THE USE OF ADDITIVES FOR SMOKE REDUCTION FROM BURNING POOL FIRES.

J.B.A. Mitchell and E. Janssen
Dept. of Physics, University of Western Ontario,
London, Ontario, Canada N6A 3K7

INTRODUCTION.

At the AMOP conference, last year, Mitchell[1] presented data which showed that the iron compound, ferrocene, was very effective in reducing smoke emissions from the laboratory scale combustion of crude oil. This has obvious applications to oil spill cleanup and this research program is continuing with the ultimate goal of the developing of protocols for the use of such additives in field situations. Ferrocene is non-toxic and insoluble in water. It therefore does not present any environmental problems associated with the contamination of the marine environment. It is however not very soluble in oil and having a greater density than water, presents problems with regard to adding it to an existing spill.

A number of other iron additives have been studied and a clear picture of the mechanism for the action of such additives in soot reduction is emerging. Some of this work has recently been published[2]. The present paper describes tests which have been performed on two such additives butylferrocene and pentylferrocene. Their effectiveness and suitablility as smoke reducing agents is discussed.

A basic question in this research is the effectiveness of the ferrocene compounds in larger scale fires. A series of 1 meter diameter pool fire burns have been performed and the results are presented. Plans are in place for a series of 6 meter burns and these should have been completed by the time of the conference. An experiment has been performed in which ferrocene was introduced into an already burning fire and this was found to be successful.

Environment Canada. Arctic and Marine Oilspill Program Technical Seminar, 14th. June 12-14, 1991, Vancouver, B.C., Environment Canada, Ottawa, Ontario, 391-397 pp, 1991

FERROCENE DERIVATIVES.

Butylferrocene $(C_4H_9.C_5H_4.C_5H_5)Fe$ is a liquid with a density of 1.172 and mixes easily with crude oil. Its melting point is 10-12C and its boiling point is 232C. Burn tests were performed in which 15ml samples of Prudhoe Bay crude oil containing varying concentrations of butylferrocene were burned in 5cm diameter ceramic crucibles. The smoke from these burns was drawn through a quartz filter and the volume of the soot thus collected was measured. The results of these tests are shown in figure 1. It can be seen that butylferrocene is an excellent smoke inhibiter.

Pentylferrocene $(C_5H_{11}.C_5H_4.C_5H_5)Fe$ is also a liquid. It has a density of 1.170, a boiling point of 80-90C. It also mixes easily with crude oil. Similar burn tests were performed with pentylferrocene and the results are shown in figure 2. Again it can be seen that pentylferrocene would be very suitable for use in inhibiting smoke emission from burning oil spills.

Both these compounds have densities greater than water but they can be mixed with appropriate proportions of kerosene to produce a liquid with the same density as the crude oil.

ADDITIVE ADDITION TO EXISTING FIRES.

The question arises, Is it possible to add one of these compounds to a fire that is already burning in order to inhibit smoke production? Ferrocene is itself flammable and when burned on its own emits copious amounts of iron oxide particulates. Adding it directly into the flames of a fire will not therefore be useful in smoke supression. An experiment was performed however in which ferrocene powder was injected below the surface of a pool of burning oil. It was found that within a few seconds, the ferrocene began to dissolve in the oil and indeed a considerable reduction in smoke output was obtained. This technique could be useful in situations involving the accidental ignition of fuel tanks or wells, provided it is possible to access the region below the fire.

1-METRE BURN TESTS.

As mentioned above, although ferrocene is very effective in eliminating soot from small laboratory scale fires, one must ensure that it will work on a large scale before it can be used in the field. As a first step in determining its applicability to large fires, a series of

1 metre burn test was performed with the assistance of the Fire Safety Department at the University of Western Ontario. Burns were performed using Varsol, Varsol + 2% ferrocene, Norman Wells Crude oil and Norman Wells + 4% ferrocene. The results of these tests are shown in figures 3-6. It can be seen that in the case of Varsol alone, copious amounts of black smoke were produced. No visible smoke was produced in the case of the Varsol+ferrocene mixture combustion.

The crude oil burn also produced a considerable amount of black smoke. When the crude oil + ferrocene mixture was burned this was eliminated although there was a small amount of white smoke emitted. This is due to the iron oxide produced from the ferrocene. The difference in the two cases may mean that in fact too high a concentration of ferrocene was used in the crude oil tests.

