Perspectives on Deposition Velocity

… Going down the rabbit hole

to explain that sinking feeling

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Discussion Framework

- Development of the HSS Deposition Velocity Safety Bulletin
- Broader discussion of appropriate conservatism within dispersion modeling and DOE-STD-3009

DOE-STD-3009 Dose Comparison

"General discussion is provided for source term calculation and dose estimation, as well as prescriptive guidance for the latter. The intent is that calculations be based on reasonably conservative estimates of the various input parameters."

- DOE-STD-3009, Appendix A.3

DOE-STD-3009 Dispersion

"The 95th percentile of the distribution of doses to the MOI … consistent with the statistical treatment of calculated χ/Q values described in regulatory position 3 of NRC Regulatory Guide 1.145."

NRC Reg Guide 1.145 – Pos. #3

"The χ/Q values that are exceeded no more than 5 percent of the total number of hours in the data set …"

"Using the χ/Q values calculated according to regulatory position 1…"

NRC Reg Guide 1.145 – Pos. #1

"*The meteorological data needed for χ/Q calculations include windspeed, wind direction, and a measure of atmospheric stability. These data should represent hourly averages.*"

The 95th percentile dose to the MOI is a function of variations in windspeed, wind direction, and stability.

Dispersion and Deposition

95th Percentile dose to the MOI is dependent on both dispersion and deposition.

- Dispersion is dependent on
  - Wind speed
  - Stability
- Deposition is dependent on
  - Wind speed
  - Stability

Dispersion and Deposition

- Since deposition is co-dependent on the same parameters used to assure 95th percentile dose from dispersion, the calculation of deposition should also reflect the variations in those parameters.
- Minimum deposition is also correlated with minimum dispersion (light winds, stable air), so maintaining a dependence is needed for appropriate conservatism.

How to re-connect deposition with its controlling parameters?

- Option #1, Direct Dependence – Run a dispersion model that calculates DV as a function of hourly meteorological data.
- Option #2, Calculate DV based on site-specific 95th percentile dispersion meteorology, use as a constant.
- Option #3, Use a highly conservative default DV as a constant.

Option #1, Direct Dependence

- Running a dispersion code that calculates DV as a function of variations in hourly wind speed and stability.
- Currently no toolbox code does this
- Non-toolbox codes such as CALPUFF and AERMOD are not well established within DOE framework.
- Potential for GENII2 as a toolbox code.

Option #2 – Calculate site-specific DV for 95th percentile conditions

- Generates a constant DV value that is representative of 95th percentile meteorological conditions.
- Can only be used within DOE-STD-3009 accident analysis framework, not a value that works as a annual average or for the median dose.
- What method to calculate the value?

Option #3 – Use a highly conservative default DV

- Not representative of site.
- Useful if impacts are so low that detailed analysis is not warranted.
- What method to calculate the value?

Calculating DV

- Don't recreate the wheel
- EPA-OAQPS 1994 Evaluation of methods
- Current model implementation
- Needs to be able to perform well in conditions reflecting 95th percentile meteorology and respirable particle size
- Sensitive to changes in surface roughness and wind speed/stability

Calculating DV

- Evaluation of ADOM1, CARB3, and GENII2
  - ADOM1 incorporated into both CALPUFF and AERMOD, used for acid deposition and visibility calculations
- Comparison to Sehmel curves for low friction velocity conditions
  - Check models against curves generated from observational data

Calculating DV

- ADOM1
  - Recommended by EPA analysis, but with the caveat that it performed poorly for lower friction velocities
  - Currently in use within CALPUFF and AERMOD (particles)
    - Used for acid deposition (annual average)
    - Used for visibility calculations (larger particles from hygroscopic growth)
  - Parameterization fails at low friction velocities

