Analysis of Atmospheric Discharge

Qualitative and Quantitative Safety Screening

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Agenda

1. Introduction
2. Qualitative Screening Criteria
    I. Non-Flammable / Non Toxic
    II. Flammable / Combustible
    III. Toxics
3. Semi-Quantitative Screening Criteria
    1. Flammable / Combustible
    2. Toxics
4. Quantitative Analysis
    1. Flammable / Combustible
    2. Toxics
5. Data Sources

Introduction

Recent incidents and regulatory pressures have companies asking:

- How many relief valves do we have going to atmosphere?
- Are these relief valves safe?
- Can we prove that they are safe?

Introduction

Venting Source Types

- Control Systems
- Pressure Relief Device
- Atmospheric Collections Systems
- Flare Systems

Considerations

- Location
- Flammability / Combustibility
- Toxicity

Safe History of Atmospheric Discharges

- Incidents Rare
- Long history

Introduction

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Qualitative Screening Criteria

“Safe” Fluids

Generally Safe, given:

- Non-flammable / Combustible
- Non-toxic Fluids

- Negative Personnel Effects
  - Impingement
  - Oxygen Deficient Atmosphere
  - Emergency Operations
- Public Relations
  - Potential to form “clouds”
  - Loud / odd noises
  - Odors

Qualitative Screening Criteria

Flammable and/or Combustible Fluids (Toxic)

These require more engineering review. Consider the following:

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Vapor Releases

- UFL → Flammable → LFL
- Ignition Sources
- Safety Factor
  - 2x (50% LFL Existing)
  - 10x (10% LFL New)

Liquid / Solid Releases

- Eliminate Scenario Credibility (SIS)
- Contain Liquids / Vent only Vapors

Semi-Quantitative Screening Criteria

Flammable and/or Combustible Fluids

Vapor Releases Acceptable* (Pop Action Relief Valves)

- Exit velocity greater than 100 ft/s (@ 25%)
- Exit velocity greater than 500 ft/s (@ full capacity)
- Wind speed under 7 MPH
- Vapor MW less than 80
- Nothing horizontally for 50 ft
- Not Cryogenic
- Qualitative Criteria Met

*API STD 521 6th ed. *Guide for pressure relieving and depressuring systems* §5.3.1

Semi-Quantitative Screening Criteria

Flammable and/or Combustible Fluids

Vapor Releases Example*

- API STD 521 Criteria
- 6Q8 Relief Device, Y-Grade Fluid

Scenario	Valve Capacity (lb/hr)	Exit Velocity (ft/s)	Jet / Wind Ratio	Jet > 100 ft/s	Acceptable
Rate Capacity	83,554	460	94	Yes	Yes
Blocked Outlet Required Rate	41,862	230	47	Yes	Yes
75% of the Rated Capacity	62,665	345	70	Yes	Yes
50% of the Rated Capacity	41,777	230	47	Yes	Yes
25% of the Rated Capacity	20,888	115	23	Yes	Yes
10% of the Rated Capacity*	8,355	46	9	No	No

Semi-Quantitative Screening Criteria

Toxic Fluids

If Vapor Releases Acceptable*

- Hydrocarbon dilutes from 100% →3%
- Per API, Jet effects result in a 30x to 50x Dilution
- Toxic Concentrations Limits Lower
  - 50 ppm IDLH for H_2S (29 CFR 1910.1000 TABLE Z-2)
  - 50 ppm IDLH for Benzene (29 CFR 1910.1000 TABLE Z-2)

