Smoke Plume Trajectory from In-Situ Burning of Crude Oil in Tomakomai
----- Field Experiments and Prediction with ALOFT-PC ----

Tokiyoshi YAMADA
National Research Institute of Fire and Disaster
14-1,Nakahara 3 chome Mitaka,
TOKYO,181-8633 JAPAN
TEL:+81(422) 44-8331, FAX:+81(422) 42-7719

Background

A series of large scale crude oil tank burning test were conducted at Tomakomai, Hokkaido in Japan Jan.'98, for obtaining basic knowledge necessary for developing "Information and Command Support System for Oil Stockpiling Base " in a case of emergency such as tank fire and oil spill. Prediction of smoke plume trajectory from *in-situ* burning is one of the key issues for the system, because hazardous combustion products can be transported by a windblown smoke plume and delivered over a wide area. For assessing and establishing emergency corresponding plan, even a coarse prediction of smoke spread will be very helpful. NIST/BFRL have been developing prediction models for such a large scale fire smoke dispersion and some of the validation have been done[1,2]. For utilizing a simple prediction model named ALOFT-PC as one of the tools for the system, validity of the model is examined by comparing between the prediction and the experiment.

Experiment and Prediction

Experiment : Total 7 test runs were conducted with 5, 10 and 20 m diameter tank of 0.3, 0.5 and 0.7 m depth respectively. As a test fuel, equivalent of Arabian Light crude oil with the API gravity of 32.8 was used. The oil was supplied into the water filled tank with 5cm depth, which enables about 20 min. burning. For ALOFT-PC model validation, two runs of 10 meter tank tests were targeted, because both of wind condition were relatively constant and stable smoke trajectory were observed. Smoke trajectory of each test was recorded with VCR and still camera at sea berth platform about 2. km away from fire source in downwind side. Also observation up in the air was made by helicopter, and main direction of smoke flow was determined by the observation. To estimate the height and downwind distance of the plume, a power plant chimney of 200 m height was referred as a landmark. Figure 1 shows the location of observatory, fire source and landmark.

Input data for prediction : Each of two runs, wind condition seemed to be relatively constant for about 6 minutes after ignition. As an input data for prediction, temperature data at the landmark of ground and 185 m height level are adopted as shown in Figure 1. Also average of wind velocity at 185m height is adopted as background velocity. For a category of Pasquill Stability, "unstable (strong)" is selected, i.e.,"C" for both runs. In this experiment, the equivalent of Arabian-Light crude oil is used as a fuel, however the effective heat release rate and emission factors were not analyzed yet. The burning rate was about 0.06kg/s/m^2 estimated from pool level decrease. Then relatively high heat release rate of Louisanna crude oil data base in ALOFT-PC(ver.3.04) was used for convenience: i.e., burning rate per unit area is 0.056 (kg/s/m^2), heat release rate per unit area 2.14 (MW/m^2) and emission factor of PM10(*particulate combustion product with diameter less than 10 micrometer)* is 130(g/kg).etc.

Summery of the Results

Rough comparisons were made between PM10 concentration prediction and view of smoke plume trajectory. Figure 2 is an example of prediction of PM10 conc. shaded contour of plume on center vertical plane. Crosswind section of the simulated plume shows two large counter-rotating vortices characterizing the structure of the rising smoke plume, and its center reaches to about 350 m height at 1.0 km downwind distance from fire. Within the 500 m distance, the prediction contour seems to be relatively primitive due to coarse calculation cells' effect. Figure 3 shows comparison of picture view of transient smoke trajectory and PM10 conc. prediction on a specific section plane. In spite of coarse estimation, both prediction of downwind and crosswind side agree well with transient smoke plume transport in the region beyond 500m downwind from fire source. Whereas in closer region to fire source, coarse calculation cells cause less accuracy of the prediction as indicated[1,2]. In this experiment, distinct two counter rotating vortices were not well observed, however similar pattern of smoke spread shape can been seen. On the whole, the ALOFT-PC can be expected as simple but powerful tool for practical purpose.

