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NRT FACT SHEET

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AERATION TECHNIQUES FOR *IN SITU* BURNING OF OIL

Enhancing an alternative spill response method

SUMMARY

Research on aeration techniques for *in situ* burning of oil at sea arose from public concerns about hazardous emissions from a burn event. The goal of this research has been to develop techniques to provide the necessary air to a burn to avoid starved combustion conditions and convert the oil completely to harmless products of combustion. Supplying all the necessary air results in: a) a partial or complete reduction in the visible smoke and the accompanying hazardous by-products; b) an increase in the burn rate of a burn event, decreasing the overall time for the response effort. Development efforts in the past resulted in a number of relatively ineffective small-scale burner devices. Recent research has shown promise in the development of large-scale aeration techniques, although substantial development is still required for a viable at-sea response technology.

BACKGROUND

In situ burning of oil spills has recently received attention as a practical and effective alternative to current response and cleanup methods**.** *In situ* burning typically results in a high percentage of oil removal, reducing the need for collection, storage, and disposal: removal rates of greater than 90% have been achieved in various tests, usually leaving a small residual sludge to be contained and collected. *In situ* burning is also effective in areas of particular environmental sensitivity or logistical difficulty, such as marshlands or arctic ice, where conventional equipment cannot be used.

Despite its advantages, *in situ* burning has had limited application in the field, often due to public concerns over the possible hazards posed by the smoke and soot. Ideally, oil oxidizes almost completely to carbon dioxide and water, as long as enough air (oxygen) is provided to the burn. In most large-scale burns, however, not enough air is drawn into the fire to supply the oxygen demand of the fire: the burn continues under conditions of “Starved combustion”, producing a thick, dense, black plume of smoke composed of partially burned byproducts in particulate (soot) and gaseous form. Usually equal to 10-15% of the mass of the burned oil, the soot is composed primarily of carbon particulates, although in large-area burns the soot may also contain unburned droplets of oil. In high concentrations, the soot can cause respiratory problems in sensitive individuals. Such concentrations, however, are usually found only in the smoke plume near the burn (within 500 meters). Gaseous emissions include polynuclear aromatic hydrocarbons (PAHs), some of which are carcinogenic, and carbon monoxide and nitrogen dioxide--known toxic gases. Tests reveal, however, that surface-level concentrations of these emissions remain well below dangerous levels during a burn.

Despite the minimal hazards posed by the soot and gas, the thick black smoke produced in an *in situ* burn often appears threatening, eroding the public confidence in the safety of the process. To address public concerns over emissions, aeration technology and research has focused on supplying sufficient air to completely oxidize spilled oil and reduce or eliminate visible smoke and its potentially hazardous components.

PAST RESEARCH EFFORTS

Aeration techniques have been explored concurrently with *in situ* burning evolution. Most past research has focused on development of small-scale floating incinerators and burners. Typical constructions consist of a partially or totally enclosed combustion chamber into which oil from a slick is drawn: air is then injected or mixed into the chamber as the oil is ignited. Some of the major burner designs and their developers, as reported by Buist, *et al*. (1994), are listed here:

- ***British Petroleum Elijah Burner:*** Investigated in the late 1960's by British Petroleum, this burner used a vortex-forming submersible pump to collect oil into a pool several inches thick; the oil was then sprayed upwards by a stream of hot air into a combustion chamber. A burn rate of 11 gal/hr (40 L/hr) was achieved with low smoke production. The effort, however, was abandoned due to low removal rates.
- ***Pittsburgh Corning Burners:*** Pittsburgh Corning patented two burners in the 1970's composed of a large combustion chamber into which air was injected. One system was a stand-alone floating unit: the other was mounted on an oil-collection vessel. Although reported to be “relatively smokeless”, neither design was pursued commercially.
- ***Acoustic Burner:*** Tested by Environment Canada in the mid 1980's, this burner used acoustic energy to lift oil off the water surface and atomize it. The atomized oil was then mixed with air from the surrounding atmosphere in a partially enclosed combustion chamber. Unfortunately, the device proved to be ineffective in a wave environment. Also, the oil droplets were often too large for effective burning.
- ***Air Jet Atomizing Burners:*** Researched by various teams in the 1980's, air jet atomizing burners use pneumatic nozzles to entrain and atomize oil directly off the surface of the water. Pneumatic jets, oriented upwards, are placed near the oil/water interface. The flow of air flow from the nozzle entrains oil from the slick surrounding it, atomizing it with the force of the air flow. Tests indicate that the mechanism has merit as a response tool in calm seas: smoke levels can be reduced as long as operating parameters, such as the placement of the air nozzles just above the oil/water interface, are correctly maintained. Unfortunately, the performance of the device is drastically reduced in a wave environment.

RECENT RESEARCH EFFORTS

Although burner technology has yielded some promising results for clean oil spill burning, its applicability to large spills has been limited because of small burner size, localized effect, operational constraints, and slow combustion rates. Only recently has research been done using aeration techniques for large-scale burn smoke reduction.

