained intact and all that was changed was the shape of the plywood and styrofoam layers. These were simply squared-off, leaving the layer of incendiary composition unchanged as a circular disc that produces a uniform peripheral flame.

A production order for 200 of the modified igniters was placed through the Department of Supply and Services with the successful bidder, ABA Chemical Limited of Guelph, Ontario. The change of shape and the styrofoam filler that now surrounds the incendiary composition are shown by Figure 3, which is a photograph of one of the first ones produced.

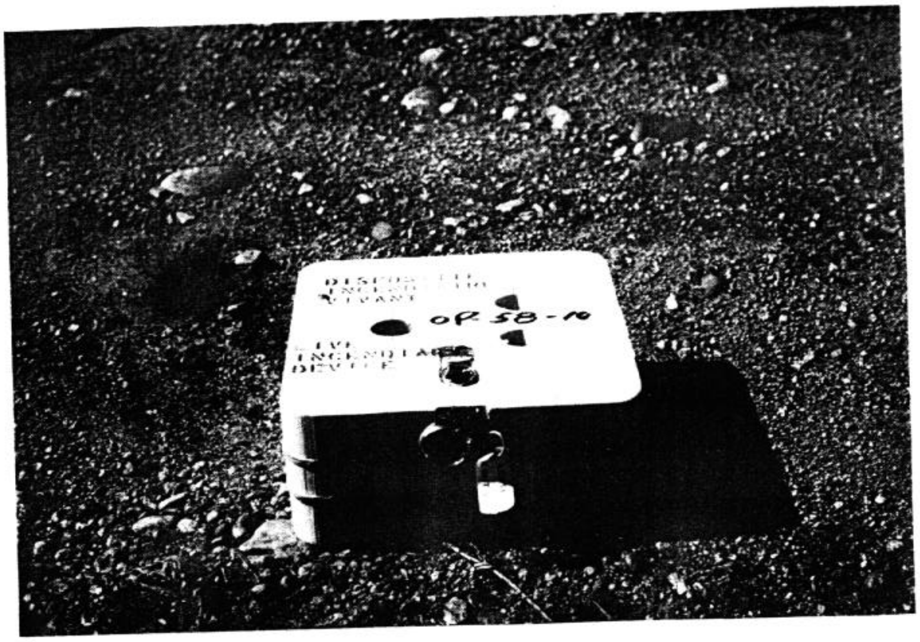

FIGURE 3 SANDWICH DEVICE - FINAL CONFIGURATION

MODIFICATION PROOF TEST

Ten of the first batch of 20 were selectd for drop-testing from a helicopter to confirm that the change to the square shape had in fact cured the roll-after-impact problem.

The area chosen for the test was on the surface of a still-frozen lake at DREV and took place on 12 April, 1981. The ice was still firm enough to walk on with care and, except that there were no melt pools, the surface was very similar in contour, texture and firmness to that observed at McKinley Bay on 11 June 1980. It was, therefore, ideal for determining the post-impact behaviour of the device when dropped from an aircraft onto a water-free surface, the situation that had disclosed the problem initially.

A small triangular marker with a base approximately 60 cm a side was used to indicate the centre of the target area. As for previous air-drop trials, a Bell 206 helicopter with the door removed was used for this set. All 10 devices were dropped, 8 of them at the design altitude and airspeed of 15 m and 15 knots. The remaining 2 were dropped from about 30 m at an airspeed of 60 knots to simulate drops from a slow-flying fixed-wing aircraft.

Although the primary purpose of the test was to confirm that the rolling problem had been eliminated, the secondary purpose was to check the functional reliability of the production version. Accordingly, both still and motion picture photography was used to record results and the ignition sequence was timed.

The final report of the trial is still being prepared but it was confirmed that the rolling problem had been eliminated. There was some bouncing and skipping following the initial impact, but it was no more than is to be expected for any non-penetrating object similarly launched, and the modified shape was approved for the remainder of the production order.

Both of the devices dropped from the higher speed and greater height functioned correctly, exceeding the specified minimums for delay time and burn time. One came to rest initially balanced on one edge, but it toppled soon after burning commenced and provided the required minimum 2-minute burn thereafter. However, two of the eight devices released at the lower speed and altitude failed to ignite, and a third ignited but only burned along part of its periphery.

The two misfires were subsequently opened for examination and, in each case, the reason for failure was found. One of the complete misfires was caused by the use of an alternate cement that failed and allowed the firing mechanism to dislodge and interrupt the ignition train. A permissable alternate cement had been used and it has since been deleted from the specification; only the bonding material that proved satisfactory in the prototypes will be used for the remainder of the order.