$$C_{Limit} > \left(\frac{C_{Effluent}}{30} \right)$$

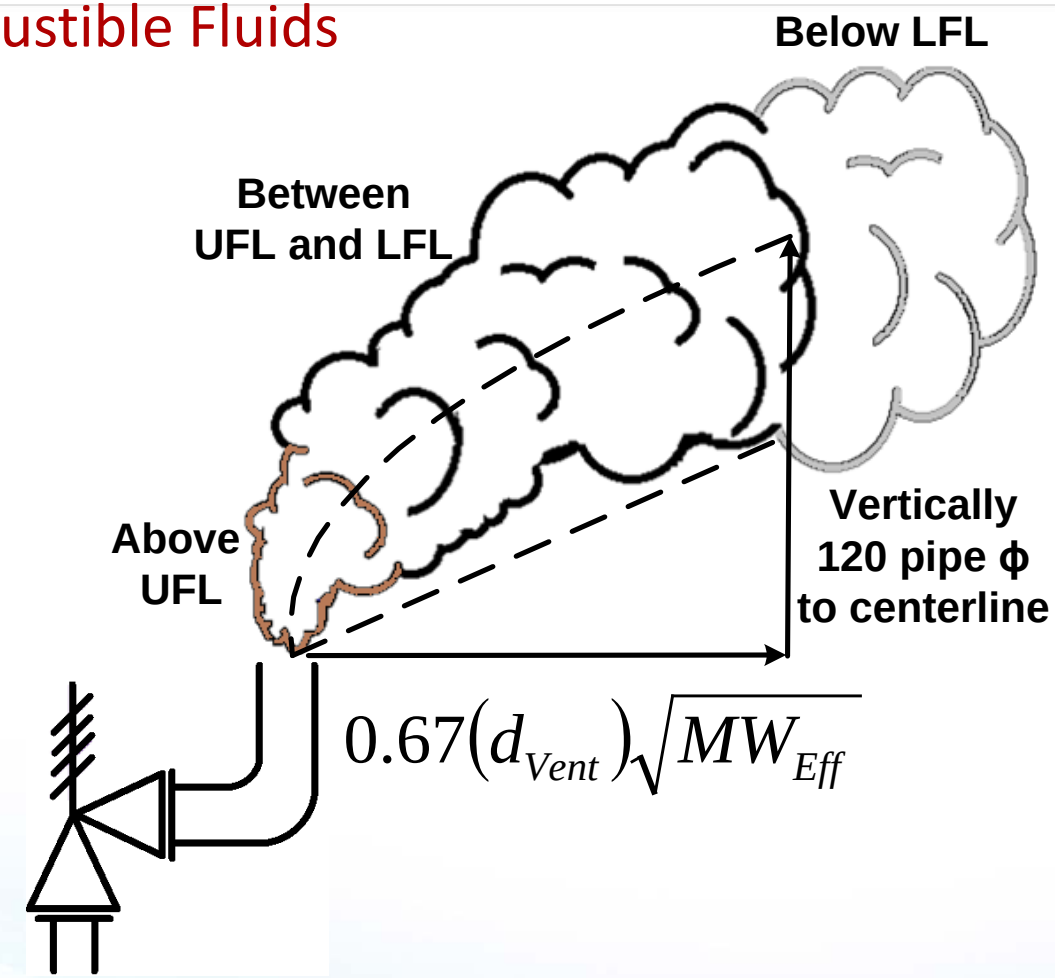
*API STD 521 6th ed. *Guide for pressure relieving and depressuring systems* §5.3.1

Quantitative Analysis

Flammable and/or Combustible Fluids

Vapor Releases Acceptable*

- API STD 521 §5.8.1
- Worst case wind speed
- Minimal temperature affects
- the bottom of cloud may be 1/6 to 1/3 the "height" below the centerline



*from API STD 521 6th ed. *Guide for pressure relieving and depressuring systems*

Quantitative Analysis

Flammable and/or Combustible Fluids

Origin of horizontal Equation*

- API STD 521 §5.8.1
- Curve Fit Figure 16, results
- Assume a perfect Gas

$$x = \frac{d_j}{12}\sqrt{\left(\frac{MW_j}{28.8}\frac{T_\infty}{T_j}\frac{P_j}{P_\infty}\right)}\left(19{,}301\left(\frac{u_\infty}{u_j}\right)^3 - 5{,}660\left(\frac{u_\infty}{u_j}\right)^2 + 334\left(\frac{u_\infty}{u_j}\right) + 37.9\right)$$

Simplified Assuming

- Release T between 70 °F and 600 °F
- Maximum vent velocity is near atmospheric pressure
- Downwind concentration of interest is ~3% (the LFL)

$$x = 0.67\left(d_{Vent}\right)\sqrt{MW_{Eff}}$$

*from API STD 521 6th ed. *Guide for pressure relieving and depressuring systems*

Quantitative Analysis

Flammable and/or Combustible Fluids

$0.67d\sqrt{MW}$	Downwind distance (ft) for Release Streams (MW_j)									
	16	**30**	**44**	**58**	**72**	**86**	**100**	**114**	**128**	**142**
Pipe Diameter (d_j) 2	5	7	9	10	11	13	14	14	15	16
3	8	11	14	16	17	19	21	22	23	24
4	11	15	18	21	23	25	27	29	31	32
6	16	22	27	31	34	38	41	43	46	48
8	22	30	36	41	46	50	54	58	61	64
10	27	37	45	51	57	63	68	72	76	80

