AN ACOUSTICAL METHOD OF BURNING AND COLLECTING OIL SPILLS ON COLD OPEN WATER SURFACES

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ABSTRACT: *A completely new method of controlled oil burning with a minimum environmental impact has been developed.*

Three macrosonic phenomena are combined in one device which is driven into an oil slick. These phenomena are: herding (moving the oil along the surface), levitating and collecting the oil, and atomizing and burning in situ. *These functions are so combined as to assist each other.*

Briefly, two vessels tow a boom through the oil slick. Distributed along the boom are herding transducers which direct the oil away from the arms of the boom to the central line and also prevent the oil from down-draining at the apex in fast current situations. Atomizing and burning transducers as well as a collecting means also are located at the apex. The oil being atomized is ignited easily by a combination of propane torch and high voltage discharge. The unburned but heated oil is suctioned off from the collection area fed by oil levitation transducers. Thus extremely thin and patchy oil may be removed in virtually any environment.

The burning may be carried on in populated areas as it is relatively non-polluting. This is due to the combined effect of primary atomization caused by the acoustic energy and secondary atomization caused by the micro-explosions of atomized water.

Another advantage of this method is the prevention of the sludge formation which results when prevalent standard methods are used. In these in situ *methods, the lighter and more volatile materials burn first, leaving a heavy sludge which is difficult or impossible to disperse. The method outlined here burns the volatile and non-volatile portions non-selectively. As a result, no residual sludge is formed.*

Another advantage of this method is that the prime motivating force applied to the oil is a lightweight transducer having such a low inertia that fast wave situations do not interfere, but serve to increase the burning rate.

In situ burning generally is the agreed-upon method to be developed in controlling spills in the Arctic where storage and processing of the collected oil is not readily available.

Previous attempts at *in situ* burning have not succeeded. Sustained burning is difficult because oil spills are very thin and become even thinner as the radiated heat from the burn develops. This leads to a huge thermal loss to the underlying water by heat transfer and convection. The portion of the oil that does burn is the more volatile fraction. The residual sludge becomes more of a problem than the oil spill before the burning. In all attempts at burning, very little thought has been given to improving the efficiency of the burn. Thus these previous attempts have caused atmospheric pollution and cast serious doubts that *in situ* burning could be carried out near populated areas.

The acoustic methods outlined are designed to yield a clean, controlled burn leaving no residual sludge and enabling simultaneous collection of a portion of the oil if desired. Thus, the method provides a flexibility in that the percentage of oil collected or burned can vary with the sea state and storage facilities available without requiring drastic change in equipment.

Theory

The two main phenomena associated in the acoustical method are radiation pressure and atomization.

Radiation pressure. A force may be generated at the interface between two media which differ greatly in acoustic impedance. Thus when high intensity acoustic energy is burned or focused from below the water surface (and the floating oil), the oil above is projected upwards. This is so because the acoustic impedance mismatch is between the air and the oil on the surface and not between the water and oil. Because the sound wave is reflected at the interface of air and oil, the radiation pressure is equal to the energy density of the sound wave in the fluid. To project the oil to a height of 1.2 meters (m), as an example, requires an intensity of 750 watts per cubic centimeter (cm).[1]

$$I = cE = 1.5 \times 10^3 \frac{M}{S} \times 5 \times 10^3 \frac{\text{Joules}}{\text{m}^3} = \frac{750 \text{ watts}}{\text{cm}^2}$$

Where: I = intensity
c = velocity of sound in the medium
E = energy density

To achieve this high intensity, a focusing ceramic transducer may be used. A parabolic trough shaped to the transducer yields a focal volume shaped like a cylinder. This will levitate the oil in the form of a sheet as wide as the transducer which is a desirable shape for collection. If the acoustic generator face presents a large angle to the surface, the oil will be projected upwardly, whereas if a small or grazing angle is used, it will move horizontally along the surface ("herding"). The ceramic material used is U.S. Navy code 5400 at frequencies of from 0.5 to 1 megahertz for levitating the oil. Lower frequencies are used for atomizing and burning as explained below.

Atomization. Atomization of fuel before combustion gradually is becoming a widely applied technique in prevention of pollution as well as in more economical use of energy. As in levitating the oil, high intensity acoustic energy is delivered from below the oil surface in the form of a cylindrical focal volume. Focusing parabolic trough, single-element ceramic transducers may be used (or a sandwich-type, as illustrated by U.S. Patent No. 4,308,006[2]). This latter has lower frequency capabilities without increasing the thickness of the ceramic material.

