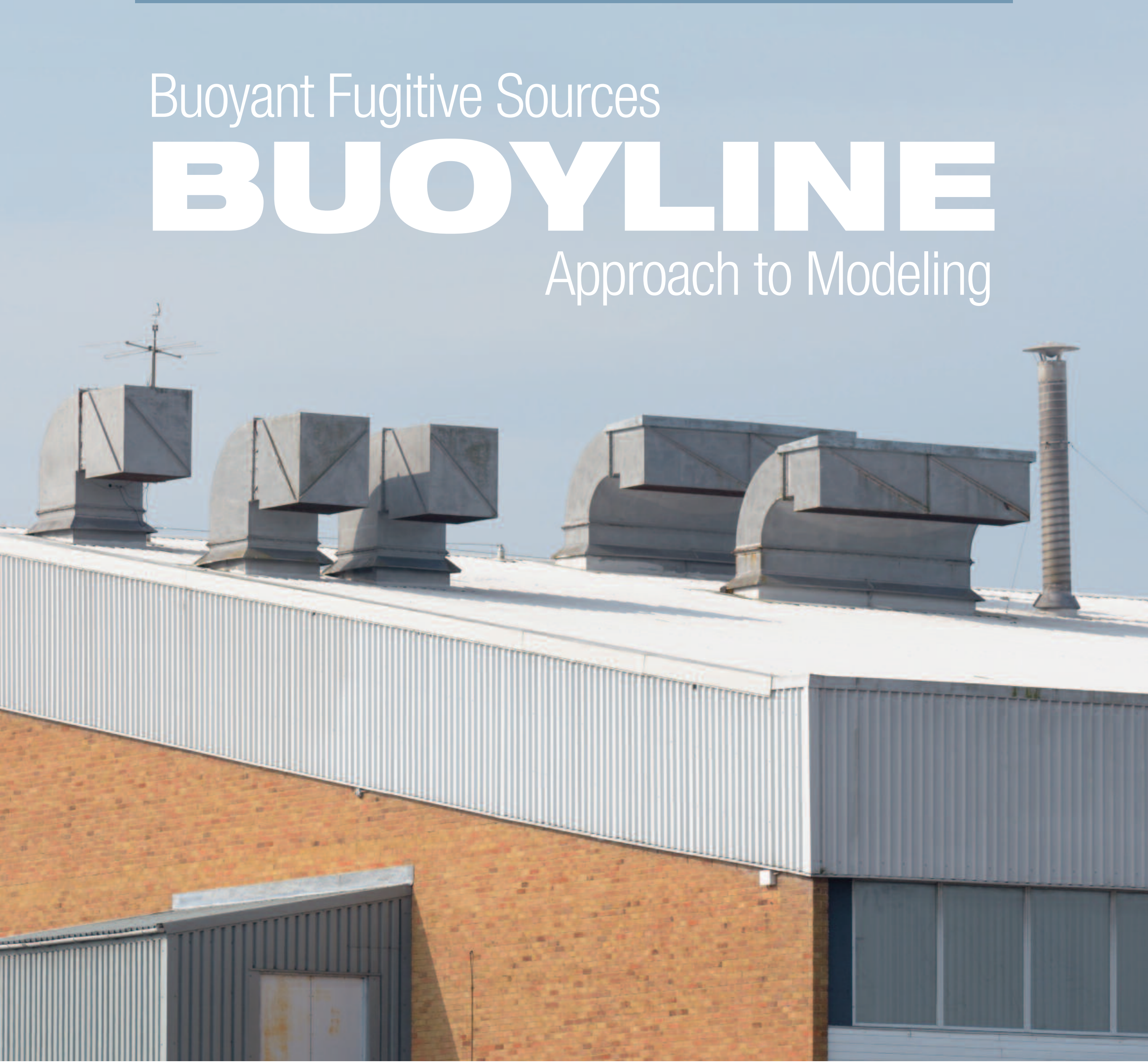
Buoyant Fugitive Sources BUOYLINE Approach to Modeling



This article describes the advent of a model specifically to address buoyant rooftop emissions.