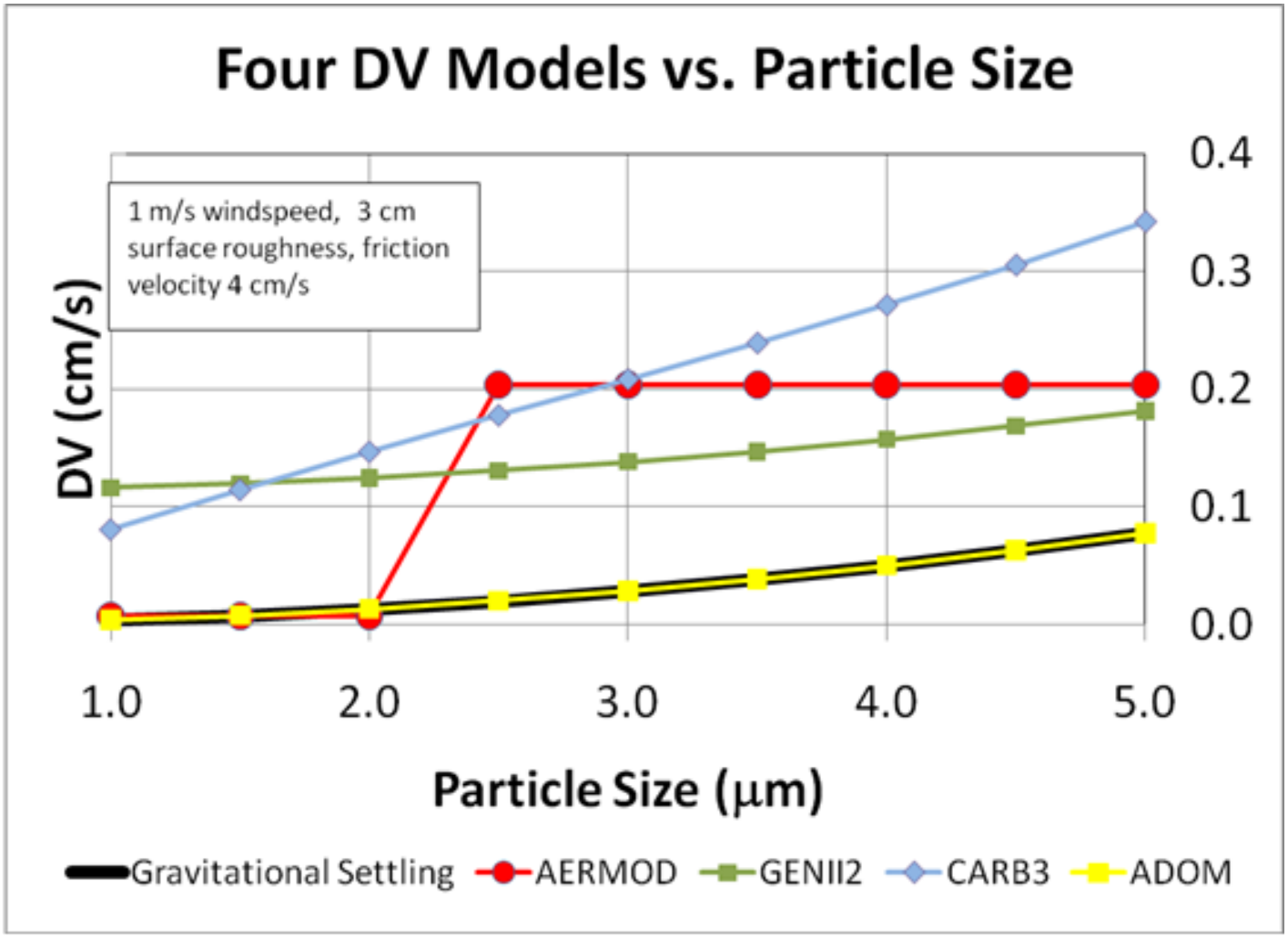
Calculating DV

- CARB3
  - Parameterization was based on wind tunnel data, did not include factors to account for increased surface roughness
  - Did show a drop in DV for sub-micron particle sizes comparable to observations