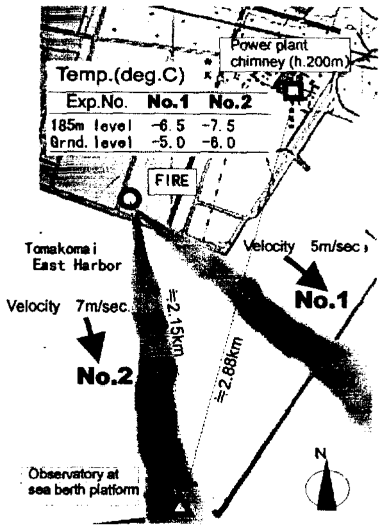


Figure 1: Location of fire source , observatory and land mark, and input weather conditions

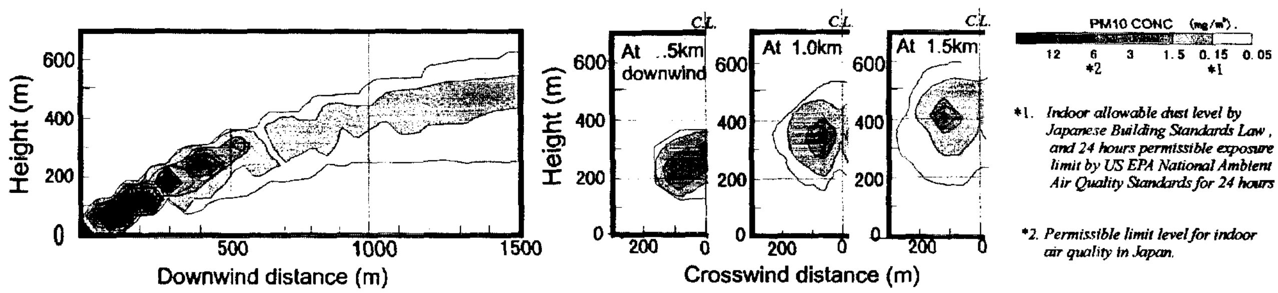
References

[1] W.D.Walton, K.B. McGrattan *et al.*, "ALOF-PC Smoke Plume Trajectory Model for Personal Computer", *Artic and Marine Oil spill Program Technical Seminar*, Calgary, Alberta, Canada 19th, Vol.2 (1996)

[2] K.B.McGrattan,H.R.Baum *et al.*,"Smoke Plume Trajectory from In Situ Burning of Crude Oil in Alaska --Field Experiments and Modeling of Complex Terrain", *NISTIR* 5958 (1997)

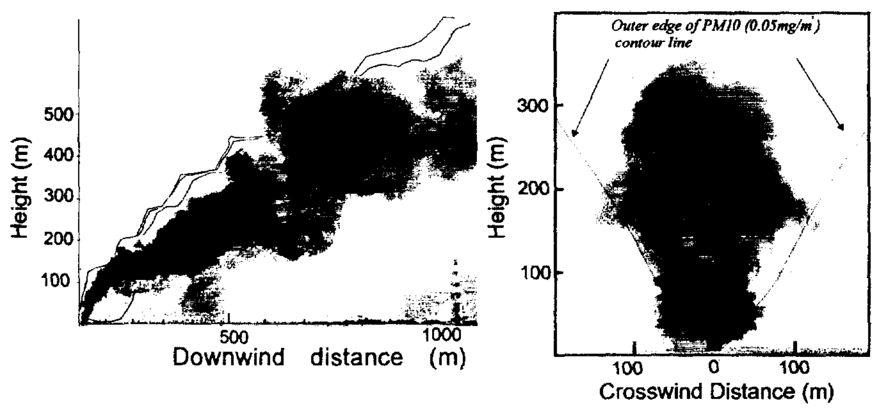
Acknowledgements

This experiment was successfully carried out by the National Research Inst. of Fire and Disaster, the Japan National Oil Corp., and Univ. of Tokyo in collaboration with Japan Ground Self Defense Force, Fire Departments concerned, and other organizations. And the prediction could be done with NIST/BFRL collaboration, especially special thanks to Drs. H.Baum and R.Rehm for giving useful advice.



(a) Downwind vertical section (b) Crosswind section

Figure 2 :Example of PM10 concentration prediction contour : Exp.No.1 (wind velocity =5m/s, Fire=10m Diameter tank of Arabian Light crude oil, Pasquil Giiffor Categ.= "C", smoke plume travels over "water")



(a) Downwind side view (b) Crosswind side view

Figure 3
Comparison with view of transient smoke transport and PM10 conc. prediction: :
(a)Exp.No.1 at 5min30sc after Ignition, contour is of downwind vertical section.
(b)Exp.No.2, at 2min.,contour is of 500m downwind cross-section.Outer contour line indicats 0.15mg/m^3 of PM10