*from API STD 521 6th ed. *Guide for pressure relieving and depressuring systems:* §5.8.1

Quantitative Analysis

Phast Dispersion Modeling

Dispersion Model Details

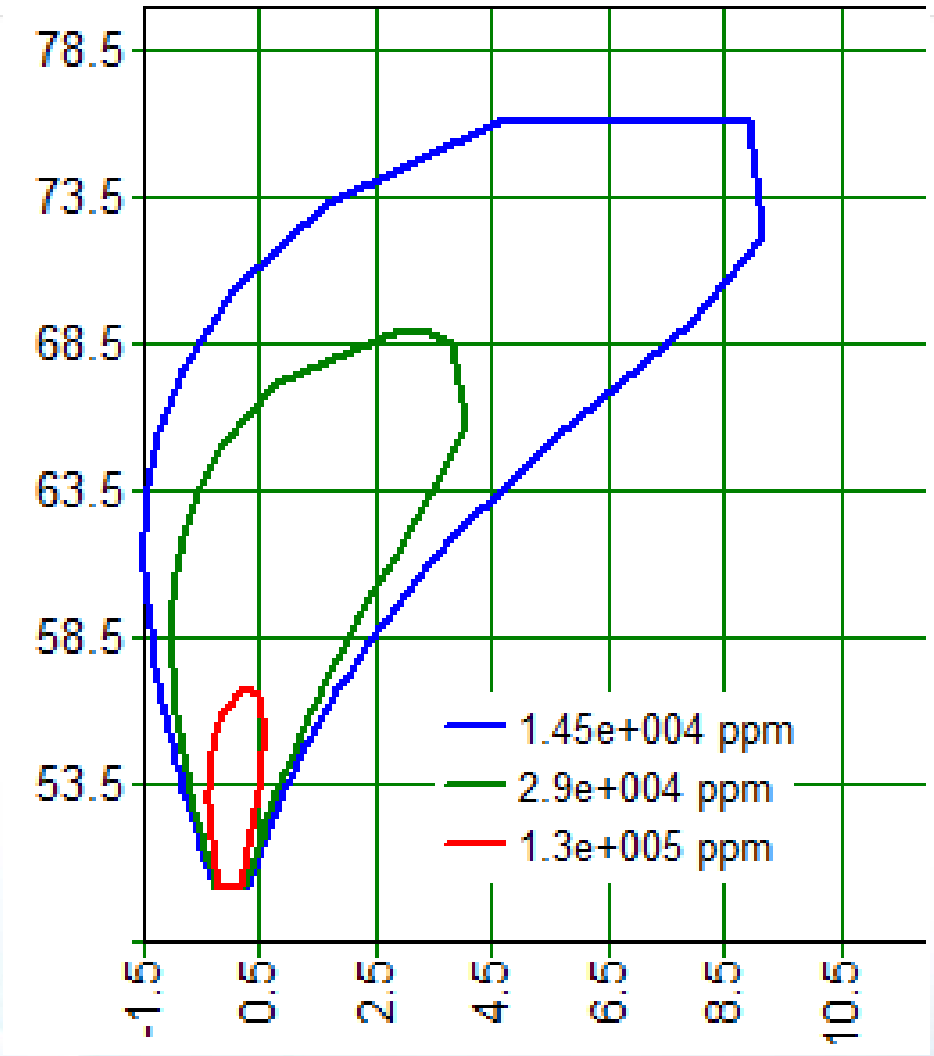
Ethane 0°F & 50 psig

4M6, 25% Capacity

Pasquill Stability D

Wind speed 3.4 MPH (1.5 M/S)

Pipe Diameter (dj)	Downwind distance			
	16	**30**	**44**	**58**
2	5	7	9	10
4	11	15	18	21
6	16	22	27	31
8	22	30	36	41
10	27	37	45	51



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Quantitative Analysis

Dispersion Modeling (Using Phast v6.7)

2½ G 3	Release to 50% LFL Downwind Distance (ft)		
	Ethane	**Pentane**	**Octane**
API §5.8.1 to "Safe", 100% LFL	**14**	**17**	**22**
50#, Cold, 25% / 100%	18[1] / 14	23[2] / 18	22 / 20
50#, Hot, 25% / 100%	16 / 13	17 / 14	17 / 16
250#, Cold, 25% / 100%	14 / 10	16 / 10	17 / 12
250#, Hot, 25% / 100%	13 / 9	14 / 10	16 / 11
Cold Temp (°F)	0*	200*	375*
Hot Temp (°F)	100	400	600