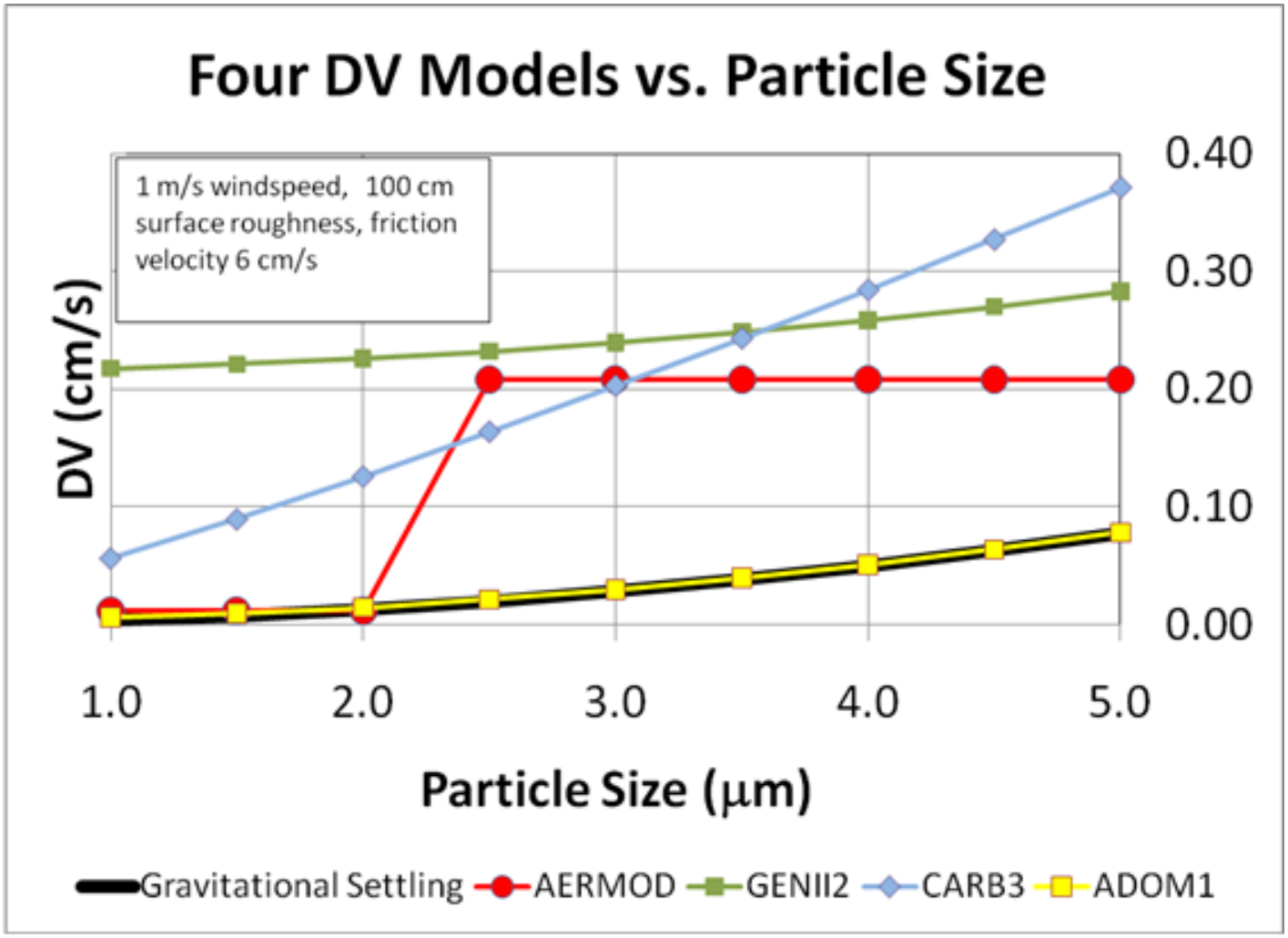
Calculating DV

- GENII2
  - Varies with surface roughness
  - Is non-zero at low friction velocities
  - Has a floor for minimum DV that is higher than observed data for submicron particles

