Using stability classes F and G in the development of Emergency Response Scenario Plans

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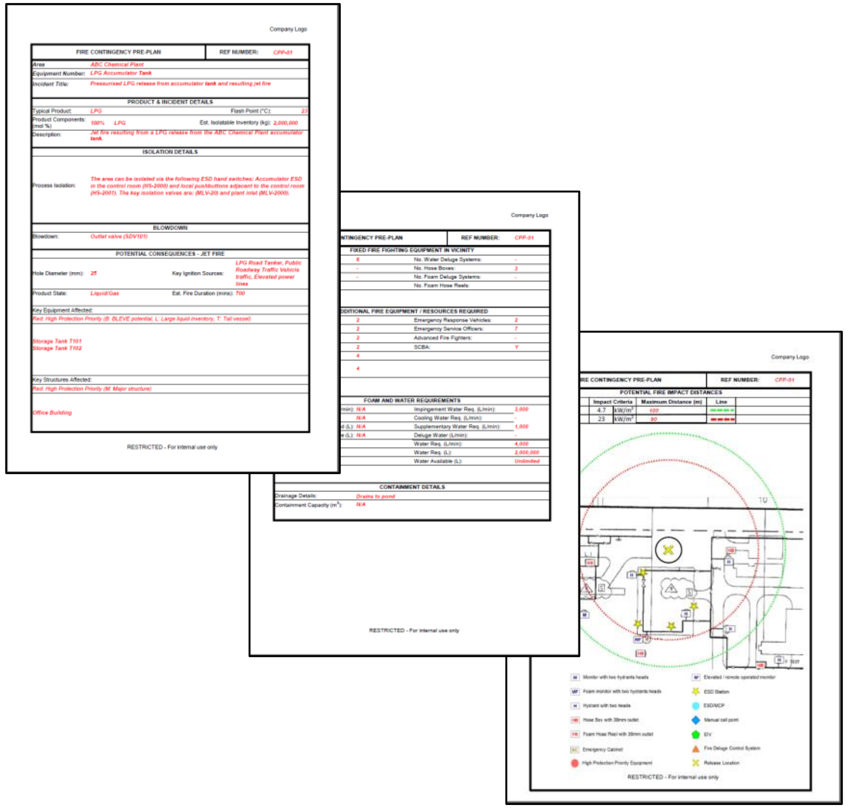
Introduction

- Emergency Response Scenario Plan
  - Overview
  - Extent of Effects
- Consequence Modelling
  - Overview
  - Inputs
- Atmospheric Stability Class / Weather Conditions
  - Overview
  - Selection
- Modelling Atmospheric Stability Class
  - Vapour Dispersion
  - Dispersion Coefficients
  - Example

Emergency Response Scenario Plan: Overview



- Information necessary to manage a major incident
- Details concerning the major incident:
  - Description
  - Process isolation
  - Response equipment on-site
  - Required additional resources
  - Extent of effects (on-site & off-site).
- Training tool used to test systems against the requirements of the emergency event
- Used in consultations with emergency services

