Chalk Point Coal Fired Power Station (2640 MW), Maryland
Courtesy of Power Plant Research Program, Department of Natural Resources, Maryland
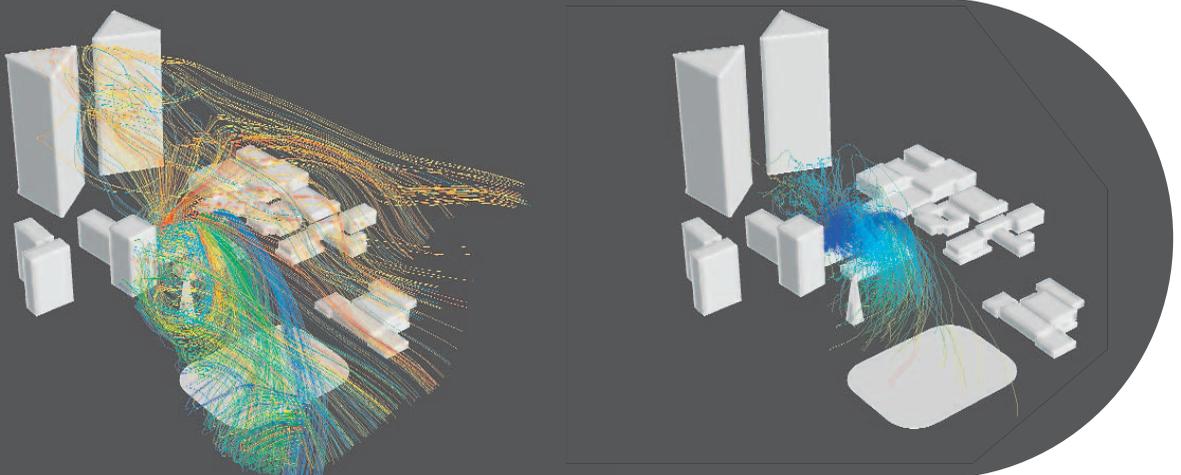
Cooling Tower Drift

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THE DRIFT OF SMALL WATER DROPLETS from mechanical and natural draft cooling tower installations can contain water treatment chemicals that can be hazardous if they make contact with plants, building surfaces, or human activity. Prediction of drift accretion is generally provided by analytic models as found in the US EPA-approved ISCST3 or SACTI codes. However, these codes are not suitable when cooling towers are located in the midst of taller structures and buildings. A CFD calculation including a Lagrangian prediction of the stochastic, gravity-driven trajectory descent of droplets is a better approach in this kind of environment. One such calculation has been performed and compared to data from the 1977 Chalk Point Dye Tracer Experiment in preparation for using such methods in more complex building configurations. The numerical analysis predicts plume rise, surface concentrations, plume centerline concentrations, and surface drift accretion within the bounds of field experimental accuracy.

Estimation of the impact of cooling tower drift on the 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 the development of more than a dozen separate analytic models to predict downwind ground-level concentrations and accretion rates. Chen [1] compared ten drift deposition models using a set of standard input conditions for a natural-draft cooling tower, and found that most of the models agreed within a factor of three. However, when all ten models were compared, the predicted maximum drift

Particle-laden exhaust flows in a typical urban setting where cooling towers emit 300 micron particles in an 8.5m/sec exhaust stream, using reference wind speeds of 5m/s at an angle of 240° from true North; pathlines are shown at left, and particle tracks are shown at right
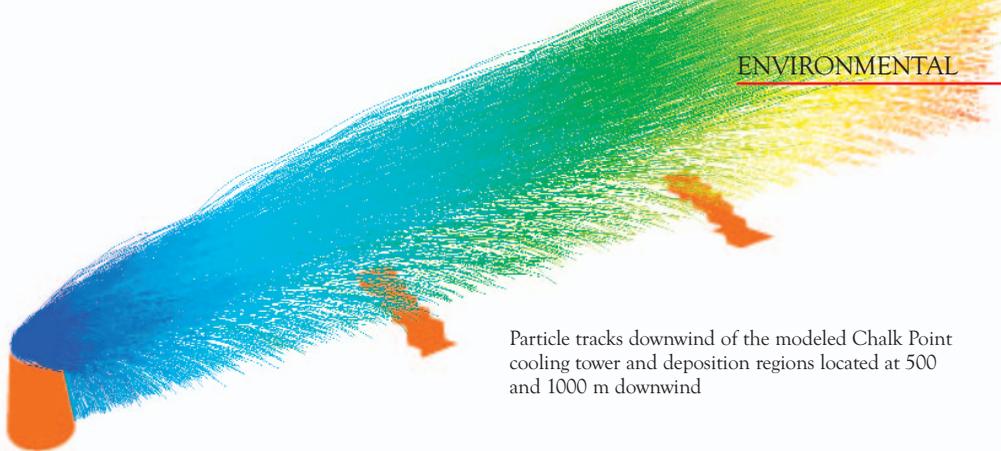
Particle tracks downwind of the modeled Chalk Point cooling tower and deposition regions located at 500 and 1000 m downwind

deposition differed by two orders of magnitude, and the downwind locations of the maximum differed by one order of magnitude. These comparisons occurred before improved sets of field data from the Chalk Point Dye Tracer Experiments became available (after 1977). Policastro et al. [2] compared most of the same drift deposition models to the new Chalk Point experimental data, and concluded that "None of the existing models performed well." A number of researchers have used CFD previously to calculate cooling tower plume behavior, but none of the CFD calculations found in the literature predicted deposition levels downwind of cooling towers.