Characterization of sources of airborne emissions is generally straightforward for sources such as stacks and vents, storage piles, continuous versus intermittent releases, high flow versus low flow through a stack, and at the location for which the emissions emanate. Even vertical, horizontal, and other angles of release can be accommodated by adjusting the volume flow. However, the release of fugitive rooftop emissions has been something of an enigma in terms of their characterization for modeling. Whether these emissions are released from an open top roof monitor, a slatted configuration, an open side-walled cupola, or just a long hole in the roof, selecting an appropriate modeling approach has been more of an art than a science. Previously, modelers have set up rows of pseudo-point sources, elongated and elevated area sources, volumes sources at rooftop, volume sources with rooftop emissions but at the size of the whole supporting structure, and combinations thereof. With all of these configurations, model accuracy and representativeness have sometimes been sold short as there has been very little has been reported in the literature as to model evaluations of any of these characterizations or the tools to support them.

Beyond this brisk walk through yesterday's tools and approaches for rooftop emissions, one more consideration must be noted. That is, all rooftop emission sources are not the same. So even if the modeling community including consultants, educational researchers, and government scientists at the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) had been clever enough to devise a recommended approach, one approach would have been insufficient to characterize the variety of rooftop emission sources. These differences include the rooftop configuration, forced flow versus natural flow, gases and particulate differences, and of course, a key component—whether the emissions and combined airflow is warmer than the ambient air. The reason temperature differential is important is that combined rooftop fugitive emissions and gases warmer than ambient air will tend to rise in the atmosphere, a phenomenon known as plume rise.

Plume rise, of course, is not a new phenomenon being reported in this article. When a gas is heated and released into a lower atmospheric temperature, the gas is said to lift or have buoyancy because the gas is less dense than the ambient air. Plume rise is common at sources where buoyant gases being released carry the plume aloft at heights higher than the point of release (i.e., the stack top). At some point downwind, the plume becomes neutrally buoyant (i.e., it stops rising) because ambient air has been mixed (entrained) into the plume. The reason this is important even for open rooftop vents and roof monitors is that the dispersion models are sensitive to these "final" plume heights when calculating downwind ambient air concentrations. If the rooftop emissions being modeled are hot or even warm with respect to the ambient atmospheric conditions and if the model being used does little to consider this plume rise, the concentration estimates

Figure 1. Typical aluminum smelter rooftop configuration. A typical arrangement of ridge vents at an aluminum smelter with an elongated rooftop vent. The buoyancy is related to the elongated internal arrangement of potrooms and other operations. These are both emission and heat emitting.

Source: http://www.mining.com/aluminum-giant-alcoa-to-close-its-three-smelters-in-canada-81140.

Figure 2. Typical arrangement of aluminum furnaces. An internal building configuration at an aluminum smelter.

Source: http://www.tigeroptics.com/TA/photo/view.php?gal=users;site,cms,files&s=orig&f=ENV%235_HF_Aluminum_ smelter_emissions.pdf.

that are calculated may err on the high side and place such occurrences closer to the facility sources than they really are.

Although the atmospheric science described above has been well-documented for more than 30 years (and stack plume rise accounted for), the phenomenon with respect to rooftop fugitive emissions have not been accounted for in either of the primary regulatory models, including the Industrial Source Complex Model (ISCST, ISCST2, and ISCST3) and AERMOD. Recently, EPA has acknowledged that such an approach is worthy of inclusion in AERMOD.[1]

The Advent of a Model to Address Buoyant Rooftop Emissions

In July 1980, two young modelers, Joseph Scire and Lloyd Schulman (now household names in the modeling community) introduced a dispersion model that could "simulate the transport and diffusion of emissions from aluminum reduction plants.

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Figure 3. Buoyant plume rise above physical stack height.

Aluminum reduction plants are a complex arrangement of emission sources, composed of parallel, low-level, buoyant line sources called potrooms interspersed, typically, by short point sources." "Some of the buoyant emissions from the reduction process escape through a continuous ridge ventilator, which is a few meters wide running the length of the potroom." The name of this model was the Buoyant Line and Point Source (BLP) Dispersion Model.[2] Figures 1 and 2 show typical external and internal potroom arrangements.

As recognized in Scire and Schulman's 1980 paper,[3] the consideration of plume rise from buoyant sources is critical in calculating accurate ground-level concentrations of the sources' emissions (see Figure 3). This was recognized very early in EPA's treatment of point sources (stacks and vents) in adopting the theory and equations of Gary Briggs for plume rise.[4] While scientists have recognized that plumes with release temperatures above ambient temperatures for line sources are buoyant for many years, not until the introduction of the BLP Model were modelers able to account for it.