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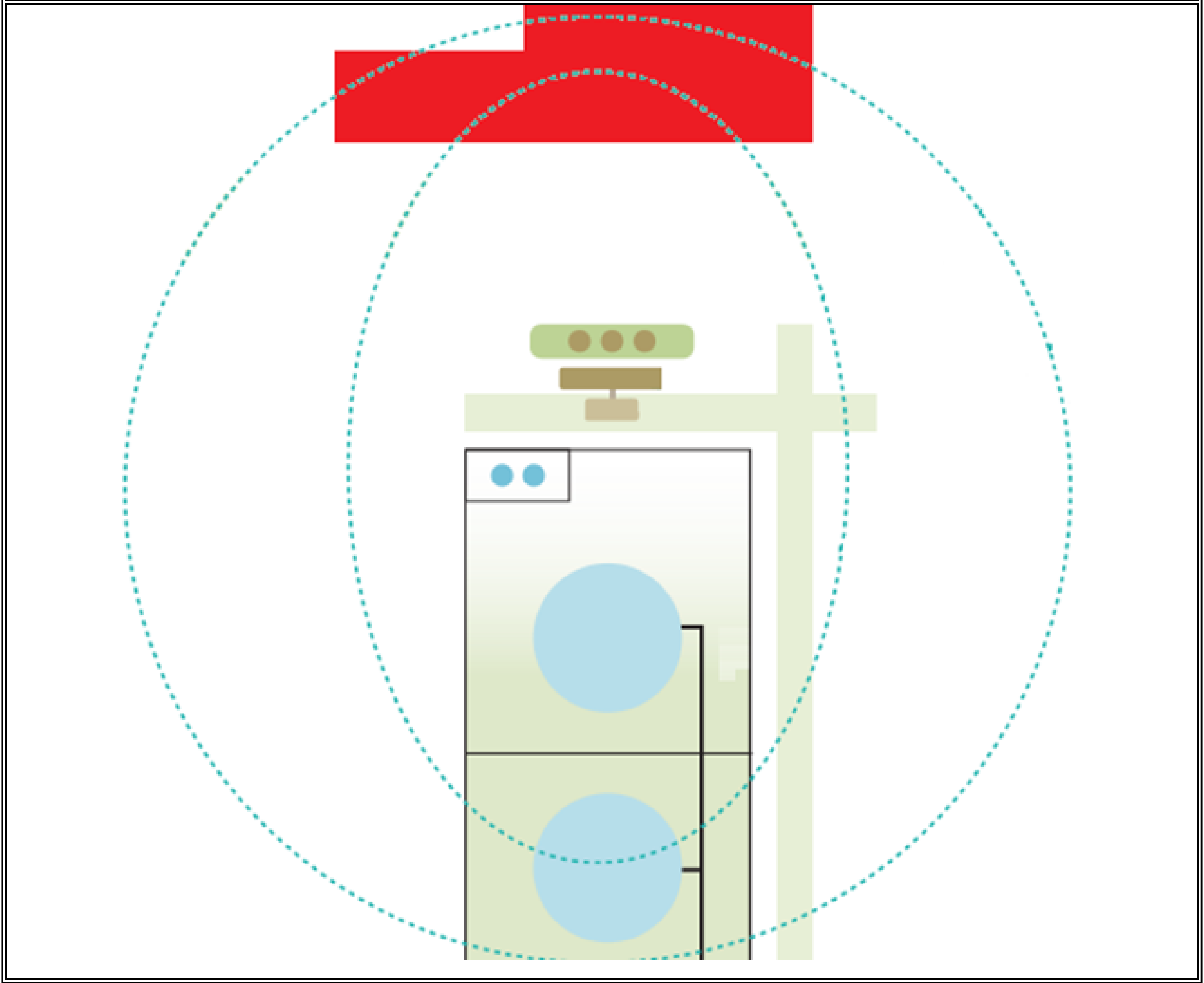
Emergency Response Scenario Plan: Extent of Effects

MHF Co.	Doc Control No: A214R
Emergency Response Plan	



Potential on-site & off-site effects

Consequence Modelling: Overview

- Consequence modelling is used to determine the extent of the impact (*effects*) of a major incident
- Consequence modelling software packages (e.g. DNV-GL PHAST) are used to evaluate the impact of:
  - Radiant heat from fires
  - Overpressure from explosions
  - Harmful concentrations from toxic releases
- Various consequence types rely on gas dispersion modelling (e.g. flammable vapour clouds, toxic impacts)

Consequence Modelling: Inputs

- Specify major incident details:
  - Material, temperature, pressure
  - Hole size
  - Release location, orientation, height
- Specify impact criteria *(effect)* of interest
  - E.g. Onset of fatality for toxic releases
- Specify weather conditions for local area
  - Wind speed
  - Temperature
  - Stability class

Atmospheric Stability Class: Overview

- Atmospheric stability class describes the turbulence generated by natural forces in the atmosphere
  - Vertical mixing caused by air particle movement

- General states of atmospheric stability:
  - Stable – Calm evening
  - Neutral – Overcast / windy evening
  - Unstable – Sunny day

- Main influencing parameters:
  - Solar insolation
  - Cloud cover
  - Wind speed
  - Temperature gradient

Atmospheric Stability Class: Overview

- Classification schemes estimate an appropriate stability class based on local knowledge of influencing parameters