Acoustic equipment

High frequency electrical energy causes a ceramic material to vibrate at this frequency (piezoelectric effect), producing sound energy. The two basic pieces of equipment are transducers and high frequency power generators (R.F. amplifiers).

Transducers. The transducer material is a ceramic made from lead-titanate zirconate (U.S. Navy specification 5400) manufactured by Channel Industries Inc. of Santa Barbara, California. One type of emitting profile is a machined spherical surface which produces a

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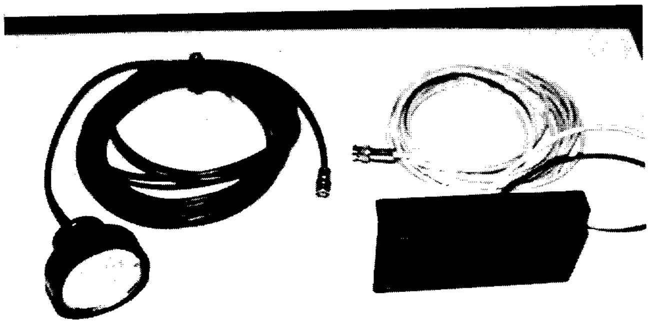

Figure 1. Two types of transducer configurations

spherical focal volume at distances of 7 cm and 30 cm (Figure 1). Another type is a flat rectangular surface to which we bonded a specially modified zone lens. This gives focal distances of 5 cm to 20 cm.

The input power is supplied through a 3 m coaxial cable with a 100 picofarad per meter capacitance and a characteristic impedance of 50 ohms. The material of the transducer is capable of radiating 60 watts/ cm^2 and had a Curie point above 300° C.

Amplifiers. The model number is A-300 manufactured by Electronic Navigation Industries, Rochester, New York. The output is directly proportional to the input and the latter was used to control power.

Single operator devices

There is a gap in the technology for single operator devices in the collection and burning of crude oil, diesel fuel, and gasoline. These can be of use in areas that will not allow a large system to be deployed.