**The Temperature for Saturated Vapor at 250 psig*

Weather Conditions

- Pasquill Stability D, Wind speeds 2.4, 3.4, 6.8 and 10 mph)
- Pasquill Stability F, Wind speeds 2.4, 3.4, 6.8 and 10 mph)

Quantitative Analysis

Dispersion Modeling (Using Phast v6.7)

2½ G 3 C2 @ 0°F	25% Capacity Release to % of LFL Downwind Distance (ft)			
	100% (0.029)	75% (0.02175)	66% (0.01914)	50% (0.0145)
API §5.8.1 to "Safe", 100% LFL	**14**	**14**	**14**	**14**
Stability F, 10 MPH Wind	8	11	13	17
Stability D, 10 MPH Wind	8	11	13	18
Stability F, 6.8 MPH Wind	8	11	13	17
Stability D, 6.8 MPH Wind	8	11	13	18
Stability F, 3.4 MPH Wind	7	10	12	16
Stability D, 3.4 MPH Wind	7	10	12	17
Stability F, 2.4 MPH Wind	6	10	11	17
Stability D, 2.4 MPH Wind	6	9	11	17

Quantitative Analysis

Dispersion Modeling (Using Phast v6.7)

2½ G 3 C5 @ 200°F	25% Capacity Release to % of LFL Downwind Distance (ft)			
	100% (0.013)	75% (0.00975)	66% (0.00858)	50% (0.0065)
API §5.8.1 to "Safe", 100% LFL	**17**	**17**	**17**	**17**
Stability F, 10 MPH Wind	10	14	16	21
Stability D, 10 MPH Wind	10	14	16	22
Stability F, 6.8 MPH Wind	10	14	16	21
Stability D, 6.8 MPH Wind	10	14	16	22
Stability F, 3.4 MPH Wind	9	13	14	21
Stability D, 3.4 MPH Wind	9	13	14	22
Stability F, 2.4 MPH Wind	8	13	14	22
Stability D, 2.4 MPH Wind	8	13	14	23

Quantitative Analysis

Dispersion Modeling (Using Phast v6.7)

4 M 6	Release to 50% LFL Downwind Distance (ft)		
	Ethane	**Pentane**	**Octane**
API §5.8.1 to "Safe", 100% LFL	**27**	**34**	**43**
50#, Cold, 25% / 100%,	12 / 24	16 / 30	18 / 33
50#, Hot, 25% / 100%	11 / 10	13 / 11	15 / 13
250#, Cold, 25% / 100%	11/ 19	12 / 22	13 / 25
250#, Hot, 25% / 100%	10 / 17	11 / 20	13 / 23
Cold Temp (°F)	0*	200*	375*
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Quantitative Analysis

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6 Q 8	Release to 50% LFL Downwind Distance (ft)		
	Ethane	**Pentane**	**Octane**
API §5.8.1 to "Safe", 100% LFL	**36**	**46**	**58**
50#, Cold, 25% / 100%	37 / 37	46 / 31	47 / 36
50#, Hot, 25% / 100%	31 / 24	34 / 26	36 / 29
250#, Cold, 25% / 100%	27/ 35	26 / 38	30 / 43
250#, Hot, 25% / 100%	25 / 30	27 / 35	28 / 41
Cold Temp (°F)	0*	200*	375*
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Quantitative Analysis

Flammable and/or Combustible Fluids

Additional Considerations

- Condensation
  - MW greater than ~100
  - Mists
  - Mist and Spray Explosions by J.H. Burgoyne Worst
- Uncertainty
  - 2x (50% LFL Existing)
  - 10x (10% LFL New)
- Potential Ignition (Hydrocarbons, Per Loudon's Work)
  - Equipment / Platforms
  - Lightning
  - Higher Thermal Radiation Limits