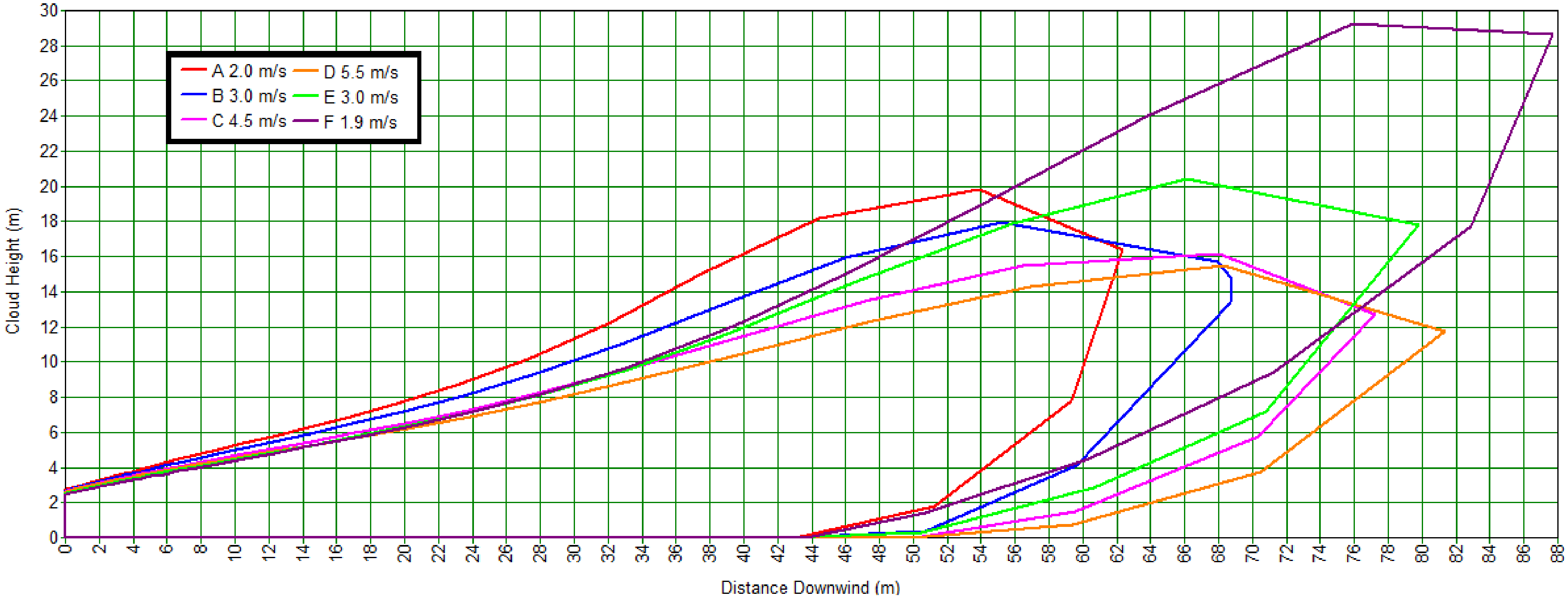
Wind Speed, m/s	Solar Insolation			Night Time	
	Strong	Moderate	Slight	Thin Overcast or >1/2 low clouds	<3/8 cloudiness
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-4	B	B-C	C	D	E
4-6	C	C-D	D	D	D
>6	C	D	D	D	D

Pasquill, F., "The estimation of the dispersion of windborne material", The Meteorological Magazine, Vol. 90, No. 1,063, Feb. 1961.

- Very low wind speed (<2 m/s) - lack of quantitative knowledge

Atmospheric Stability Class: Overview

Side View of a Dispersing Vapour Cloud



Atmospheric Stability Class: Selection

Stable Categories of E & F

- In dispersion modelling, stable conditions are used to represent "worst-case" impacts

- Stability class E classified by:
  - Slightly stable conditions
  - Night-time, low wind speeds (2-4 m/s)
  - Temperature inversion

- Stability class F classified by:
  - Moderately stable conditions
  - Night-time, low to very low wind speeds (<3 m/s)
  - Moderate temperature inversion

- Terrain characteristics (*surface roughness*) are also influential

Atmospheric Stability Class: Selection

Most Stable Category G

- Extremely stable

- Occurrence in specific situations / environments:
  - Arid rural areas
  - Clear night with ground frost / heavy dew
  - Over water

- Stability class G classified by:
  - Night-time
  - Cloudless
  - Strong temperature inversion
  - Very low wind speed (<2 m/s)
  - Flat terrain

