Estimating the Flammable Mass of a Vapor Cloud
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APPENDIX A

ATMOSPHERIC STABILITY CLASSIFICATION SCHEMES

Atmospheric stability is defined in terms of the tendency of a parcel of air to move upward or downward after it has been displaced vertically by a small amount. This is described in Hanna, Briggs, and Hosker (1982). Essentially, unstable atmospheres of Stability Class A tend to develop vertical updrafts which increase boundary-layer turbulence intensity. Stable atmospheres (Stability Class F) tend to suppress vertical updrafts and reduce turbulence intensity. Since it is difficult to measure turbulence intensity directly, correlations are sought to indicate stability class as a function of readily measurable variables.

The earliest stability classification scheme, attributed to Pasquill (1961), is summarized in Table A.1. This simply requires an estimate of solar radiation and wind speed. It has been shown to produce inconsistent classifications in comparison with other classification schemes during the Thorney Island dispersion tests (McQuaid, 1981).

TABLE A.1
Correlation of Atmospheric Stability Class According to Gifford (1976)

Wind Speed, m/s	Solar Insolation Strong	Solar Insolation Moderate	Solar Insolation Slight	Night Time Thin overcast or >1/2 low clouds	Night Time Conditions <3/8 cloudiness
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-4	B	B-C	C	D	E
4-6	C	C-D	D	D	D
>6	C	D	D	D	D

If a meteorological tower is available it is possible to obtain measurements of both the vertical temperature profile and the vertical wind speed profile. These measurements are needed to evaluate the Richardson number, *Ri*, which is the ratio of the vertical temperature gradient to the squared vertical gradient of the wind speed. The numerator is related to the destabilizing forces that generate updrafts. The denominator is related to the kinetic energy that destroys updrafts. A larger value for the Richardson number should indicate more unstable atmospheres. Unfortunately, *Ri* varies with height, *z*. A correlation for stability class with Richardson number is given in Table A.2

Several Richardson numbers are in use. The one used in Table A.2 is designated by Sedefian and Bennett (1980) as the Businger version. It is defined below in finite difference form:

$$Ri = \frac{g}{T(z_1)} \frac{\left[\dfrac{T(z_1)-T(z_2)}{z_1 - z_2}\right]}{\left[\dfrac{u(z_1)-u(z_2)}{z_1 - z_2}\right]^2} \tag{A.1}$$

The potential temperature, θ, can be used instead of the actual temperature, T, to better account for the normal decrease in temperature with height, where

$$\theta = T - \lambda(z_2 - z_1) \tag{A.2}$$

and λ is the adiabatic lapse rate, ≈ -0.01 K/m over the distances to the mixing height.

A simpler correlator that requires only vertical temperature information is the vertical temperature gradient, $\Delta T/\Delta z$. Theory relates the vertical temperature

TABLE A.2
Atmosphere Stability Class Correlated with Richardson Number

Pasquill Stability Class	$Ri = \dfrac{g(\Delta T/\Delta z)}{T(\Delta u/\Delta z)^2}$
A	$Ri < -0.86$
B	$-0.86 \le Ri < -0.37$
C	$-0.37 \le Ri < -0.10$
D	$-0.10 \le Ri < 0.053$
E	$0.053 \le Ri < 0.134$
F	$0.134 \le Ri$

TABLE A.3
Atmospheric Stability Class Correlated with Vertical Temperature Gradient

Pasquill Stability Class	$\Delta T/\Delta z$ (degrees K/100 m)
A	$\Delta T/\Delta z < -1.9$
B	$-1.9 \le \Delta T/\Delta z < -1.7$
C	$-1.7 \le \Delta T/\Delta z < -1.5$
D	$-1.5 \le \Delta T/\Delta z < -0.5$
E	$-0.5 \le \Delta T/\Delta z < 1.5$
F	$1.5 \le \Delta T/\Delta z < 4.0$
G	$4.0 \le \Delta T/\Delta z$

gradient to atmospheric stability when wind speeds are low. Table A.3 gives this correlation for each stability class.

An algorithm listed in Table A.4 has been adopted by the US Nuclear Regulatory Commission (NRC) as originated by Islitzer and Slade (1968). This is based on the standard deviations in the horizontal wind direction, σ_θ. Bivane anemometers record both σ_θ and the corresponding variations in the vertical component of wind speed, σ_ϕ . Since σ_θ varies with height; the values listed in Table A.4 apply to heights up to 10 m.

TABLE A.4
Atmospheric Stability Class Correlated with Standard Deviations of Horizontal Wind Direction

Pasquill Stability Class	σ_θ at 10 m, degrees
A	$\sigma_\theta > 22.5$
B	$22.5 \ge \sigma_\theta > 17.5$
C	$17.5 \ge \sigma_\theta > 12.5$
D	$12.5 \ge \sigma_\theta > 7.5$
E	$7.5 \ge \sigma_\theta > 3.75$
F	$3.75 \ge \sigma_\theta > 2.0$
G	$2.0 \ge \sigma_\theta$

Gifford (1976) reviewed stability typing schemes and preferred a scheme which uses the Monin–Obukov length, L, defined by

$$L = -\frac{\rho_{\text{air}} C_{\text{p}} T u_*^3}{kgH_{\text{v}}} \tag{A.3}$$

Here u_* is the friction velocity, C_{p} is the heat capacity of air, ρ_{air} is the ambient air density, T is the ambient temperature at the reference height, k is von Karman's constant (0.4), g is the gravitational constant, and H_{v} is the vertical heat flux. The difficult measurement to obtain is, of course, H_{v}. The correlation developed by Pasquill and Smith (1971) for flow over short grass, with $z_{\text{o}} = 0.01$ m is given in Table A.5.

TABLE A.5
Pasquill–Gifford Stability Class Correlated with Monin–Obukov Length

Stability Class	*L*, m
A	–2 to –3
B	–4 to –5
C	–12 to –15
D	∞
E	35 to 75
F	8 to 35