Toxic Fluids – Far Field Effects

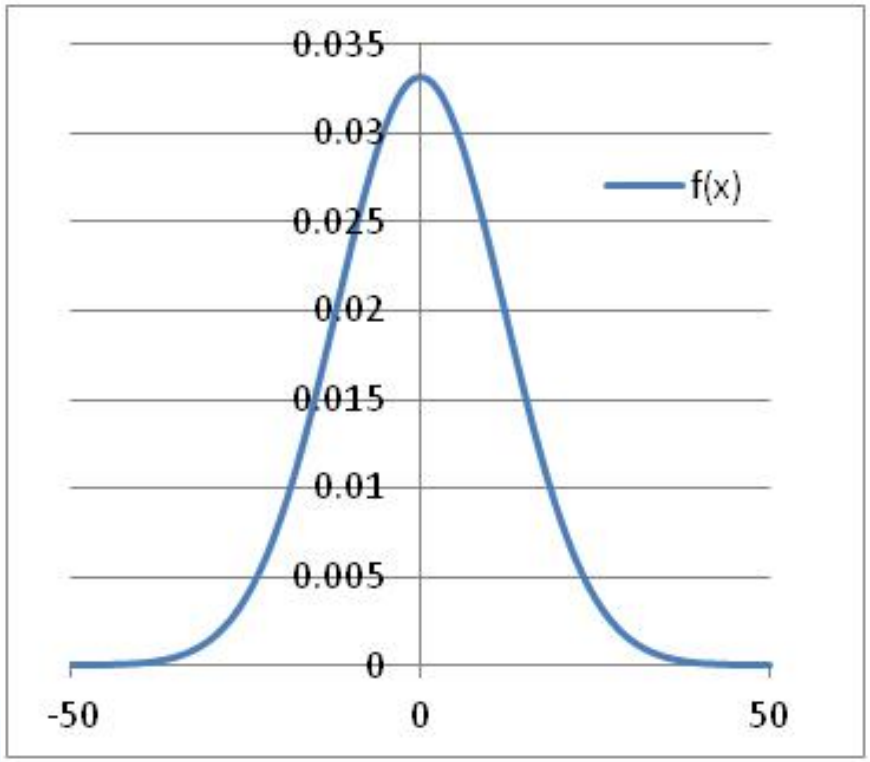
Basis

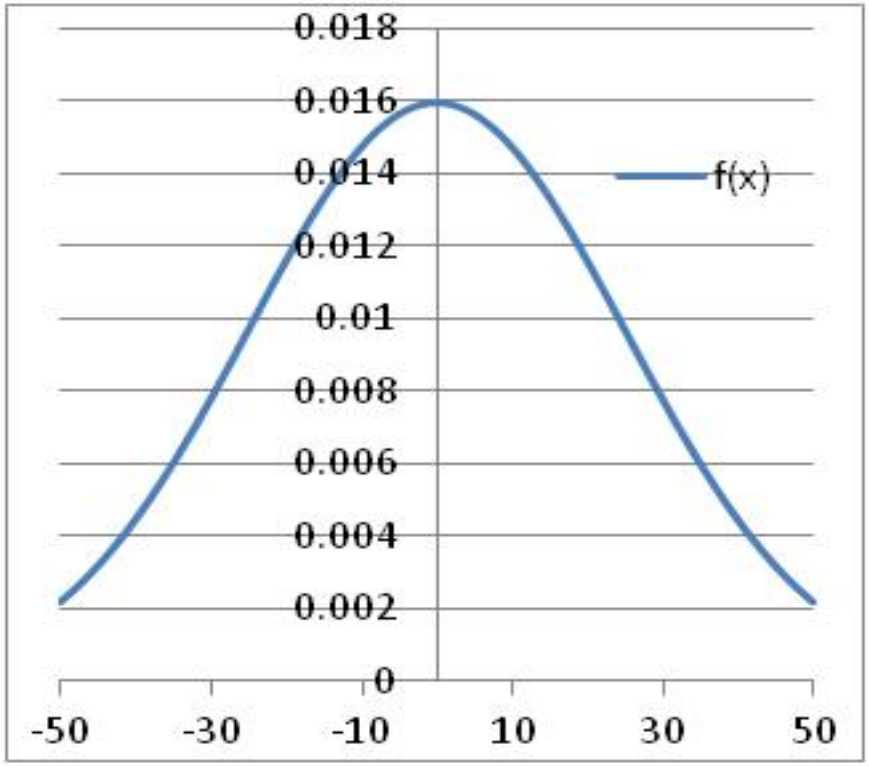
- Gaussian Distribution
- Dependent on Atmospheric Stability
- Dependent on Wind Speed

$$C = \frac{Q}{2\pi \cdot u\sigma_y\sigma_z} e^{-\frac{y^2}{2\sigma_y^2}} \left[e^{-\frac{(z-H)^2}{2\sigma_z^2}} + e^{-\frac{(z+H)^2}{2\sigma_z^2}} \right]$$

Quantitative Analysis

Toxic Fluids – Far Field Effects





Gaussian Distribution, Relative cloud widths for Standard Deviation of 12 Right and 25 Left