Example of Stability Class G: Nevada Nuclear Test Site

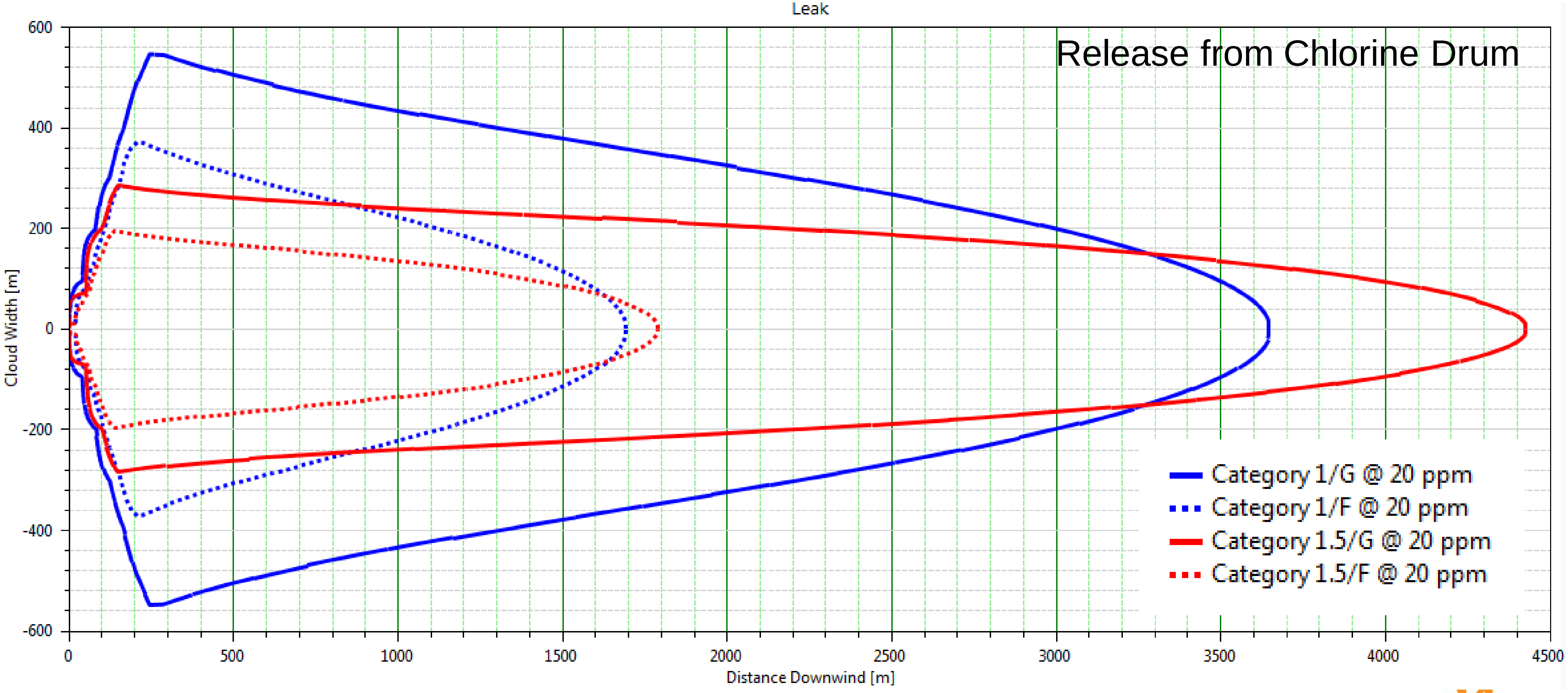
Atmospheric Stability Class: Selection

- Stability classes A-F selected from well-established classifications
  - Applicable to different situations
- Basis for selecting stability class G is less clear:
  - Typically not adopted in classifications
- Use of stability class G requires consideration as to whether the very specific atmospheric conditions are actually possible for the location
- Stability class F is preferred in low wind speed, night time conditions

Atmospheric Stability Class: Example

- Small liquid release from chlorine drum (920 kg)
- Toxic vapour dispersion modelling of effects to a specific toxic impact criteria
- Examine night-time wind speed / stability class categories:
  - 1.5/F ; 1.5/G
  - 1.0/F ; 1.0/G