Previous to the development of BLP, early attempts to model the buoyant ridge emissions as a line of point sources was promising in that it allowed the consideration of plume rise. However, when using a line of point sources, the entrainment of air as the plume was carried downwind differed from the actual entrainment from a long vent of adjacent plumes. Point sources assumed nearby horizontally entrained air was ambient, thereby cooling each plume, becoming neutrally buoyant and resulting in higher calculated impacts close to the source. In reality, the nearby air was is from other plume elements at higher temperatures and thus, the plume remains buoyant farther downwind.

EPA has the responsibility to recommend specific models and modeling procedures for regulatory air quality compliance analysis of new and modified sources of emissions. The BLP Model has been recommended for several decades as the appropriate model to use for buoyant line sources, most recently in the "Guideline on Air Quality Models," Section 4.2.2.c, Refined Analytical Techniques, which states "If buoyant plume rise from line sources is important for the modeling analysis, the recommended model is BLP."

One conundrum facing modelers that needed to use the BLP Model came after the 2005 adoption of the AERMOD Model as the regulatory model for nearfield modeling. AERMOD did not consider buoyant line sources. BLP did not consider fugitive emissions. BLP was limited to a small number of receptors (some users expanded this number by changing the code but it can be difficult to obtain EPA approval for these type of changes). And most importantly, BLP used the PCRAMMET meteorological data processor which generated specific stability classes (six classes from very unstable, A, to stable, F) while AERMOD uses AERMET, which calculates a continuum of atmospheric turbulence over many conditions in estimating atmospheric parameters in the planetary boundary layer. Because of the need to consider different source types in the most representative manner, users typically concatenated the results of the two models, certainly a tedious process with cumulative results that were somewhat difficult to interpret when attempting to identify critical receptors, events, and influencing meteorological conditions.

BLP: Now a Part of AERMOD…Almost

Today, dispersion modeling continues to play a central role in the regulation of sources and emissions in the U.S. air quality management program. Since 2005, the science of dispersion and transport in the planetary boundary layer has matured, leading to the need for an update to the Guideline. In response to the many outstanding issues, EPA responded with proposed revisions including the addition of the BLP Model to AERMOD.

On July 14, 2015, EPA published the proposed "Revision to the Guideline on Air Quality Models: Enhancements to the AERMOD Dispersion Modeling System and Incorporation of Approaches to Address Ozone and Fine Particulate Matter;

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Proposed Rule," which was subsequently published in the *Federal Register* on July 29, 2015.[5] The proposed revisions indicate that the BLP Model has been incorporated into AERMOD and that BLP is no longer a preferred stand-alone model. In AERMOD, the BLP Model is an option called BUOYLINE, which is selected as a source type for individual source locations that are characterized by a composite buoyant line source with averaged parameters. EPA proposes the use of BLP as a default option in the model when needed not requiring further justification.

The proposed changes to the Guideline also reference a docket item regarding EPA's development and evaluation of the performance of the AERMOD-BLP option.[6] In this evaluation, a buoyant line source was modeled in BLP and in AERMOD/BLP. For the one- and four-day data sets of meteorology used in the testing, the models compared well but, upon using a full year of meteorology, the receptors closest to the buoyant line sources had much higher concentrations in AERMOD/BLP than BLP alone. Upon further review, some of the receptors were determined to be located directly on the line sources but others in the same situation had lower concentrations. The model testers and evaluators had not pursued this evaluation any further and concluded that these issues required further exploration. Nonetheless, BLP is recommended to be made a sub-model of AERMOD under the July 2015 proposed guidelines.

Conclusion

Challenges surrounding the application of dispersion models for buoyant line sources have been around as long as dispersion modeling has been used for regulatory purposes—more than 40 years. The use of the BLP Model while perhaps elegant in its treatment of nearby buoyant ridge vents has been limited based on array size, source types considered, and limitation of using older formatted meteorological data sets. Meanwhile, permitting for new and modified sources goes on, air dispersion modeling is still required, and sources must still show compliance with ambient air quality standards. Recognizing this need, EPA has implemented BLP directly within the framework of AERMOD. Although this seems to be welcome progress, initial testing based on tweaking of model switches and initial conditions did not prove satisfying in terms of combined AERMOD/BLP model performance. The redemption of this performance was hopefully fulfilled since the proposed guidelines were released in July 2015 and now as of the printing of this article, we stand ready to use the final, improved version as will be promoted by the fully promulgated 2016 version of the Guideline on Air Quality Models. **em**

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