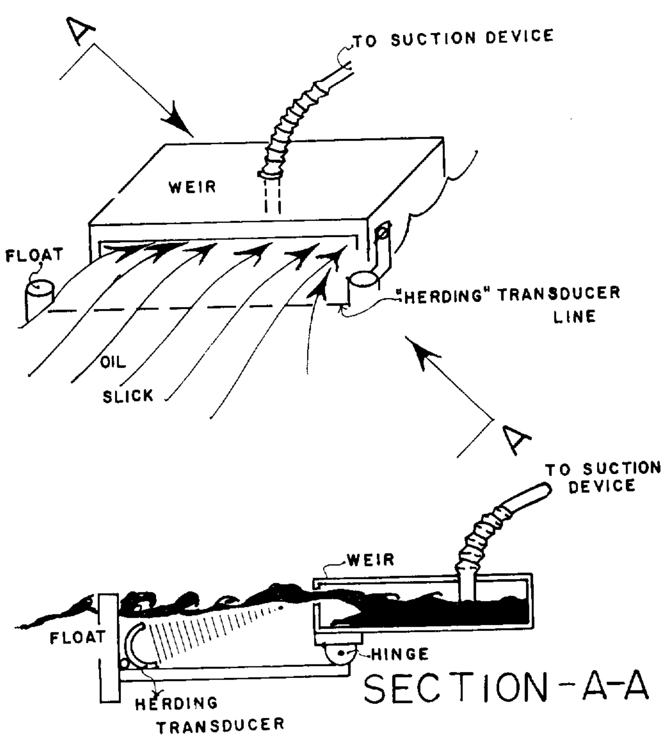

Figure 2. Combination weir and herding device

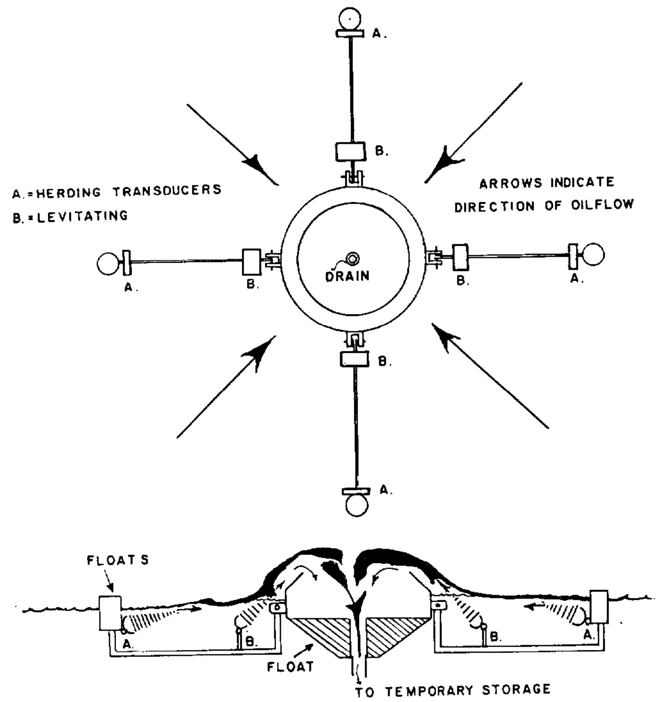

Figure 3. Combination oil herding and levitation device

Description of these devices will aid in the explanation of the larger systems for handling oil slicks and offshore oil well blowouts.

Prototype 1. This is a combination weir and "herding" device. Figure 2 shows a floating device which may be operated in a stationary or mobile mode. For this purpose, the transducers should be a parabolic trough type or a flat type (8 cm by 15 cm) with a focusing lens. Several of these can be placed end to end with spaces of 30 cm between. These then are in a line ahead of the weir and as wide as the mouth.

These single element transducers probably would be operated at 200 watts as an average, depending on the viscosity of the oil. These transducers then force only the oil into the mouth of the weir. Without the transducers, the weir would draw mostly water. A suction hose removes the oil continuously.

This small single operator device can outperform most very large skimming devices involving a crew and a vessel and may be operated in choppy water.

Prototype 2. This is a combined oil herding and oil levitation device (Figure 3).

The transducers are the same as in Prototype 1, although usually operated at higher power. One group of transducers is placed at a grazing angle to the surface, but aimed toward the main body of the device. Another group is placed closer to the body and has a large angle to the surface but aimed at a collection pan above the surface. The oil is levitated into the central collection pan above the surface. Below, the pan is connected to a flexible hose and suction device which continually removes the oil.

The device may be operated in a mobile or stationary mode. In the mobile mode, or where the current brings the oil to the levitating transducers, the herding function becomes less important.

Prototype 3. This is a combination oil herding and atomizing device (Figure 4). This combination is very useful in extremely cold climates and all variety of oils.

Oil is herded to a small boom just above an atomizing transducer and below a small stack. A propane torch is ignited by a high voltage discharge and its flame aimed so as to follow the splash guard at the base of the stack. The atomizing transducer is turned on low power and the atomized oil is ignited.

The atomizing transducer then is turned to a higher power level and a clean burn results. Some of the heat is radiated to the surrounding oil, making the atomization of very viscous oil very efficient.