Toxic Fluids – Far Field Effects

Max Concentration at Grade

$$\frac{dC}{dx} = \frac{Q}{2\pi \cdot u\sigma_y} e^{-\frac{y^2}{2\sigma_y^2}\left[\frac{H^2}{2\sigma_z^2} - 1\right]} \frac{d\sigma_z}{dx}$$

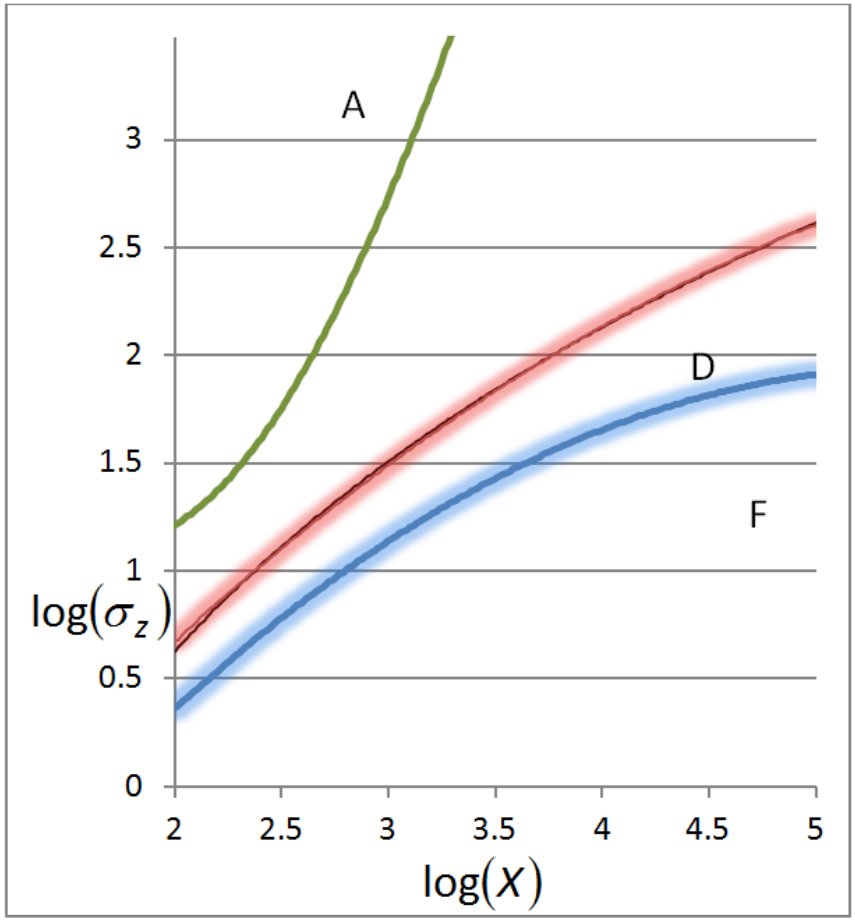
$$\sigma_z = \frac{H}{\sqrt{2}} \quad \text{Read distance from chart}$$

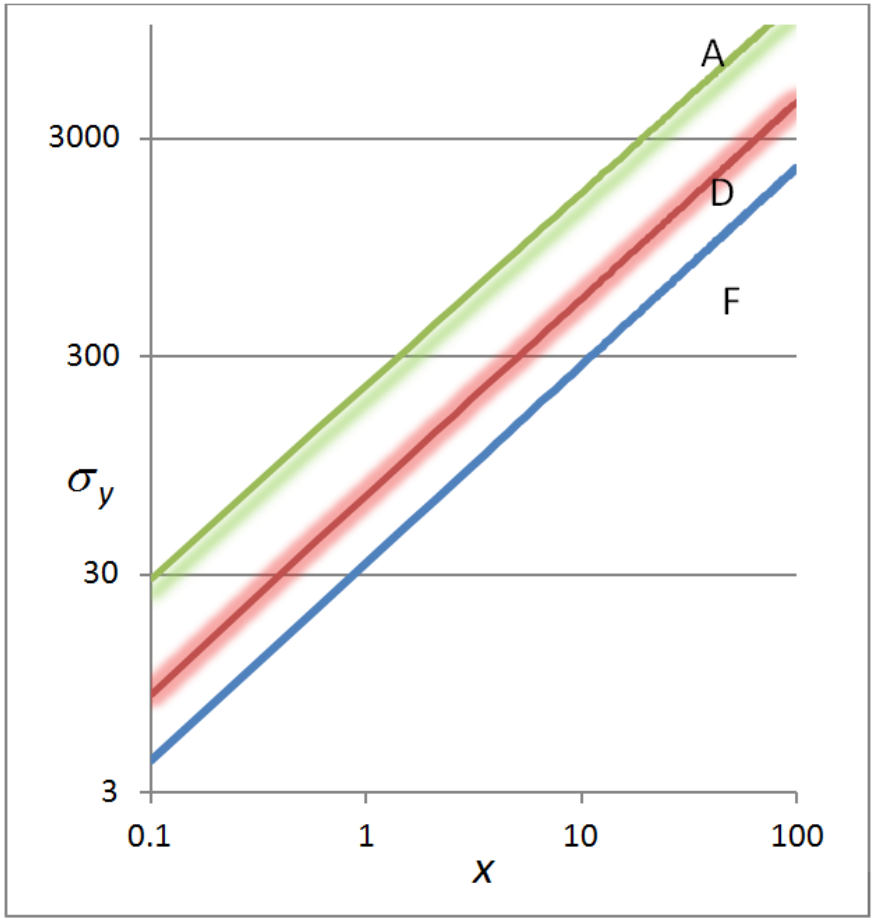
$$C_{m,D} \approx \frac{Q}{e\pi H^2 u} \text{ (D stability)}$$

