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Dispersion Parameters: Impact on Calculated Reactor Accident Consequences

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Much attention has been given in recent years to the modeling of the atmospheric dispersion of pollutants released from a point source.[1,2,3] Numerous recommendations have been made concerning the choice of appropriate dispersion parameters.[4,5] A series of calculations has been performed to determine the impact of these recommendations on the calculated consequences of large reactor accidents. Results are presented and compared in this paper.

The consequence model (CRAC) of the Reactor Safety Study (RSS)[6,7] used a modified Gaussian dispersion model with Pasquill-Gifford (PG) dispersion parameters[8] for releases of 0.5 hour duration.* The PG curves, however, have important limitations. The curves were based on data obtained at distances of less then 1 km from the release point, for near-surface releases of <u>3 minute</u> duration over terrain having a low surface roughness (grasslands, with roughness length** $r \approx 3$ cm)[3]. A recent workshop[5] on models used for the atmospheric transport of radionuclides suggested the use of at least two sets of σ_y and σ_z curves. For surface releases, the PG curves were recommended with an adjustment for release duration (t) suggested by Pasquill,[9] $\left[\sigma_{y_2}/\sigma_{y_1} = (t_2/t_1)^{0.2}\right]$, and with a surface roughness

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*0.5 hour was the shortest duration assumed in the RSS. Correction for longer release durations was made using the factor $(\Delta t \text{ (hours)}/0.5)^{0.33}$.

**Normally termed z_o.

adjustment $\left[\sigma_{z_2}/\sigma_{z_1} = (r_2/r_1)^{0.2}\right]$ suggested by Briggs.[4] For elevated releases (including surface releases with considerable plume rise), use of either the Smith[10] or Vogt[1] curves was recommended. Pasquill[3] suggests an additional adjustment for wind direction shear to be used with the PG curves; for $x \geq 20$ km, $\sigma_y^2 = \sigma_{y_{PG}}^2 + 0.03\ \Delta\theta^2 x^2$, where $\Delta\theta$(radians) is the shear over the entire depth of the plume. A simple correction has also been proposed[4] to allow for the increased growth of σ_z due to plume buoyancy; $\sigma_z^2 = \sigma_{z_{PG}}^2 + \Delta H^2/10$, where ΔH is the height of plume rise above the release point. Finally, Briggs[2,6] has proposed a set of interpolation formulas that agree with the PG curves out to 10 km, except for "unstable" σ_z values.

To determine the impact of the above recommendations on calculated reactor accident consequences, a series of calculations was performed using CRAC. Consequences were calculated for the worst accident category in the RSS (PWR 1), assuming both COLD (small ΔH) and HOT (large ΔH) releases.[6] The assumed release duration was 0.5 hour. A uniform population density of 100 persons/mile^2, and evacuation of persons within 25 miles with a speed of 1.2 mph were also assumed. Stability categories were assigned according to temperature lapse rate.[6] For each set of dispersion parameters, 91 weather sequences were used to calculate a probability distribution for both early and latent cancer fatalities. The mean and peak values of these distributions are compared in Tables 1 and 2 for the COLD and HOT releases, respectively. All values have been normalized to the corresponding value calculated using the PG (3 minute, 3 cm) curves.

The results indicate that latent fatality predictions are in general quite insensitive to assumed dispersion parameters. Correction for wind direction shears of 25–45° does increase latent fatality predictions somewhat, although shears of this magnitude may be unreasonable for average conditions. Peak predicted early fatalities are also quite insensitive to the dispersion parameters assumed. However, adjustment of the PG curves from a 3 to a 30 minute release duration substantially reduced (COLD - 60%, HOT - 30%) mean predicted early fatalities. Mean early fatalities were increased to some extent by use of the Vogt curves for HOT releases, and surface roughness adjustments for COLD releases. Early fatality predictions were minimally affected by corrections for wind shear and ΔH, and by use of the Briggs formulas. In conclusion, calculated reactor accident consequences are not strongly sensitive to assumed dispersion parameters. The PG curves, with correction for release duration and surface roughness, appear to be appropriate for surface releases with small ΔH. For releases with large ΔH, the Vogt curves (or a similar set) should probably be used. Work is ongoing to further detail this analysis.

References

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Table 1

COLD Release - Comparison of Calculated Health Effects
for Selected Dispersion Parameter Sets

Dispersion Parameters	Early Fatalities[f] Mean[a]	Early Fatalities[f] Peak[a]	Latent Fatalities[f] Mean[a]	Latent Fatalities[f] Peak[a]
Pasquill-Gifford				
3 min,[b] 3 cm[c] (RSS)	1.0	1.0	1.0	1.0
30 min, 3 cm	0.4	0.9	1.2	1.3
30 min, 10 cm	0.6	0.9	1.2	1.3
30 min, 30 cm	0.7	0.9	1.2	1.3
30 min, 100 cm	0.7	0.9	1.2	1.4
30 min, 3 cm, 10°[d]	0.4	0.9	1.2	1.3
30 min, 3 cm, 25°	0.4	0.9	1.5	2.0
30 min, 3 cm, 45°	0.4	0.9	2.0	1.8
30 min, 3 cm, ΔH[e]	0.5	0.9	1.2	1.3
Briggs				
30 min, 3 cm	0.4	1.0	0.9	0.8

a) 91 weather sequences are used to generate a probability distribution for each consequence. The mean and peak refer to this distribution.
b) Release duration. Values of 3 or 30 minutes are assumed.
c) Roughness length. Assumed values range from 3 cm (grasslands) to 100 cm (forest).
d) Assumed wind direction shear over height of plume.
e) Includes plume rise adjustment. ΔH for each weather sequence is calculated by the code.
f) Normalized to the mean and peak calculated using the PG curves (as in the RSS) with 3 minute release duration and 3 cm roughness length.

Table 2

BOT Release - Comparison of Calculated Health Effects for Selected Dispersion Parameter Sets

Dispersion Parameters	Early Fatalities[f] Mean[a]	Early Fatalities[f] Peak[a]	Latent Fatalities[f] Mean[a]	Latent Fatalities[f] Peak[a]
Pasquill-Gifford				
3 min,[b] 3 cm[c] (RSS)	1.0	1.0	1.0	1.0
30 min, 3 cm	0.7	1.0	1.3	1.5
30 min, 10 cm	0.7	1.0	1.3	1.5
30 min, 30 cm	0.7	1.0	1.3	1.5
30 min, 100 cm	0.7	1.0	1.3	1.5
30 min, 3 cm, ΔH[d]	0.7	1.0	1.3	1.5
Vogt (100 m release height)[e]				
60 min, 100 cm	0.8	1.0	1.3	1.5
30 min, 100 cm	0.9	1.2	1.2	1.5
Vogt (50 m release height)[e]				
60 min, 100 cm	1.1	1.2	0.9	0.9
30 min, 100 cm	2.3	3.3	0.9	0.9
Briggs				
30 min, 3 cm	0.9	1.0	0.9	0.9

a) 91 weather sequences are used to generate a probability distribution for each consequence. The mean and peak refer to this distribution.

b) Release duration. Values of 3, 30, or 60 minutes are assumed.

c) Roughness length. Assumed values range from 3 cm (grasslands) to 100 cm (forest).

d) Includes plume rise adjustment. ΔH for each weather sequence is calculated by the code.

e) Two sets of Vogt dispersion parameters are available, corresponding to release heights of 100 m and 50 m.

f) Normalized to the mean and peak calculated using the PG curves (as in the RSS) with 3 minute release duration and 3 cm roughness length.