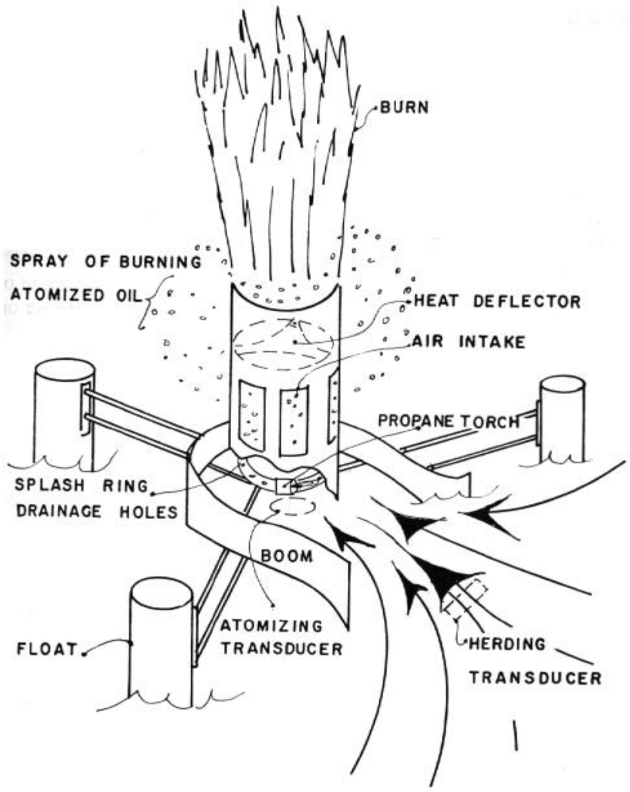

Figure 4. Combination oil herding and atomizing device

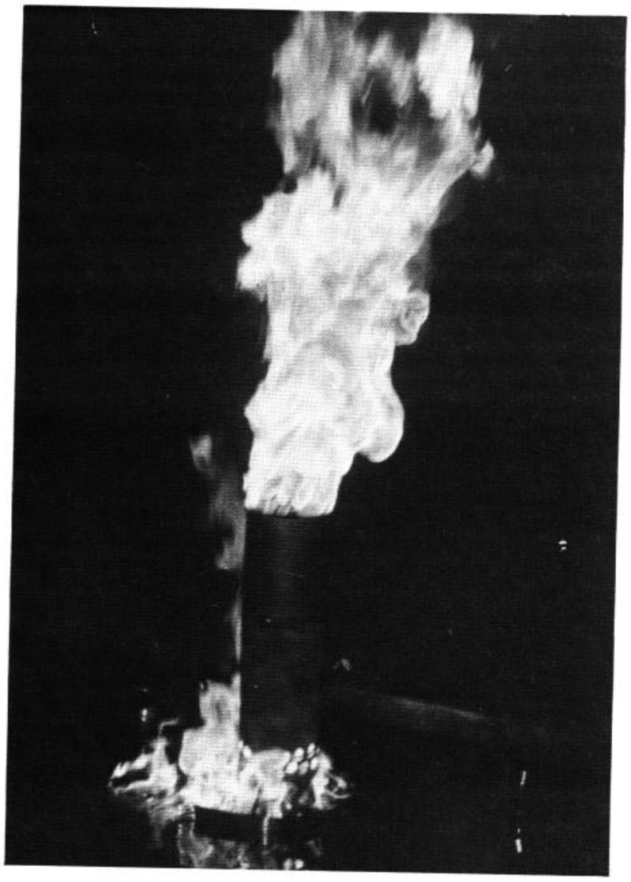

Figure 5. Combustion of weathered crude oil in herding/atomizing device

Figure 5 shows the combustion at 12° C of a 0.5 mm thickness of weathered Alberta crude oil. (The oil was left in an open tank and agitated for one week). A 50 watt input to the atomizing transducer was found sufficient to maintain a clean burn even though the transducer was capable of 2,000 watts of acoustical energy.

This combined oil herding and atomizer device may be used as the igniter to initiate the oil burning in a large oil spill system such as described below.

Operation of system for large oil spills

Since this is an extremely small draught, boom herding transducers are used as shown in Figure 4 to direct the oil slick towards the ignition burner. A high voltage discharge ignites a propane torch within the burner. (If the crude oil is fresh and the temperature warm, the propane is unnecessary). The atomizing transducer directly below is turned on. This results in the ignition of the slick in this area.

It is preferable not to allow the oil to build to a large thickness as this could result in an uncontrolled burn with contamination of the atmosphere and deposition of a heavy sludge. Heat is radiated to the surrounding area and the remainder of the atomizing transducers (wihout a stack) may be turned on. The power is increased until a very clean burn results.

If it has been decided not to collect any of the oil, the levitating transducers are turned so as to exert a resulting force pushing the oil away and upward from the apex of the boom. Thus, even though the water may drain down, the oil will not. This enables a good control of the burn. If some of the oil is to be collected, the transducers at the apex of the boom are directed so as to levitate the oil into the collection weir of the fireproof boom (Figure 6). Since the oil has been heated, its viscosity is sufficiently low to be easily suctioned off and collected.

Rate of oil combustion. The burning will occur as rapidly as the boom can collect the oil. The more oil, the thicker the oil layer, the less the heat loss to the water, and the more efficient the atomization.

The concern is to provide enough power to the atomizing transducers to enable the oil to burn clearly. If atomizing capacity is insufficient, one could increase the collection rate at the apex of the boom.