$$C_{m,F} \approx \frac{Q}{3e\pi H^2 u} \text{ (F stability)}$$

Quantitative Analysis

Toxic Fluids – Far Field Effects





Correlation of Vertical Dispersion Coefficients, σ_z and σ_y, from Turner 1969

Quantitative Analysis

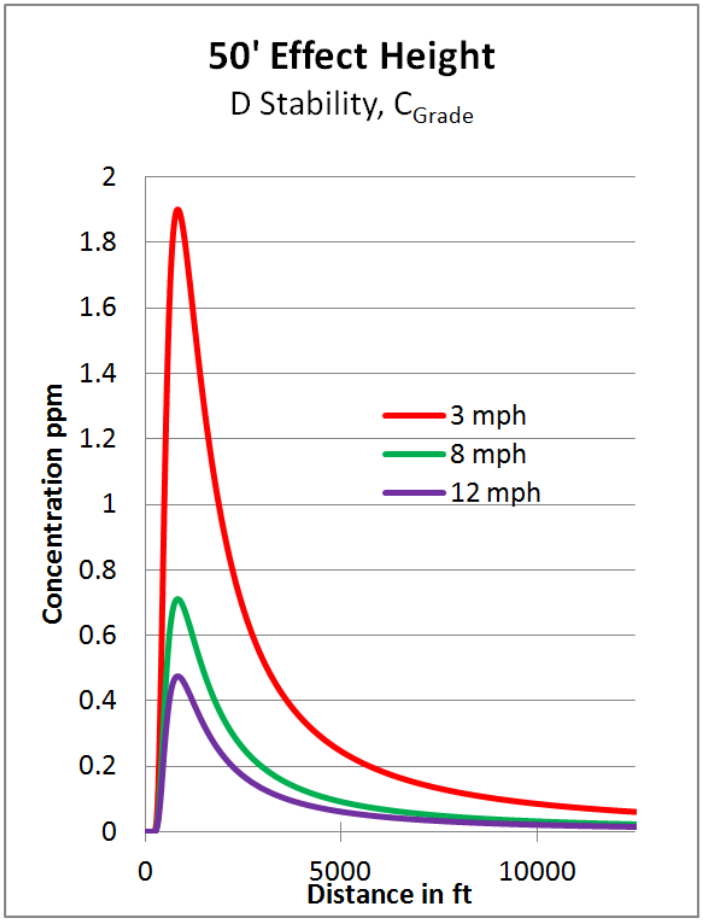
Toxic Fluids – Far Field Effects

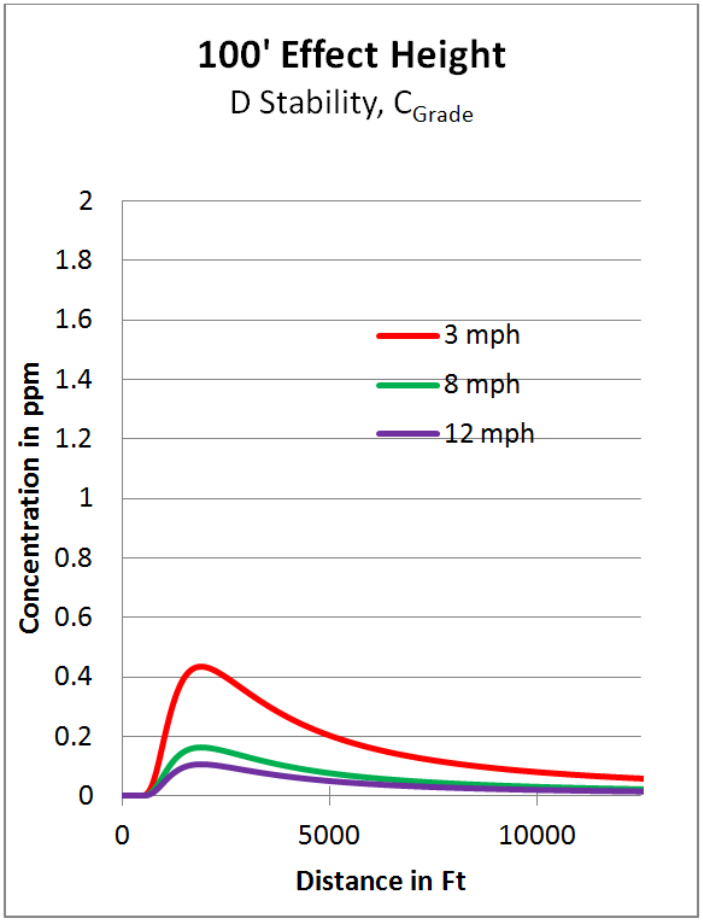
Max Concentration at Grade

H, effective height (ft)	Stability D C_{max} Distance (ft)	Stability F C_{max} Distance (ft)
50	840	2,244
75	1,384	4,167
100	2,001	6,771
125	2,688	10,222
150	3,443	14,745
200	5,159	28,366

Quantitative Analysis

Toxic Fluids – Far Field Effects





Concentrations Profiles at Grade for Two Different Elevation Releases, 50 ft and 100 ft

Quantitative Analysis

Model Data

Summary of RAWS Weather / Climate Data

Location	Wind Speed (% Less than listed)				%Greater
	1 MPH	2 MPH	4 MPH	7 MPH	13 mph
California, LA Area	0.9	11.8	45.7	77.9	11.7
California, SF Bay Area	16	19.7	29.8	49	12.4
Illinois, Near Chicago	2.6	6.6	21.4	51.1	12.4
Louisiana, Coastal	2.6	3.9	11.4	35.7	17.3
New Jersey, Coastal	5.6	10.9	32.1	66.7	2.8
Ohio Valley	9.5	19.5	60.2	91.9	0.3
Pennsylvania, Philadelphia	35.5	56.7	89.7	99.2	--
Texas, Near Houston (Coastal)	**21.7**	**25.7**	**39.6**	**63.4**	**8.8**