Atmospheric Stability Class: Example

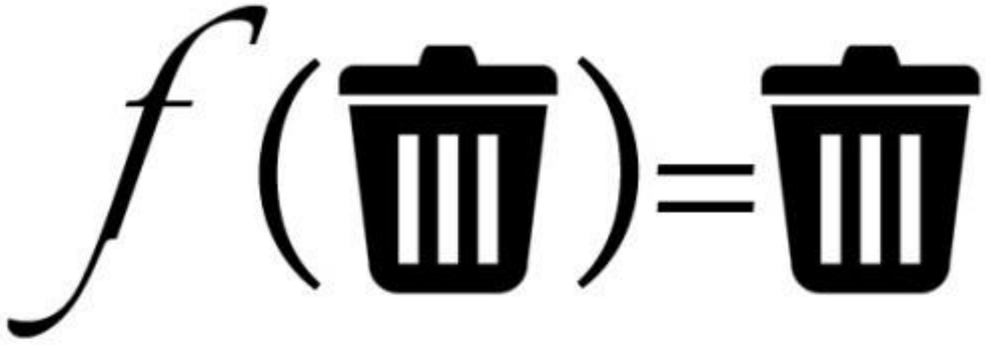


Atmospheric Stability Class: Example

- Demonstrates that the inappropriate selection of stability class leads to larger impact zones

- **Significant implications for Emergency Response Scenario Plans**

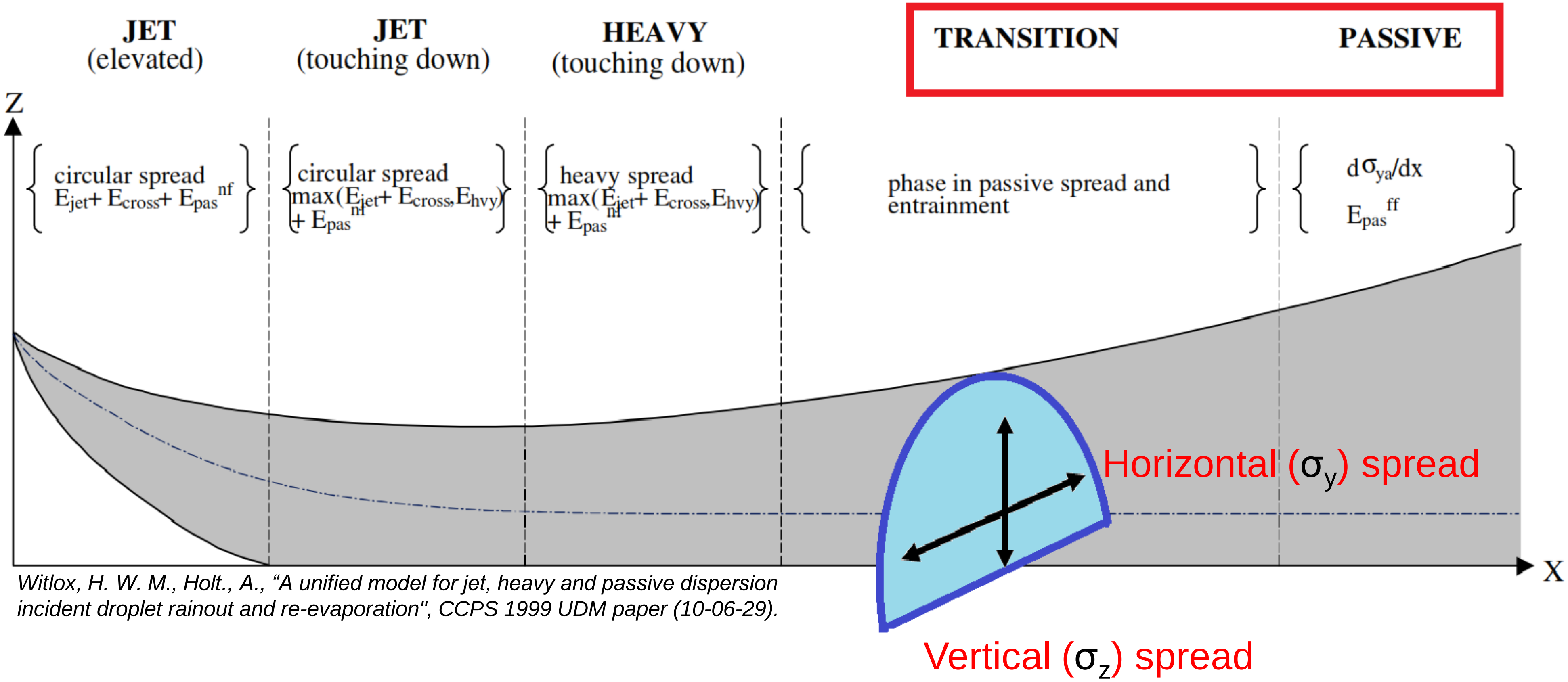
Atmospheric Stability Class



"…all models are wrong, some are useful…"

- George E. P. Box

Modelling Atmospheric Stability Class: Vapour Dispersion



Witlox, H. W. M., Holt., A., "A unified model for jet, heavy and passive dispersion incident droplet rainout and re-evaporation", CCPS 1999 UDM paper (10-06-29).