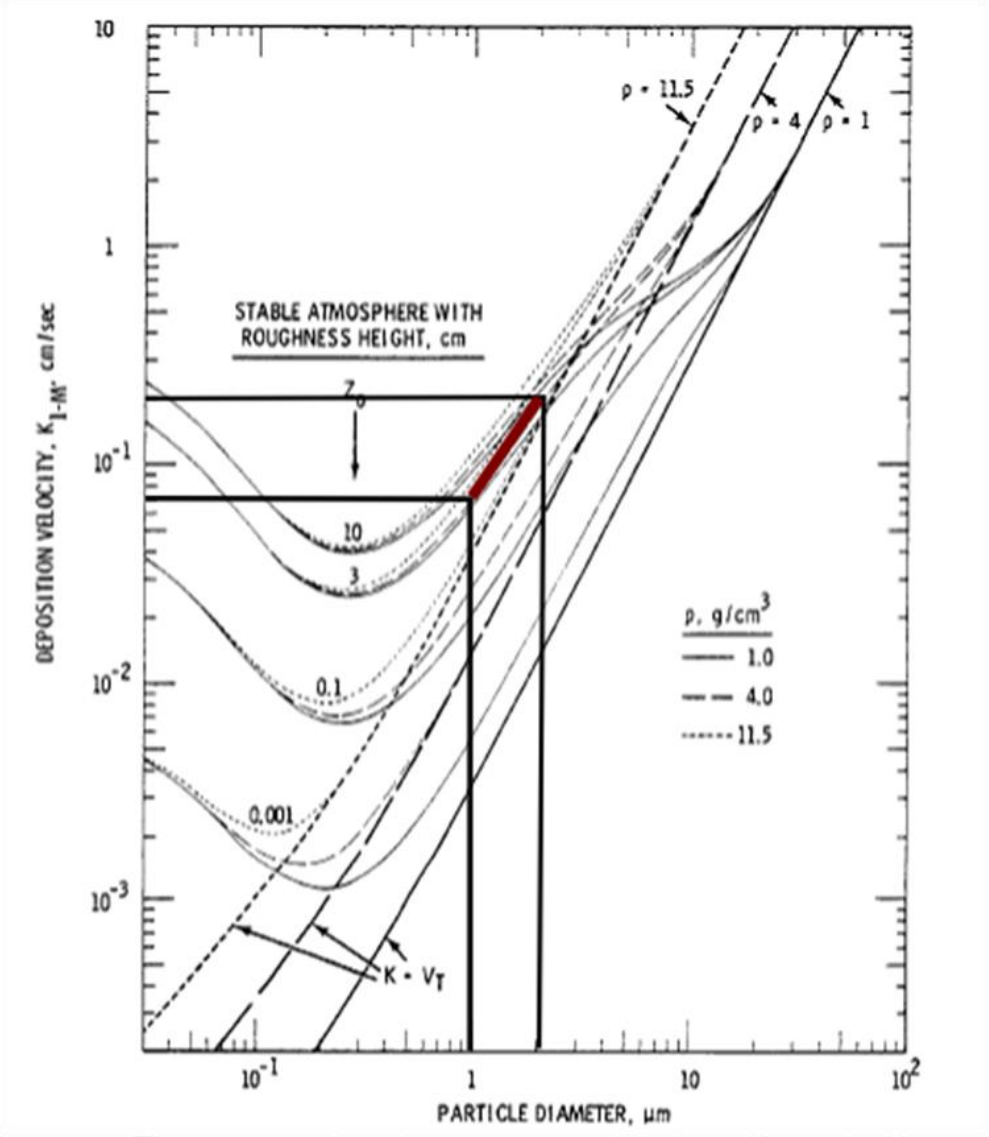
Calculating DV



Calculating DV



Calculating DV



The range enclosed encompasses the deposition velocities expected for particle sizes of 1 - 2 microns, and a surface roughness of 3 cm. For particles with a density of 4 g/cm3, this corresponds to a AED of 2-4 microns. The resulting deposition velocity is 0.1 - 0.2 cm/sec.

Calculating DV

- Recommendation for GENII2 method for unfiltered particles. Default of 0.1 cm/sec.
- Recommendation of 0.01 cm/sec for filtered (submicron) particle.

Back out of the Rabbit Hole

- DV as a semi-quantitative concept
  - Plume depletion from deposition is real
  - DV as mathematically presented is a modeling construct
  - Models as parameterizations of theoretical construct based on
    - Curve fitting
    - Best guesses on dependence of physical process
- Not entirely unsimilar to Gaussian Plume dispersion

Perspectives on Dispersion

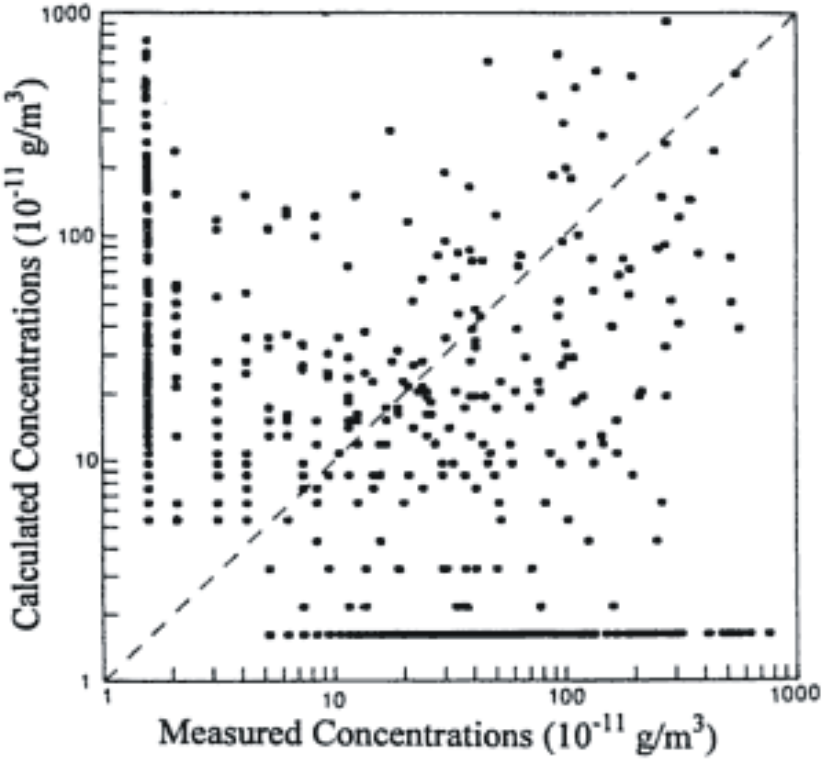


Figure 2

Results obtained in a year-long series of tracer experiments conducted in Washington, DC, in 1987. Note that many occasions occur for which either observed concentrations indicated a plume "hit" whereas the model predicted a "miss," or *vice versa* (after DRAXLER, 1987).