University of Arizona Burn Experiments: As reported by Buist, *et al* (1994), a research team at the University of Arizona has focused on the mechanical enhancement of air entrainment and mixing in the combustion perimeter of a burning pool of oil. A buoyant column of heated air tends to have a swirling motion as it rises, creating what is commonly called a “fire whirl”. This can be a desirable condition, since it encourages the entrainment of air from the surrounding atmosphere, increasing the mixing of air into the center of the flame column. In 1990, the Arizona research team investigated two approaches to encourage the fire whirl and air mixing in small-scale pools:

- **Vanes**: Sheet metal vanes were positioned vertically in tangential directions to the perimeter of a burn pool eight feet (2.4 m) in diameter. In this pattern, the vanes guided the inflowing air into a cyclonic pattern, entraining it into the center of the flames. With eight vanes in place, smoke was reduced by roughly 50%, and the burn rate was effectively doubled over the normal "free burn" rate. However, large-scale tests of the vanes by Alaska Clean Seas in 1991 could not reproduce these results. Also, the ease with which vanes could be operated at sea is questionable.

- **Blowers**: Another method tested by the Arizona team used various air blower arrangements to supply air to the flames. After many experiments, the team concluded that it was not effective to supply the stoichiometric ratio of air required for combustion (15 lbs of air for 1 lb of oil) using high volume, low velocity blowers. Rather, it was more efficient to introduce a low volume of air (less than the stoichiometric ratio) in high-velocity compressed streams. The most effective arrangement combined strategically placed streams of compressed air with the vane ducting arrangement around a pool of oil. One air nozzle was placed in the center of the pool aimed up the axis of the flames, and three others were placed around the perimeter of the pool, tilted 30¿ from the vertical along the tangent of the flame perimeter. This arrangement increased the burn rate 3_ times over the vanes alone--nearly 8 times the normal free burning rate. In addition, flame temperatures were dramatically increased, and overall smoke production was noticeably decreased.

MSRC Mesoscale Burn Experiments: Building upon the technology pioneered by the University of Arizona team, Marine Spill Response Corporation (MSRC) has sponsored a series of medium-scale *in situ* burn tests as a median step for development of at-sea response technology. Employing the support of Navy Supervisor of Salvage (SUPSALV), MSRC tested the smoke reduction capabilities of three air delivery systems on a pool of diesel 14 feet (4.25 m) square--nearly double the pool size used by the Arizona team. Results of these tests are listed as follows:

- **High Volume/Low Velocity Diffusers**: Heavy industrial blowers were used to provide up to 150% of the stoichiometric requirement of air. The air was delivered to the test pool via four high-temperature air ducts positioned outside the burn perimeter, aimed across the surface of the oil. Various trials revealed that this arrangement could noticeably reduce smoke production, concurrently doubling the natural free burn rate and increasing flame temperatures. Much of the supplemental air, however, was carried away by the rising hot air at the periphery of the flames, preventing the necessary aeration at the center of the burn. Also, the duct equipment was cumbersome and prone to failure in high-temperature environment (Kupersmith, 1995).

- **Air Jet Aeration**: Compressed air at high velocities was supplied to the center of the burn through a network of five steel nozzles positioned in a pattern similar to the Arizona arrangement: one nozzle was placed in the center directed up the axis of the flames, and four were placed in a circle around it, halfway between the center and the outer edge of the burn, tilted 30¿ along the tangent to enhance cyclonic velocities. Various nozzle sizes, heights, and air flow rates were tested. The most effective arrangement had the nozzles just above the surface of the oil: visible smoke production was nearly eliminated, with only 10% of the stoichiometric air requirement being supplied. Unfortunately, the method was sensitive to winds: even a light breeze would push the flames to the side beyond the influence of the air nozzles, reducing the overall effectiveness (Buist, 1995).

- **Sub-sea Air Bubbler System**: A small amount of compressed air, equivalent to less than 5% of the stoichiometric requirement, was bubbled up from beneath the oil slick around the perimeter and in the center of the burn using a network of submerged piping. The air bubbles produced a roiling surface turbulence, creating a spray of oil and water that was cast up into the flames. Visible smoke production was reduced, although not as dramatically as the air jet aeration. This arrangement was not affected by external environmental conditions such as wind or temperature. The surface turbulence decreased the effective area of the burn, however, slowing the burn rate by at least a factor of three. (Buist, 1995).

FUTURE NEEDS IN R&D

Future research and development should focus upon those aeration technologies that promise to yield substantial reduction in visible smoke. Particular attention should be paid to advancing burner technology and air jet and bubbler aeration techniques. Specific goals for R&D are:

- Continue mesoscale research begun by MSRC to accurately determine the optimum operating parameters of the air jet aeration systems and sub-sea bubbler under various environmental situations;

- Perform detailed analysis of emissions from aerated burns to quantify the reduction in soot and hazardous gases;

- Develop a system of aeration, based the upon air jet or bubbler concepts or both, that is suitable for large-scale, at-sea *in situ* burn situations: the system must be easy to deploy, handle, and maintain, and must be operationally feasible in a marine response situation;

- Investigate the effectiveness of using multiple floating burners in a large-scale *in situ* burn event.

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