Modelling Atmospheric Stability Class: Dispersion Coefficients

- Stability classes are represented in the dispersion models using Gaussian dispersion coefficients

- Dispersion coefficients describe the horizontal (σ_y) and vertical (σ_z) spread of the cloud in the “passive” dispersion phase

- Dispersion coefficients are derived from experimental results and theory

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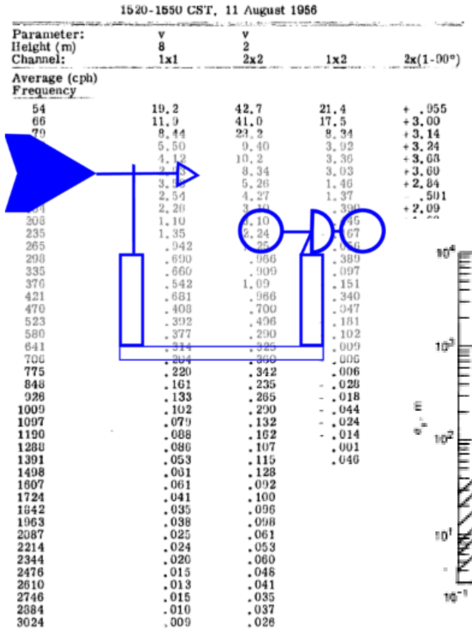
Modelling Atmospheric Stability Class: Dispersion Coefficients



1520-1550 CST, 11 August 1956

Parameter:	v	v		
Height (m)	8	2		
Channel:	1x1	2x2	1x2	2x(1-90°)
Average (cph) Frequency				
54	19.2	42.7	21.4	+ .955
66	11.9	41.0	17.5	+3.00
79	8.44	23.2	8.34	+3.14
[illegible]	5.50	9.40	3.92	+3.24
[illegible]	4.12	10.2	3.36	+3.68
[illegible]	[illegible]	8.34	3.03	+3.60
[illegible]	[illegible]	5.26	1.46	+2.84
[illegible]	2.54	4.27	1.37	.501
[illegible]	2.20	[illegible]	[illegible]	+2.09
208	1.10	[illegible]	[illegible]	[illegible]
235	1.35	2.24	[illegible]	
265	.942	[illegible]	[illegible]	
298	.690	.966	.389	
335	.660	.909	.097	
376	.542	1.09	.151	
421	.681	.966	.340	
470	.408	.700	.047	
523	.392	.496	.181	
580	.377	.290	.102	
641	.314	.325	.009	
700	.204	.360	.006	
775	.220	.342	.006	
848	.161	.235	- .028	
926	.133	.265	- .018	
1009	.102	.290	- .044	
1097	.079	.132	- .024	
1190	.088	.162	- .014	
1288	.086	.107	.001	
1391	.053	.115	.046	
1498	.061	.128		
1607	.061	.092		
1724	.041	.100		
1842	.035	.096		
1963	.038	.098		
2087	.025	.061		
2214	.024	.053		
2344	.020	.060		
2476	.015	.048		
2610	.013	.041		
2746	.015	.035		
2884	.010	.037		
3024	.009	.026		

Barad, M.L. (Editor) (1958): Project Prairie Grass, A Field Program In Diffusion.

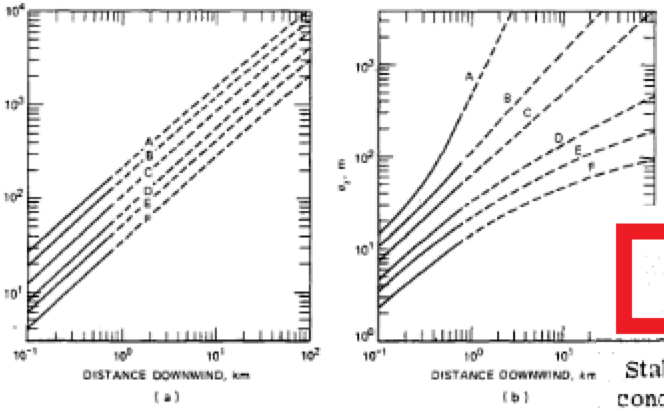


Fig. 4.4 Curves of σ_y and σ_z for turbulence types based on those reported by Pasquill
F. A. Gifford, Turbulent Diffusion-Typing Schemes: A Review, *Nucl. Saf.*, 17(1): 71 (19

$$\sigma = \exp\left[I + J(\ln x) + K(\ln x)^2\right]$$

Stability condition*	I	J	K
A	5.357		−0.0076
B	5.058		−0.0096
C	4.651		−0.0076
D	4.230		−0.0087
E	3.922		−0.0064
F	3.533		−0.0070

