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ISB

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## R & D COMMITTEE

### IN-SITU BURNING OF OIL

An Alternative Approach to Spill Response

An information update for using at sea burning of oil as a primary spill response strategy.

August 1992

### SUMMARY

The purpose of this fact sheet is to provide recent information on in situ burning for consideration as an alternative technology to present cleanup methods such as mechanical recovery or dispersants. In-situ burning of oil can essentially be defined as the controlled burning of spilled oil while it is still on the water surface. Ongoing research suggests that this technology looks promising as a viable response method within certain constraints: the slick must be at least 2 to 3 millimeters thick for ignition, wind and wave conditions must be moderate, the oil must not have significantly emulsified, and the downwind emissions must be below threshold concentrations for sensitive populations. Experimental results have shown that 50 - 95% of oils tested could be removed from the water surface by burning if emulsification of the oil had not occurred before ignition and if an adequate slick thickness was maintained to support burning.

### INTRODUCTION

Conceptually, burning has distinct advantages over other countermeasures. It offers the potential to rapidly change large quantities of oil into its primary combustion products -- water and carbon dioxide, with a smaller percentage of other unburned or residual byproducts (e.g., efficient combustion of a South Louisiana crude is estimated to produce, by weight, 75% carbon dioxide, 12% water vapor, 10% soot, 3% carbon monoxide, and 0.2% other miscellaneous products). This prevents a large amount of shoreline contamination and damage to biota by removing the oil before it spreads and moves. In-situ burning requires minimal equipment, although some is

specialized (i.e., fire boom, igniters), and less labor than other techniques. It can be applied in areas where many other methods cannot be due to distances and lack of response infrastructure such as in oil/ice situations or remote locations. Because the oil is gasified during combustion, the need for physical collection, storage, and transport of recovered product is reduced. The volume to be handled is only a few percent of the original spill volume after burning. The remaining residue, however, is much more viscous than the original product and may require different removal techniques than required for the original product.

## HISTORY

In-situ burning of oil is not a new idea. The first major oil spill in which burning was tried was during the TORREY CANYON (1967) incident in Great Britain. The results were unsuccessful due to emulsification of the oil and served to discourage others from trying. In 1969, Dutch authorities were successful in igniting test slicks at sea and on shore. In 1970, Swedish authorities were very successful in igniting and burning Bunker C oil from a ship accident in ice. During the 1970's and 80's there were many studies and tests conducted on in-situ burning, including the burning of 15,000 to 30,000 gallons of North Slope Crude from the EXXON VALDEZ oil spill, but the results have been varied. In 1983, MMS initiated an in-situ burning program to evaluate the burning of spilled oil in different environments, including the factors limiting combustion and the resulting byproducts. This program has subsequently been joined by U.S. Coast Guard (USCG), Environment Canada (EC) and the National Institute of Standards and Technology (NIST). The majority of the research results discussed below are based upon this program.

## COMBUSTION AND BURNING RATES

In order to understand in-situ burning it is necessary to comprehend the basics of combustion of oil products. Most, if not all oils, will burn on water or land if of sufficient thickness. Since it is the oil vapor that burns, and not the oil itself, the fire must be hot enough to maintain a vapor flow. The thickness of the oil must be maintained at no less than 1 millimeter (mm) to avoid a heat sink effect that transfers the heat from the oil layer to the water and extinguishes the fire. A "prime-rule" of in-situ burning is that oil slicks will ignite if they are at least 2-3 mm thick. The depth of most oil pools can be reduced through burning at a rate of about 2 to 3 mm per minute. As a rule of thumb, one can burn about 100 gallons of oil per square-foot per day.

## EMISSIONS AND RESIDUES

Concerns over atmospheric emissions remain the primary reason against widespread acceptance of burning as a response tool. Burning oil produces a visible smoke plume

containing smoke particulates, combustion gases, unburned hydrocarbons, residue left at the burn site and other products of combustion. It also results in the evaporation and release of volatile compounds in the oil. Public health concerns relate to the chemical content of the smoke plume and the downwind deposition of particulates. NIST and EC are presently assessing the chemical content of the plume through measurements during experimental burns.

Studies have been performed on the gaseous emissions of burning. Although the dominant products of combustion are carbon dioxide, water and heat, incomplete combustion and chemical compounds in the oil may produce small amounts of carbon monoxide and sulfur dioxide; benzene, toluene and xylene; and polyaromatic hydrocarbons (PAH's). Studies show that sulfur dioxide production is directly proportional to the sulfur content of the oil, which ranges from 0.1% to 5% of the oil weight. Plume modeling shows that a typical burn would produce concentrations that are well under concern levels beyond 1 kilometer. Benzene, toluene, and xylene concentrations are similar to those found above a non-burning slick. PAH's, which are naturally found in petroleum, are partially destroyed or converted to higher molecular weight PAH's which are considered less acutely toxic. Chronic toxicity of these compounds and potential significance, however, has not been determined, although some PAH's are known carcinogens. Soot particles, although consisting of largely carbon particles, have chemicals absorbed and adsorbed to their surface. The most frequent compounds identified were aldehydes, ketones, esters and acids in concentrations of parts-per million or less formed by incomplete oxygenation of the oil. Similar analysis of the residue for the same minority compounds show similar concentrations.

The bulk of the burn residue is unburned oil. The residue is primarily composed of higher molecular weight compounds of oil with minimal lighter or more volatile products. This resultant "tar paddy"; exhibits little water or lipid solubility and has no detectable acutely toxic compounds. Although the residues do not appear to be acutely toxic, it is advisable that the residue, which may become denser than seawater over time, be collected before sinking. While not conclusive, these studies suggest that no toxic combustion by-products are produced.

## WHEN TO BURN

Burning may be applied efficiently for only a limited time after the spill. Factors influencing the viability and efficiency of an in-situ burning operation include emulsification, vapor loss (i.e., weathering), slick thickness and oil submersion as affected by wind, rain, waves and sunlight. Heavily emulsified oils, (oils mixed with water), have not been effectively burned. Research shows slick thickness is usually the major controlling factor because the fire extinguishes when slick thickness is less than 1 mm. Since most oils spread quickly following a discharge of oil into the

marine environment, the slick will rapidly become thinner than the required minimum burning thickness. Thus, containment in a fireproof boom or by other method, including by pack ice, is required to concentrate the oil slick so that it is of sufficient thickness (2 to 3 mm) to ignite and burn efficiently.

In some cases, however, ignition of the oil is a controlling factor. Heavy oils require longer heating times and a hotter flame to ignite compared to lighter oils. Emulsified oils will not ignite and sustain combustion. Ignition of floating oil is substantially hampered by dispersion (chemically or naturally) and the formation of oil-in-water emulsions. The temperature of the oil is not as important as the water content, however, for burns have been conducted from - 1 degree to + 15 °C ambient temperature with little or no loss of efficiency. Winds up to 52 knots and 99 % ice coverage have been observed to have minimal effect on the outcome of the burns.

## FUTURE RESEARCH PLANS

If permits can be obtained, MMS, EC, NIST, and the USCG are planning two full-scale at sea experiments, one offshore Louisiana and one off Newfoundland. These efforts are to verify the efficiency of in-situ burning, to quantify the pollutants resulting from the burn, and to demonstrate the operational feasibility of in-situ burning. Requests for both permits are pending, although neither burn will be conducted before 1993. In addition, the USCG and Alaska Clean Seas submitted a permit application to EPA for a controlled in-situ burn in the Beaufort Sea during summer, 1992. This application was not approved in time to conduct the test.

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These reports are available from Joseph Mullin (703/787-1560), Minerals Management Service.