Perspectives on Dispersion

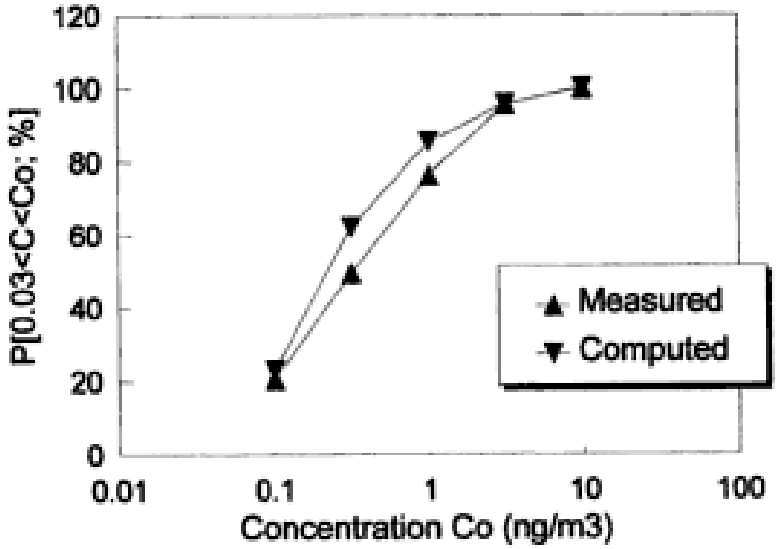


Figure 3
Distributions of the concentrations shown in Figure 2. For this examination of how well the models mirror the distribution of actual concentrations, the analysis is limited to occasions for which the plume direction was predicted accurately, by omitting all data for which either the measured or the predicted concentration was below 0.03 ng/m^3.

Back to the Big Picture

"The EG is 25 rem total effective dose equivalent. The dose estimates to be compared to it are those received by a hypothetically MOI at the site boundary for an exposure duration of 2 hours."

"It should be made clear that the EG is not to be treated as a design acceptance criterion, nor as justification for nullifying the general design criteria relative to defense-in-depth safety measures. The value of 25 rem TEDE is not considered an acceptable public exposure either."

"Dose calculations for comparison against the EG are based on the concept of an unmitigated release to determine whether the potential level of the hazard in the specific facility warrants SC SSC designation."

"an individual located at any point on its boundary for 2 hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 25 rem."

"[the dose of 25 rem] is not intended to imply that these numbers constitute acceptable emergency doses to the public under accident conditions"

"used in the evaluation of reactor sites for reactors that reflect through their design, construction, and operation an exceedingly low probability for a major accident, and through location and other safeguards against the hazardous consequences of an accident, should one occur, a low probability of public damage"

Back to the Big Picture

DOE-STD-3009-94, Appendix A

Atomic Energy Commission,

Technical Information Document – 14844,

Calculation of Distance Factors for Power and Test Reactor Sites,

March 23, 1962

What can TID-14844 tell us?

- Some assumptions have a long pedigree
  - 2-hour fenceline dose compared to 25 rem.
  - 25 rem EG based in part on National Bureau of Standards work on permissible doses from 1950's.
  - Initial assumptions included inversion weather conditions. 1 m/s wind and F stability specifically quoted.
  - Acknowledged new method of Pasquill as option

What can TID-14844 tell us?

- Acknowledged that regulatory framework required
  - Simplifying assumptions
  - Specifying secondary factors to be ignored
  - Fixing the values of certain key parameters
- The net effect of assumptions and approximations resulted in conservative results
  - This is intended and consistent
  - The state of the art science can be improved

Tie in the Modern Regulatory Framework

- EPA regulatory model
  - Intent is to use accurate models. Models are to be subject to improvement.
  - Point of comparison with standards uses conservative meteorology (High 2nd high).
  - Many parameters and modeling choices are pre-defined.
  - Flexibility is in designing the site or operations.
  - Desire is to create stable regulatory framework.

Challenges for DOE

- Regulatory model
  - Value of consistency vs. flexibility
  - Predictability in design to reduce late changes
  - Potential for screening to minimize analysis that does not provide major value
- Specific Topics
  - Calm wind guidance
  - Consistent application
  - Accident Analysis Handbook