McMullen, R., "The Change of Concentration Standard Deviations with Distance", APCA NOTE-BOOK, Vol. 25, No. 10, Oct. 1975.

Modelling Atmospheric Stability Class: Dispersion Coefficients

- Correlations for stability classes A-F obtained from experimental observations and theory

- For stability class G, no dispersion coefficients / experimental data available to derive correlations

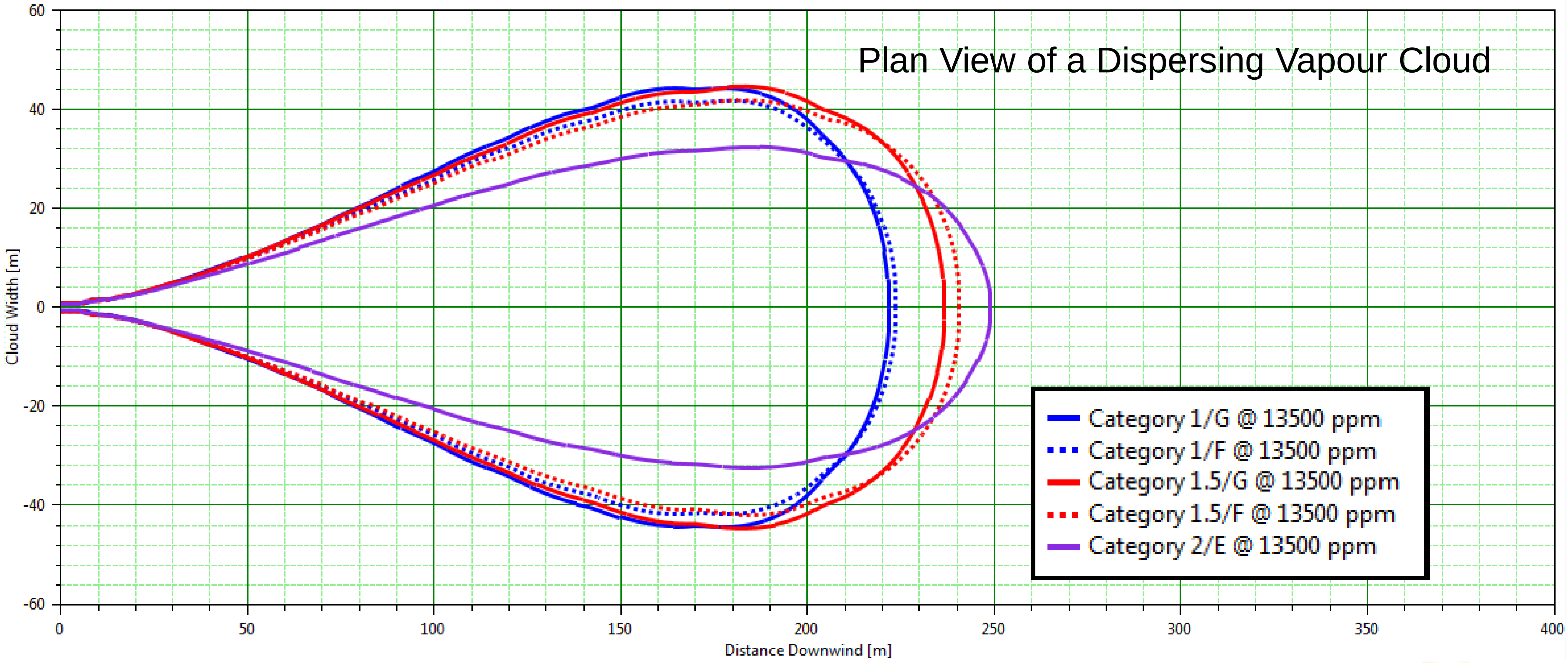
- Correlations derived by extrapolating from the dispersion coefficients for stability classes A-F
  - Assumes less dispersion for G than F

