Validation of CFD Prediction of Cooling Tower Drift

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INTRODUCTION

Drift of small water droplets from mechanical and natural draft cooling tower installations can contain water treatment chemicals such that contact with plants, building surfaces and human activity can be hazardous. Prediction of drift accretion is generally provided by analytic models such as the US EPA approved ISCST3 or SACTI codes; however, these codes are not suitable when cooling towers are located midst taller structures and buildings. A computational fluid dynamics code including Lagrangian prediction of the gravity driven but stochastic trajectory descent of droplets is considered and compared to data from the 1977 Chalk Point Dye Tracer Experiment in preparation for using such methods in more complex building configurations.. The CFD program predicts plume rise, surface concentrations, plume centerline concentrations and surface drift accretion within the bounds of field experimental accuracy.

COMPUTATIONAL PREDICTION OF COOLING TOWER DRIFT

Estimation of the impact of cooling tower drift on downwind deposition of droplet born toxins is difficult. A few field studies performed between 1965 and 1984 examined cooling tower plume rise, visibility, and downwind concentrations. Unfortunately, only a couple of these actually measured deposition rates downwind. Despite limited field data, concern about drift and deposition led to more than a dozen separate analytic models to predict downwind ground-level concentrations and accretion rates. Chen (1977) compared ten drift deposition models using a set of standard input conditions for a natural-draft cooling tower.[1] They concluded most of the models agree within a factor of three; however, when all ten models are compared, the predicted maximum drift deposition differs by two orders of magnitude, and the downwind locations of the maximum differ by one order of magnitude. These comparisons occurred before improved sets of field data from the Chalk Point Dye Tracer Experiments were available after 1977. Policastro et.al. (1978) compared most of the same drift deposition models to the new Chalk Point experimental data.[2] They concluded, “None of the existing models performed well.” A number of researchers have used CFD previously to calculate cooling tower plume behavior. No CFD calculations were found in the literature that predicted deposition levels downwind of cooling towers.

CFD SIMULATION OF THE CHALK POINT DYE TRACER EXPERIMENT

Results from the 1977 Chalk Point Dye Tracer Experiment are described in papers and reports by Hanna (1978).[3] These experiments are considered to have produced the best single source cooling tower deposition data available. Two natural draft hyperbolic cooling towers are located on the site on a peninsula that extends into the local bay and wet lands. The two towers and the turbine building are located along a east-west line each separated from one-another by about 500 ft. The hyperbolic cooling towers are 400 ft (124 m) tall by 374 ft (114 m) diameter base by 90 ft (27.4 m) diameter exit. Instruments to measure drift deposition were placed at 5^o intervals on 35^o arcs at distances of 0.5 and 1.0 km north of the cooling towers. The average deposition of the dye tagged sodium droplets on the 0.5 and 1.0 km arcs was 1080 and 360 kg/km^2-mo, respectively. Drift droplet sizes at the measurement stations had a mass median diameter of 340 and 260 ?m on the 0.5 and 1.0 km arcs, respectively. Most of the drop sizes were between 250 and 450 ?m on the 0.5 km arc and 200 and 400 ?m on the 1.0 km arc.

Calculations for the Chalk Point Cooling Tower simulation were performed using the FLUENT CFD code on a domain 2000 m long, 1000 m wide and 500 m height using 165,000 tetrahedral cells. The simulated hyperbolic cooling tower height was 124 m, radius of the tower exit was 27.4 m, and plume vertical exhaust speed was set to 4.5 m/sec. Mean wind speed profiles were set to field values of 5 m/s at

100 m height. Setting the plume virtual ambient temperature to 295.3o K included plume buoyancy, and the virtual exhaust temperature was set to 315.3^{o} K. Virtual temperatures are used to account for water vapor content and ambient humidity.

Once FLUENT calculated the overall flow and turbulence field, a Lagrangian discrete particle model was used to sample this data to predict downwind distribution of a particle distribution equivalent to measured field cooling tower exit values. Ground level accretion of the particles were noted at the 0.5 and 1.0 km distances downwind of the cooling tower.

RESULTS OF CHALK POINT VALIDATION EXERCISE

Height of the centerline of the cooling tower plume was determined based on the height of the maximum in the water vapor and temperature profiles downwind of the cooling tower. The calculated points agreed very well with the predictions of the Briggs plume-rise formulae calculated by Hanna (1978) as well as with the trend of the visual observations for plume height recorded during the experiment. Predictions of ground level and plume centerline (Figure 1) water vapor isocontours in terms of log K factors (log C^*U_{ref} / Q_{source}) were compared to values predicted by the ISCST3 program. Agreement was within 25% magnitude. Finally CFD calculated deposition accretion magnitudes were compared to observed and analytic values predicted by ISCST-3 and Hanna (1978) in Figure 2. CFD grid face values for the specified inlet profile and Rosin-Rammler representation of the Chalk Point source droplet distribution agreed within factors of 0.75 and 0.5 at 0.5 and 1.0 km, respectively. Even the worst comparisons at 0.5 and 1.0 km would be within a factor of 4.

REFERENCES

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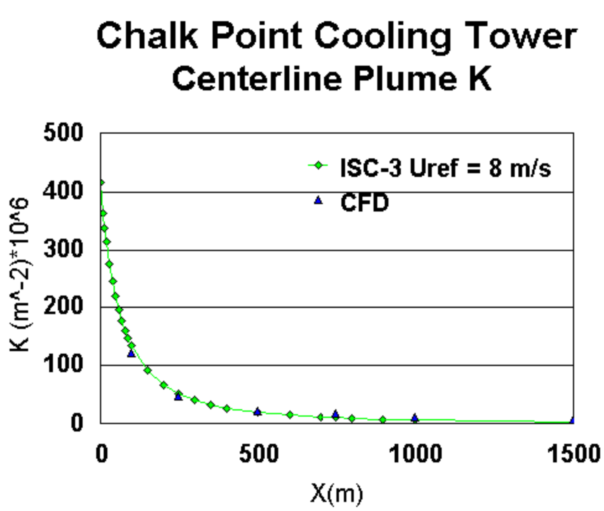

Fig. 1 Predicted plume centerline concentration.

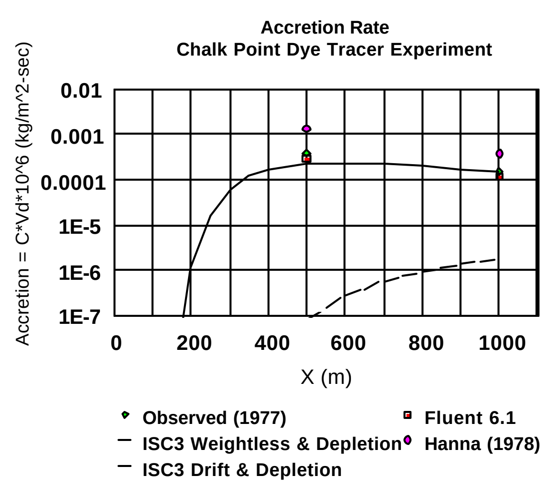

Fig.2 Accretion observed and predicted.