Central Fire Brigades Advisory Council
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Computer Modelling of Large Oil Tank Fires Feasibility Study Summary Report

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ISBN 0-86252-743-0

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A request for research in the area of fire-fighting in large oil storage tanks was made by CACFOA in 1987, to advise on the best logistics, tactics, foam monitors and media to ensure success.

In an earlier study for FRDG by Ewbank Preece Ltd, on fire-fighting foams and associated equipment and tactics, it was suggested that computer modelling should be considered for the case of very large oil tank fires where knowledge and experience are lacking.

In 1991 AEA Technology, under contract to FRDG, carried out a feasibility study into the use of computer models in this area.

OIL TANK FIRES

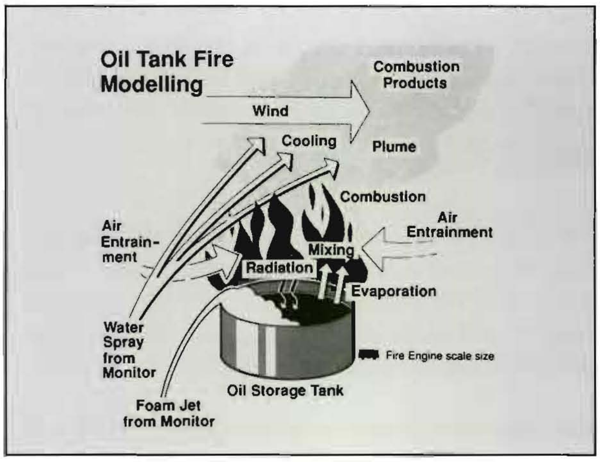
Only rarely does a major fire occur in a large oil storage tank, but when one does occur it can pose a significant safety threat and can be extremely difficult to control. A recent example of such a fire was at Milford Haven in 1983. Due to their rarity there is little practical experience of dealing with such fires and full-scale experiments are impractical. However, computer modelling offers a possible method of providing information.

THE SCENARIO

The oil tanks relevant here contain crude oil or refined product and have diameters ranging from 18 - 90 metres and heights up to 27 metres. When a tank fire is well established, the flames can rise many hundreds of metres, causing massive updraught. Strong winds can cause this column of fire to be deflected very nearly horizontal. The heat output from a large oil tank fire is estimated to be of the order of 1000 million Watts or about the same as the electric power produced by a large power station.

It is understood that many small fires are extinguished with fixed protection systems, but when these systems fail to extinguish, are absent or are disabled, the fire fighter must be able to project foam into the top of the tank, either from ground level or from an elevated hydraulic platform.

The foam is projected using a suitable foam monitor, that is, a hose nozzle typically mounted on a trailer. The foam solution may have varying amounts of induced air and several foam types are in current use. To be effective, the foam must reach the fuel surface and form a foam layer.



It has also been suggested that projection of water sprays into the 'plume' of flame and hot gases rising from the tank may cool the plume significantly and allow more foam to reach the oil surface.

MODELLING THE FIRE

There are several aspects of the fire which need to be modelled:

(i) The fire plume. Heat radiated downwards from the plume evaporates more oil from the surface. The vapour mixes with air, drawn in from around the tank, before igniting and adding more heat to the fire. The effect of wind on the plume is also important.

(ii) The foam. The projection of foam onto the oil surface and the spread of the foam layer across the surface are both important. The foam is blown about by the strong draughts in and around the plume and is also subjected to strong heating before landing on the oil surface. Once applied, the foam layer is gradually destroyed by evaporation and drainage.

(iii) The water sprays. Water sprayed into the plume in droplets would evaporate and cool the plume.

Computer programs already exist which can model fluid motion and heat radiation in the plume. For instance, the programmes FLOW3D and RAD3D are available at AEA Technology. The main difficulties here are with modelling the turbulence in the plume, which is important in mixing the gases before combustion, and modelling the absorption of radiation by the plume, especially by soot which is not yet well understood. However, it would probably be sufficient to make approximations to take account for these factors.

Modelling of the foam is the most difficult area. Projection of the foam onto the oil surface can be modelled simply if validated by experimental data, although some foam falls out of the jet as a 'snow' which would have to be allowed for. To model the destruction of the foam by evaporation and drainage and movement of the foam across the oil surface would need experimental data.

The water spray can be modelled by tracking the water drops and calculating their evaporation. This is possible, for instance, with FLOW3D. Data on water drop sizes produced by a spray, necessary for the calculation, is readily available.

Modelling of all aspects of a large oil tank fire is technically possible with the computer software presently available.

CONCLUSIONS

The models used would need to be demonstrated to be accurate by comparing their predictions with experimental data. In the case of foams, data is lacking, and further experiments would need to be carried out.

Because of the large dimensions of an oil tank fire, the use of models is an extrapolation beyond the region in which the models can be validated against experiment. This means that the results, particularly of the empirical models, would need to be treated with some caution.

PROPOSED FURTHER WORK

As part of this feasibility study AEA Technology were asked to make proposals for a possible modelling study. It consists of four separate phases:

(i) Construct the model. A model of the plume would be constructed. The effects of radiation absorption and wind would be included.

(ii) Validate the model and develop it further. The results from the model would be compared with an experiment and the model would be modified where necessary.

(iii) Addition of water spray and foam. Models for the foam and the water sprays would be developed and tested against experimental data.

(iv) Analysis of a large oil tank fire. Once the first three phases were completed, the model would be run with different wind speeds, water sprays and foam application to predict the effect on the fire.

A separate programme of experimental work would be required to provide input data for the model and also to validate results. The experiments required are:

(i) plume tests, with a reduced scale oil fire;

(ii) water spray tests to look at the effect of water sprays on a reduced scale oil fire;

(iii) foam ballistics tests in which a foam jet would be recorded on video or high-speed film;

(iv) foam destruction and mobility tests, to determine foam drainage times, rate of destruction by radiation, and mobility across the oil surface.

Although the combination of the modelling and experimental work would permit some guidance to be given to brigades on how best to tackle a large oil tank fire, the difficulties involved and the uncertainty of obtaining definitive results, coupled with the high cost, have made the Home Office decide not to proceed with this work.

References.

AEA Technology, CFD Department, "Computer Modelling of Large Oil Tank Fires - Feasibility Study", Report for the Home Office, 1992.

Designed by Home Office Design and Illustration Branch

ISBN 0-86252-743-0