The other misfire was also caused by a disruption in the ignition train, and the partial burn was attributed to a similar discontinuity. A minor design change has been incorporated that will not only preclude a recurrence of both types of failure, but it will also simplify production and reduce cost.

With these changes it is confidently expected that the 70% functional reliability demonstrated by this small initial sample will be substantially improved and the 75% goal will be surpassed.

PRODUCT APPROVAL TESTING

The incendiary devices developed by DREV for igniting pools of oil contain compositions that burn energetically and contain all the oxygen necessary for combustion. As such, they are classed as fireworks and their manufacture, purchase, use and possession are controlled by the Explosives Regulations of the Canada Explosives Act. Those regulations require that all firework compositions contained in legally manufactured or imported fireworks be tested by the Chief Inspector of Explosives and must comply with specific criteria. The finished firework in its casing or contrivance must also withstand tests for safety and reliability, and periodic run-of-work samples are tested to ensure that the required quality is maintained.

The transportation of such devices is also controlled in accordance with Department of Transport regulations for the applicable material category as determined by test and/or physical examination.

Providing devices for the tests associated with these regulatory requirements was one of the reasons for the previously mentioned order for 200 commercially manufactured devices of the selected design. The other reasons were to:

a) effectively transfer the technology from the military research establishment to Canadian industry;

b) obtain a quantity for evaluation of other possible applications; and

c) provide DREV with the number required for a series of environmental tests.

Those tests subject the product to extremes of temperature, high humidity, vibration, shock and rough handling in keeping with the design objectives, and serve both to prove the design and to confirm that the production version conforms to specification. To the extent that they satisfy requirements, the results of these tests will also be used by the regulatory authorities to avoid unnecessary duplication of effort.

A total of 120 devices will be expended for the environmental tests at DREV. The several tests will be performed in the sequence shown by Table 1, with new devices being added after each test. In this way, the ability of the device to withstand various combinations of tests will also be ascertained.

Briefly, the tests are as follows, and all devices subjected to only one test should function normally when activated; for those subjected to more than one test there should be no more than one failure after each stage:

a) <u>High/Low Temperature</u> - Items are to be conditioned for 24 hours at 50°C/-40°C as applicable, and are then to be functioned at their soak temperature.

b) <u>Vibration</u> - Items are to be subjected to a sequence comprising four separate periods of 7 hours each at a frequency of 50 hertz and an amplitude of 0.25 mm. The items shall then be inspected for damage and functioned at ambient temperature.

TABLE 1 ENVIRONMENTAL TEST PLAN

Test	No. of Items Sequentially Tested	No. of New Items Added to Test Lot	No. of Items Functioned
High temperature	60		12
Low temperature	48	12	12
			12
Vibration	36	12	12
			12
Temperature and Humidity Cycling	24	12	12
			12
Rough Usage	12	12	12
			12
12-metre Drop		12	

c) <u>Temperature and Humidity Cycling</u> - Items shall be subjected to one 14-day cycle with temperature extremes of -50°C and 70°C, the relative humidity at the upper temperature limit being 90%. The items shall then be examined and functioned at ambient conditions.

d) <u>Rough Usage</u> - Items shall be placed loosely in a tumbling machine and tumbled for 15 minutes at the rate of approximately 12 revolutions per minute. No item shall function during the test and all items shall be safe to handle after testing. Items shall then be inspected for damage and functioned at ambient conditions.

e) <u>12-metre Drop</u> - Items shall be subjected to a free-fall drop from a 12 m height onto a hard surface. Items must not function during the test and must be safe to handle afterwards.

EVALUATION FOR OTHER APPLICATIONS

Ten of the initial batch of 20 have been allocated to the Baffin Island Oil Spill (BIOS) experiment for evaluation at Cape Hatt as igniters of stranded oil on Arctic shorelines.

The remainder, less the few that may be required by the regulatory departments for examination and test, will be delivered to the Canadian Coast Guard for evaluation by operational personnel and to familiarize them with the capabilities of the device.

CONCLUSION

Subject to satisfactory results from the environmental test program at DREV, the multi-year project initiated in 1978 to develop an air-droppable incendiary device for igniting confined oil slicks on Arctic melt pools will be successfully completed by late 1981 or early 1982. The goal of making a safe, reliable and effective device commercially available for use in the event of an Arctic oil spill will have been achieved, and no further development is planned beyond that point.

REFERENCES

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Twardawa, P. and G. Couture, "Incendiary Devices for the In-Situ Burning of Oil Spills", Proceedings of the Third Arctic Marine Oilspill Program Technical Seminar, Environmental Protection Service, Department of the Environment, Ottawa, (June 1980).