Texas, Near Houston (Inland)	3.8	5	15.6	48.1	14.7
Texas, Panhandle	2.0	5.0	18	46.8	18
Utah, Near CO/WY Boarder	21.5	27.8	40.8	57.8	14.3
Washington, Puget Sound Area	74.7	82.7	92.6	98.1	--
West Virginia	4.3	9.3	41.2	75	3.3

Quantitative Analysis

Model Data

Descriptions of the Pasquill-Gifford Stability Classes

Conditions	Pasquill-Gifford Stability Class					
	A	**B**	**C**	**D**	E	**F**
Pasquill-Gifford Stability Class	Very Unstable	Unstable	Slightly Unstable	**Neutral**	Slightly Stable	**Moderately Stable**
Day / Night	Day	Day	Day	**Either**	Night	**Night**
Winds Relative	Low	More	Most	**Most**	More	**Low**
Winds (mph)	< 4.5	< 4.5 to 11	4.5 to 13.4+	**7 to 13.4+**	4.5 to 11	**< 4.5 to 6.5**
Cloud Cover	No Clouds	Few Clouds	Less Cloudy	**Cloudy**	Less Cloudy	**Few Clouds**
Radiation	Very Sunny	Sunny	Slightly Sunny	**Minimal**	Night time	**Night time**
Turbulent Mixing	Most	More	Some	**Less**	Little	**Minimal**

Quantitative Analysis

Model Data

Sources of Exposure Concentrations from Various Agencies

Org	Guidance	Target
EPA	AEGL	Public Exposure
AIHA	ERPG	Public Exposure
NIOSH	REL & IDLH	Worker Exposure
OSHA	PEL	Worker Exposure
ACGIH	TLV	Worker Exposure
DOE - SCAPA	TEEL	DOE workers and public
HSE	SLOT & SLOD	Public Exposure

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