These are operational techniques which can be changed according to the type of oil burned, proximity to the oil, proximity of other flammable material, and the availability of storage facilities. By using this technique, complete controlled combustion can occur, because the moment the atomizing transducers are shut off, the burn will subside because of oil thinning and thermal loss to the underlying water.

Offshore oil well blowout. Equipment identical to that in Figure 6 may be used. However, the tugs should be anchored to the sea floor or other anchor point if available from the shore. The boom is placed so as to collect the oil with the aid of wind and current (Figure 7).

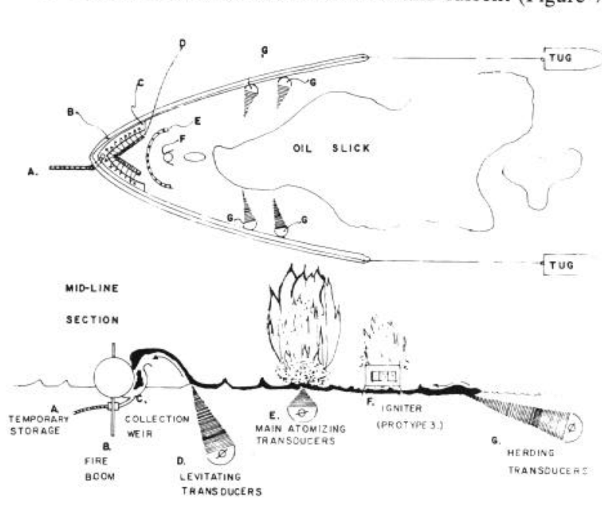

Figure 6. Operation of a system for large oil spills

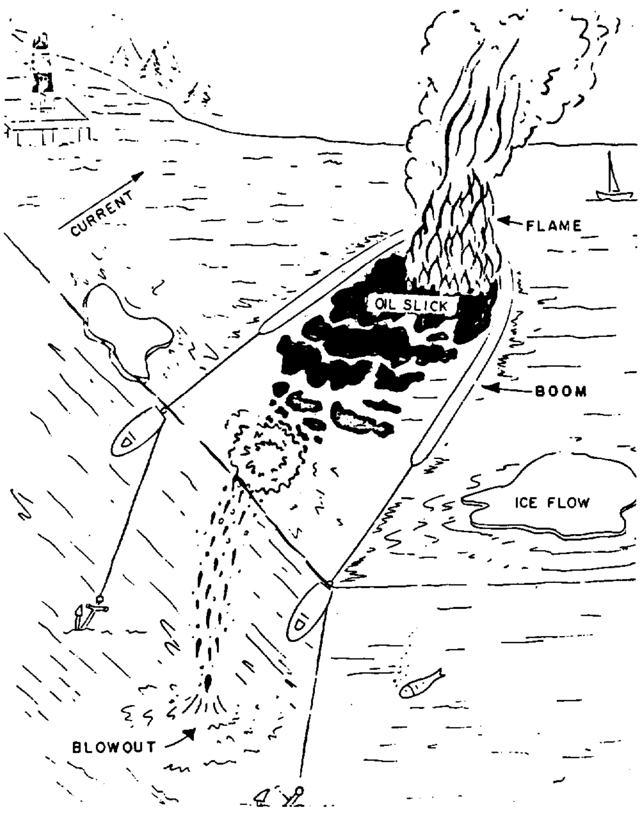

Figure 7. Use of large-scale oil herding/atomizing device offshore

Summary

The acoustical method can improve most existing weir-type skimmers by increasing their output many-fold, increasing their oil to water ratios, and enabling them to function under conditions in which they otherwise could not. This is accomplished by adding a row of sound-focusing transducers near the mouth of the weir.

In addition, a small, single operator burner (which can be used as an igniter in large-scale, open water situations) may be used to burn crude oil, diesel oil, and gasolines spilled in limited access areas such as docks and swamps.

A large-scale acoustical system has flexibility in the proportion of oil burned to collected. This method can be applied to offshore oil well blowouts in areas like the Beaufort Sea.

References

1. Koblanski, John N., 1981. Oil spill removal in the marine environment utilizing acoustic energy. *Journal of Canadian Petroleum Technology,* v20, n3, pp92–96
2. Koblanski, John N., 1981. Method and Apparatus for Atomizing and Burning Liquid Hydrocarbons Floating on Water. U.S. Patent No. 4,308,006, December 29, 1981