- Actual dispersion characteristics ill-defined
  - Irregular, meandering, no definable travel

Modelling Atmospheric Stability Class: Example

- Large liquid release from Ethylene Isotainer
- Vapour dispersion modelling to determine the extent of the potential flammable effects
- Stable atmospheric categories:
  - 2.0/E
  - 1.5/F ; 1.5/G
  - 1.0/F ; 1.0/G

Modelling Atmospheric Stability Class: Example



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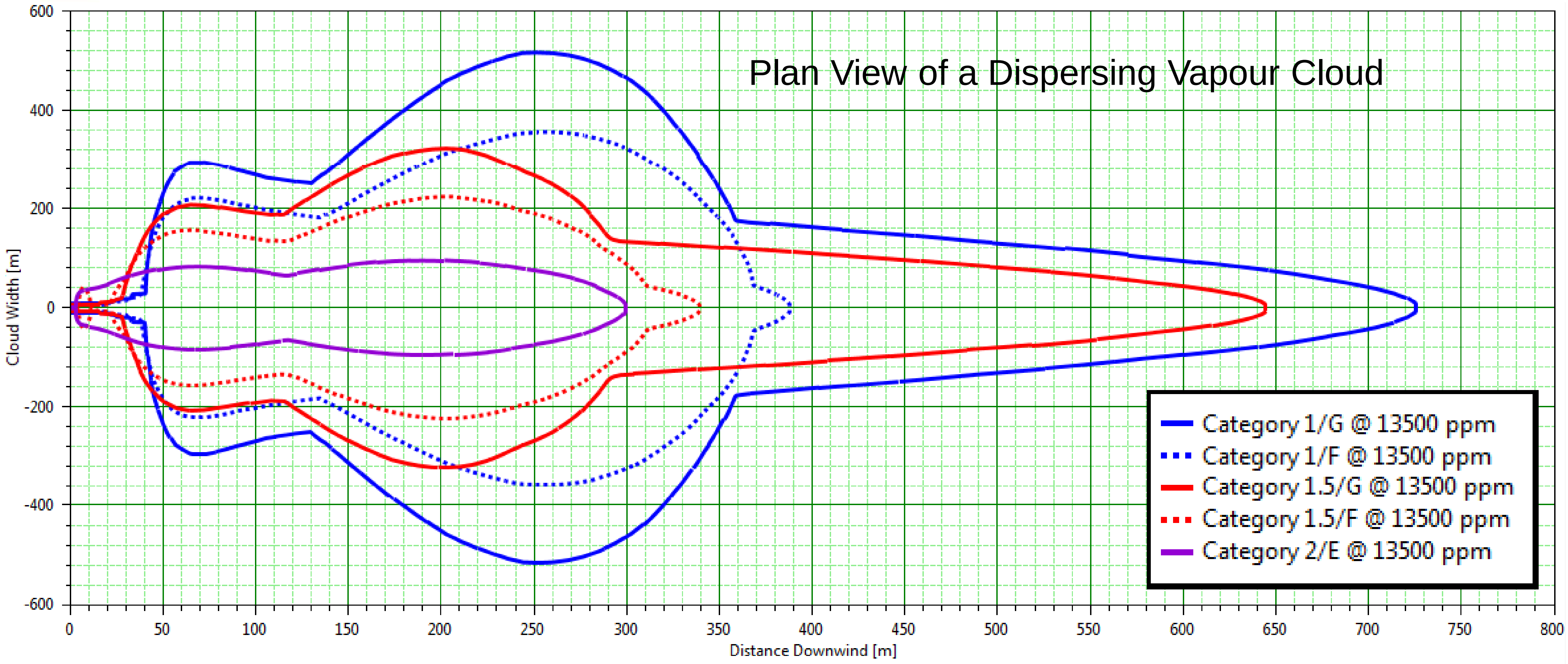
Modelling Atmospheric Stability Class: Example



Conclusion

- Gas dispersion modelling is critical component of Emergency Response Scenario Plans (e.g. toxic releases)
  - Quantification of off-site impact

- Stable conditions used to quantify “worst-case” extents
  - However, inappropriate use of the extremely stable stability class G leads to overstated impact distances

- Stability class F is preferred:
  - Stable conditions most appropriate for sites examined
  - Dispersion correlations based on experiment results, rather than an assumed extrapolation

Thank you

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