What was particularly interesting was the fact that in both cases, when the ferrocene was used, black smoke was seen emanating from the base of the fire, at the edge of the pool, but this was rapidly destroyed within the fire and was not emitted. Also, although secondary flames were visible, high up in the fire, they did not lead to soot output. This is very encouraging and points the way to larger scale tests.

6-METRE BURN TESTS.

A series of 6 metre diameter burn tests are scheduled for the month of June 1991, and will be held at the Fire Training Facility in Calgary Alberta. These tests will involve particulate, CO_2, CO and hydrocarbon sampling and burns will be performed using both crude oil and fuel oil, with and without the addition of premixed ferrocene. It is hoped that the results can be presented at this meeting.

CONCLUSION.

The results obtained in this program to date are very encouraging and lead us to believe that the addition of ferrocene or ferrocene derivatives can be a useful and viable method of reducing smoke emissions from the combustion of oil spills.

ACKNOWLEDGEMENTS.

The generous financial support of ESSO Resources Canada Ltd and the invaluable assistance of Drs. Ron Goodman and Michael Moir of that organization are gratefully acknowledged. Thanks are also due to Mr. Mark Vansteenkiste of the Fire Safety Section at the University of Western Ontario for assistance in conducting the 1 metre burn tests.

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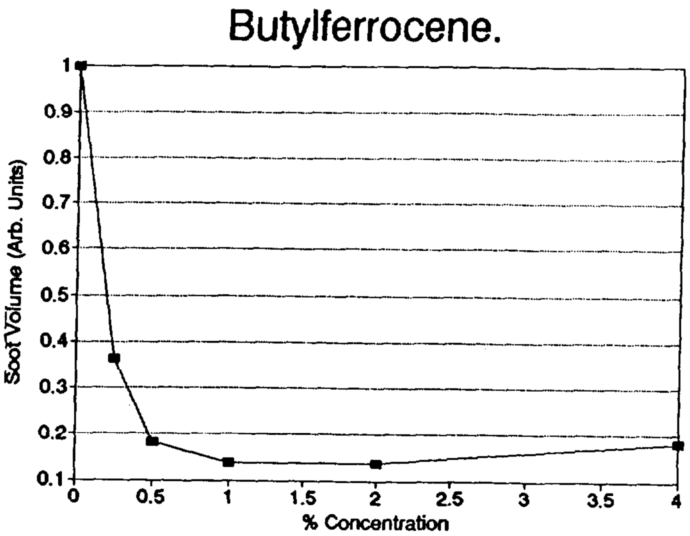

Figure 1. Soot volume emitted from the burning of butylferrocene seeded samples of Prudhoe Bay oil vs. additive concentration.

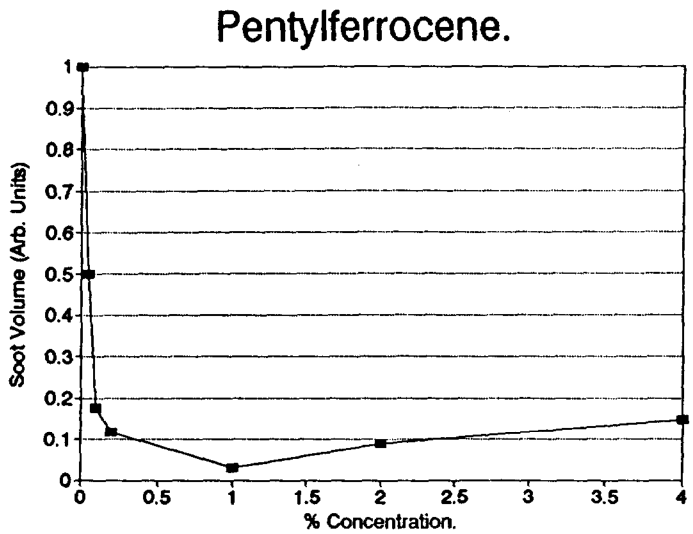

Figure 2. Soot volume emitted from the burning of pentylferrocene seeded crude oil samples vs additive concentration.

Figure 3. 1 metre Varsol burn without additive.

Figure 4. 1 metre Varsol burn with 2% ferrocene.

Figure 5. 1 metre Norman Wells burn without additive.

Figure 6. 1 metre Norman Wells burn with 4% ferrocene.