Results from the 1977 Chalk Point Dye Tracer Experiment are described in papers and reports by Hanna [3]. These experiments are considered to have produced the best single source of cooling tower deposition data available. Two natural draft hyperbolic cooling towers are located on the Chalk Point site in Maryland, on a peninsula that extends into the local bay and wetlands. The two towers and the turbine building are located along an east-west line, and are separated from one another by about 500ft. The hyperbolic cooling towers are 400ft (124m) tall, 374ft (114m) in diameter at the base, and 180ft (54.8m) in diameter at the exit. Instruments to measure drift deposition were placed at 5° intervals on 35° arcs at distances of 0.5 and 1.0km north of the cooling towers. The average deposition rate of the dye-tagged sodium droplets on the 0.5 and 1.0km arcs was 1080 and 360kg/km²/month, respectively. Drift droplet sizes at the measurement stations had a mass median diameter of 340 and 260°μ on the 0.5 and 1.0km arcs, respectively. Most of the drop sizes were between 250 and 450°μ on the 0.5km arc and 200 and 400°μ on the 1.0km arc.

Calculations for the Chalk Point Cooling Tower simulation were performed using FLUENT on a domain 2000m long, 1000m wide and 500m high, using 165,000 tetrahedral cells. The simulated hyperbolic cooling tower height was 124m, with a diameter of 54.8m at the tower exit. The plume vertical exhaust speed was set to 4.5m/sec, and mean wind speed profiles were set to field values of 5m/s at a height of 100m. Rather than specify the actual temperatures, virtual temperatures were used to account for the water vapor content in the plume mixed with the ambient humidity of the background atmosphere. The plume virtual ambient temperature was set to 295.3K, and the virtual exhaust temperature was set to 315.3K. Buoyancy was included in the calculation.

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

The 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 formula calculated by Hanna [3] as well as with the trend of the visual observations for plume height recorded during the experiment. Predictions of ground level and plume centerline water vapor concentration were compared to values predicted by the ISCST3 program, and the agreement was within 25%. The calculations were done in terms of log K factors, where K is the dimensionless water vapor concentration: CU_{ref} / Q_{source}, where C is the actual concentration, U_{ref} is the approaching wind velocity at the cooling tower release height, and Q_{source} is the water vapor content of the exhaust emissions at the cooling tower exit. Particle tracks for a typical Rosin-Rammler particle distribution release with a mean diameter of 0.09mm and spread parameter, n, of 0.65 were also examined. The calculated deposition accretion magnitudes were compared to observed and analytic values predicted by ISCST-3 and Hanna [3]. The 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 1.0km, respectively. ■

References

1   Chen, N.C.J.: A Review of Cooling Tower Drift Deposition Models; Oak Ridge National Laboratory, ORNL/TM-5357, 1977.

2   Policastro, A.J.; Dunn, W.E.; Breig, M.; Ziebarth, J.: Comparison of Ten Drift Deposition Models to Field Data Acquired in the Chalk Point Dry Tracer Experiment; *Symposium on Environmental Effects of Cooling Tower Plumes*, U. of Maryland, May 2-4, 1978.

3   Hanna, S.R: A Simple Drift Deposition Model Applied to the Chalk Point Dye Tracer Experiment; *Symposium on Environmental Effects of Cooling Tower Plumes*, U. of Maryland, PPSP CPCTP-22, WRRC Special Report No. 9, May 2-4, 1978.
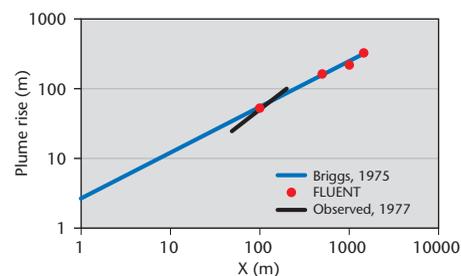
Cooling tower plume rise comparison
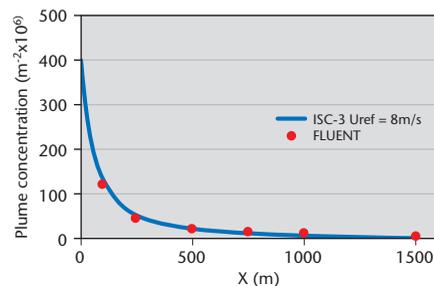
Predicted plume centerline concentration
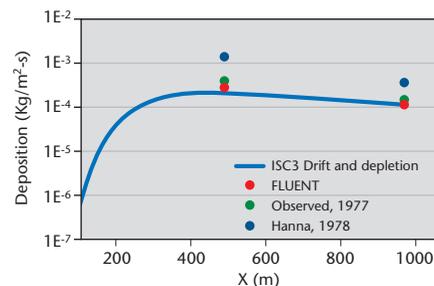
Deposition observed and predicted