UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 7
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Dear Mr. Bridgers:

Region R7 requests Model Clearinghouse (MC) review and concurrence regarding the use of fluid modeling studies to develop "equivalent building dimension" (EBD) parameters to replace building parameters generated by BPIPPRM for use in the AERMOD air dispersion model. Region R7 believes that this case requires MC review because the issues involved may affect other applications nationwide as well as the facility for which this study was done.

BACKGROUND

The Alcoa Davenport Works (Alcoa) facility is a large aluminum producing plant located in Davenport, Iowa. The facility stretches about 1700 meters southwest-northeast adjacent to the Mississippi River. The lateral extent is about 600 meters. The buildings are low, about 20 meters high with little variation in height, and they are attached. This forms a very complex building area. There about 200 small stacks in the plant. Higher terrain is located west of the plant.

In addition to the source data for the Alcoa facility, data from the AERMET, AERMAP, AERSURFACE, and The Building Profile Input Program for PRIME (BPIPPRM) programs were used as input to the AERMOD air dispersion model. AERMOD was used to model PM10 emissions from the facility. There were predicted exceedances. Alcoa believes that BPIPPRM does not adequately represent the complex building area. Alcoa also believes that fluid modeling of the buildings and stacks will give a better representation of the building area than what BPIPPRM does.

FLUID MODELING

Fluid modeling has been used as a method to determine good engineering practice (GEP) stack heights under Section 123 of the Clean Air Act (CAA). EPA developed guidelines on the use of fluid modeling of atmospheric diffusion (EPA, 1981), and also developed guidelines on the determination of GEP stack heights (EPA, 1985). The GEP stack height guidelines defined the criteria for determining whether a particular building or structure would potentially influence plumes from nearby sources on a direction-specific basis. These criteria were later used in the development of the Building Profile Input Program (BPIP), developed for the EPA's Industrial Complex Source (ISC) model in order to automate the process of determining building parameters for nearby structures for input to the dispersion model. Due to limitations of the dispersion model formulations for building downwash, a single "controlling" structure was selected as the basis for the building parameters input to the model. In the early 1990's, the concept of using fluid modeling to simplify complex building areas emerged as a method to determine simplified building parameters that would produce an "equivalent" influence as the complex structures when input to the dispersion model. The object was to replace building parameters calculated by BPIP with the "equivalent" building dimensions (EBDs) developed from the fluid modeling. Given the limitations of the ISC model downwash algorithms, the stack was located at the center of the equivalent building's downwind or lee side.

A Model Clearinghouse memo from Joe Tikvart, dated July 1994, documents several issues associated with the procedures for determining EBDs through fluid modeling and also summarizes typical practices in use at that time. The 1994 MC memo indicates that several aspects of the procedures may need to be reassessed as more experience is gained and as improvements are made to the dispersion models. However, the standard procedures have not been updated since 1994, whereas the model formulations have changes significantly with the promulgation of AERMOD in 2005, with PRIME downwash, as the replacement for the ISC model in Appendix W. The ISC model dispersion algorithm is based on P-G stability classes, whereas AERMOD employs more up-to-date for dispersion based on boundary layer similarity parameters. The PRIME downwash algorithm in AERMOD also accounts for the location of the stack relative to the building, instead of assuming the stack to be collocated with the building as in ISC.

ALCOA WIND TUNNEL STUDY

CPP, Inc., Alcoa's consultant, proposed a fluid modeling study for Alcoa's Davenport Works facility to determine EBD parameters that could be used in place of parameters calculated by BPIPPRM (CPP, 2008). These directions specific EBDs would be used in AERMOD to predict concentrations from the several stacks selected for the study. The assumption was that fluid modeling could replace BPIPPRM building parameters with more representative parameters for the complex structures. The majority of the buildings at the Alcoa facility are long, low, and the building length to width ratios are much larger that than those used in the development of the PRIME algorithms. A protocol was developed by CPP, Inc. but it was never approved by EPA.

The procedure used in the CPP wind tunnel study for Alcoa Davenport Works was to place all the modeled facility buildings (scaled to 1/400) on a turntable, install stacks at their actual locations, and rotate the turntable so that different wind directions/effects could be evaluated. The only wind directions studied (from 100 to 260 degrees) were those where AERMOD had predicted exceedances of the PM10 NAAQS in ambient air based on building parameters developed by BPIPPRM. Stack flow or momentum was considered but buoyancy from the stacks was not modeled. This was considered to be conservative. Turbulent flow due to the heat from the facility was not modeled nor was any terrain effect. Approach flows and downwind flow were developed in the wind tunnel by placing blocks to simulate the surface roughness in the approach and downwind flows for the actual site. Concentrations were measured downwind of the turntable in 5 arcs with the closest being an equivalent distance of about 226 meters at 180 degrees extending to about 744 meters downwind to the furthest distance at 240 degrees extending from about 487 meters to about 1018 meters. There were 9 equally spaced measuring points on each arc.

To determine EBDs, the actual buildings were removed and tests involving a single rectangular/block building were inserted in place of the actual facility structures. Again concentrations were measured at several arcs downwind of the stacks. The object was to have the concentrations caused by a single block building, or EBD, to nearly match those associated with the actual facility structures. The approach flow remains the same between simulations with actual structures and EBDs. The stack to be tested was placed at the center of the downwind side of the EBD building. In the actual building area, the stacks that were modeled were at their actual locations within the large building complex. For the EBD tests, additional blocks were added to the turntable to represent the surface roughness of the actual facility. The differences between the tests are in the buildings and the simulated roughness on the turntable. Only one wind speed, the 98% of wind speed distribution at the meteorological site (Moline airport) and one atmospheric condition (neutral) were used in the wind tunnel simulations.

In order to simulate surface roughness in the wind tunnel, various wooden blocks ("roughness elements") were inserted upwind and downwind of the actual facility or the EBD. As noted above, additional roughness element blocks were added to the turntable when the EBD building was evaluated to simulate the surface roughness associated with the actual facility. In many of the tests these roughness blocks were about the same size of the EBD being tested.

The range of block-shaped structures used to determine EBD parameters was similar to those used in the fluid modeling studies used in the development of the ISC downwash algorithms (Huber and Snyder, 1976; Huber and Snyder, 1982), with height-width-length ratios (H:W:L) of 1:2:1. However, structures with somewhat larger width/length ratios were used in a few cases, and EBD structures oriented at 45-degrees to the wind direction were also used in a few cases.

REGION R7 REVIEW

The use of a wind tunnel fluid modeling study to determine equivalent building parameters to replace actual parameters from a complex building area presents many technical challenges. In our view, these challenges have increased with the promulgation of the AERMOD dispersion model with PRIME downwash algorithms as compared to earlier studies conducted for use with the ISC model. Several enhancements incorporated into the AERMOD model may affect the procedures for determining EBDs; for example, the PRIME downwash algorithm in AERMOD accounts for the location of the stack relative to the controlling structure, rather than assuming that they are collocated as in ISC.

Beyond the differences in PRIME downwash as compared to the Huber-Snyder downwash algorithms, the boundary layer algorithms in AERMOD are more advanced than the algorithms used in ISC, and the parameterization of the boundary layer in AERMOD can be strongly influenced by the surface roughness at the meteorological measurement site. One of our major concerns is with the practice of including roughness elements to simulate the surface roughness of the actual facility along with the EBD structure. As noted above, it appears that the roughness elements are similar in size to the EBD in many cases. The measured concentrations in the wind tunnel for the EBD tests may be influenced significantly by these roughness elements, whereas the AERMOD model will only account for the simulated influence of the single EBD structure. Since the EBD is intended to replace the actual facility with a simplified structure that produces an equivalent downwash effect, we do not believe that it is appropriate to also include roughness elements to simulate the roughness of the actual facility. This may result in some "double counting" of the effect of the facility structures on plume dispersion.

CONCLUSION

Due to a number of technical issues and concerns summarized above, the use of EBD parameters determined by CPP, Inc., in its wind tunnel study for Alcoa Davenport Works, for use in place of BPIPPRM-derived building parameters in AERMOD is not approved. Given the range of technical changes in the AERMOD model generally, and specifically the PRIME downwash algorithm in AERMOD, as compared to the ISC model, we believe that more studies and additional guidance are needed before the EBD approach for determining building parameters can be accepted for use in AERMOD analyses.

Sincerely,

Michael Jay
Section Chief
Atmospheric Programs Section
Air Planning and Development Branch

REFERENCES

EPA, 1981: Guideline for Fluid Modeling of Atmospheric Diffusion. EPA-600/8-81-009. U.S. Environmental Protection Agency, Environmental Sciences Research Laboratory, Research Triangle Park, NC 27711.

EPA, 1985: Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations). EPA-450/4-80-023R. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.

Tikvart, J.A., Chief, Source Receptor Analysis Branch, United States Environmental Protection Agency, Letter to Brenda Johnson, Regional Modeling Contact, Region IV and Douglas Neeley, Chief, Air Programs Branch, Region IV, July 25, 1994.