

Lecture 12

Plume Behaviour

Plume Types

“ Plume types are important because they help us understand under what conditions there will be higher concentrations of contaminants at ground level.

Stability

” Dry adiabatic lapse rate – temperature decreases due to lower pressure (ideal gas law)

$$\Gamma = -\frac{dT}{dz} = -1.00\text{ }^{\circ}\text{C}/100\text{ m} = -5.4\text{ }^{\circ}\text{F}/1000\text{ ft}$$

” Ambient (actual) lapse rate

< Γ (temperature falls faster) unstable or superadiabatic

> Γ (temperature falls slower) stable or subadiabatic

= Γ (same rate) neutral

Example

| Z(m) | T(°C) |
|------|-------|
| 2 | -3.05 |
| 318 | -6.21 |

$$\frac{\Delta T}{\Delta z} = \frac{T_2 - T_1}{z_2 - z_1} = \frac{-6.21 - (-3.05)}{318 - 2} = -0.0100 \text{ } ^\circ\text{C/m}$$

$$= -1.00 \text{ } ^\circ\text{C/100 m}$$

Since lapse rate = , atmosphere is neutral

Example

| Z(m) | T(°C) |
|------|-------|
| 10 | 5.11 |
| 202 | 1.09 |

$$\frac{\Delta T}{\Delta z} = \frac{T_2 - T_1}{z_2 - z_1} = \frac{1.09 - 5.11}{202 - 10} = -0.0209 \text{ } ^\circ\text{C/m}$$

$$= -2.09 \text{ } ^\circ\text{C/100 m}$$

Since lapse rate is more negative than Γ ,
(-1.00 °C/100 m), atmosphere is unstable

Example

| Z(m) | T(°C) |
|------|-------|
| 18 | 14.03 |
| 286 | 12.56 |

$$\frac{\Delta T}{\Delta z} = \frac{T_2 - T_1}{z_2 - z_1} = \frac{12.56 - 14.03}{286 - 18} = -0.0055 \text{ } ^\circ\text{C/m}$$

$$= -0.55 \text{ } ^\circ\text{C}/100 \text{ m} \quad \text{Suppress Vertical Dispersion}$$

Since lapse rate more positive than , atmosphere is stable

Plume Behavior

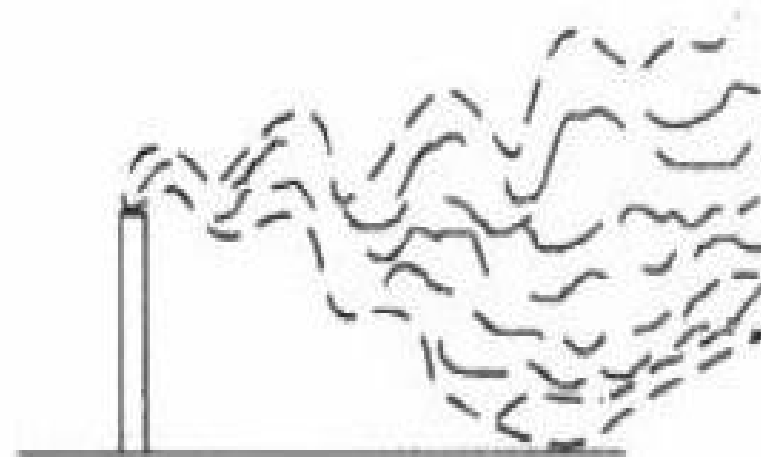
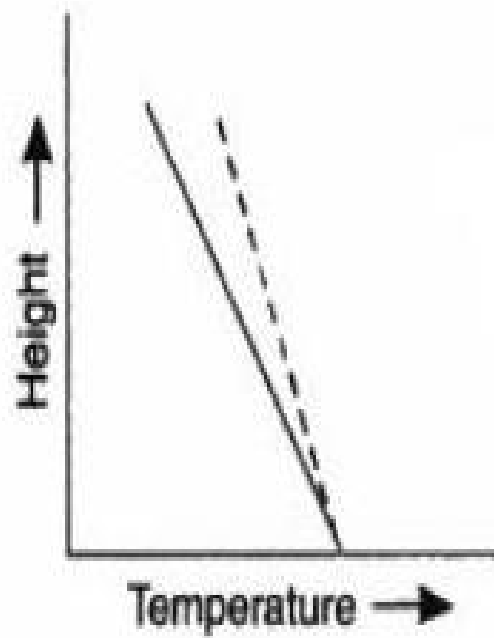
- “ The behavior of the plume emitted from an elevated source such as a tall stack depends
 - “ Degree of instability of the atmosphere
 - “ Prevailing wind turbulence

Looping Plume

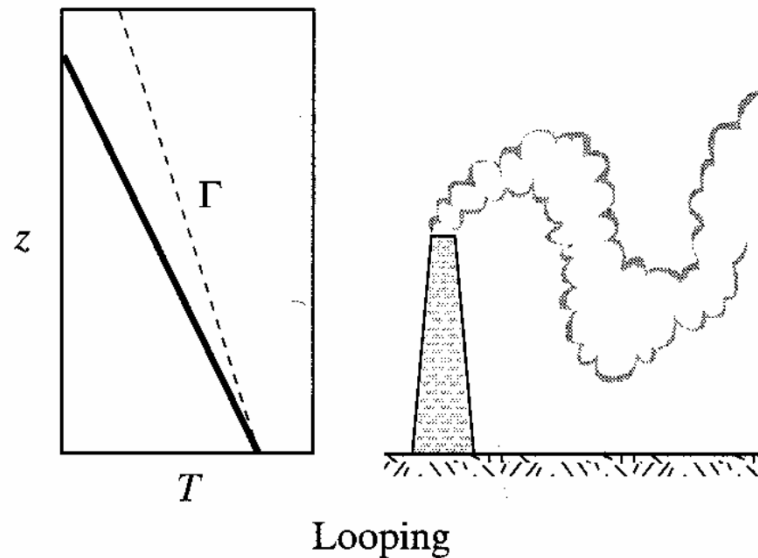
- Common type of plume behavior
- Describes wavy character
- High degree of convective turbulence
- Occurs under Superadiabatic lapse rate -- strong instabilities with light to moderate wind speed
- On hot summer afternoon when large scale thermal eddies are present
- Associated with clear daytime conditions
- High probability of high concentrations sporadically at ground level close to stack.
- Occurs in unstable atmospheric conditions.



(dry adiabatic lapse rate - - -, ambient lapse rate —)



Strong instability (looping)



- In unstable air, the plume will whip up and down as the atmosphere mixes around (whenever an air parcel goes up, there must be air going down someplace else to maintain continuity, and the plume follows these air currents). This gives the plume the appearance that it is looping around.
- Vertical dispersion is very high.
- Less wind speed: Strong & Moderate radiation, day time Mechanical Turbulence is enhanced.
- High probability of high concentrations sporadically at ground level close to stack.

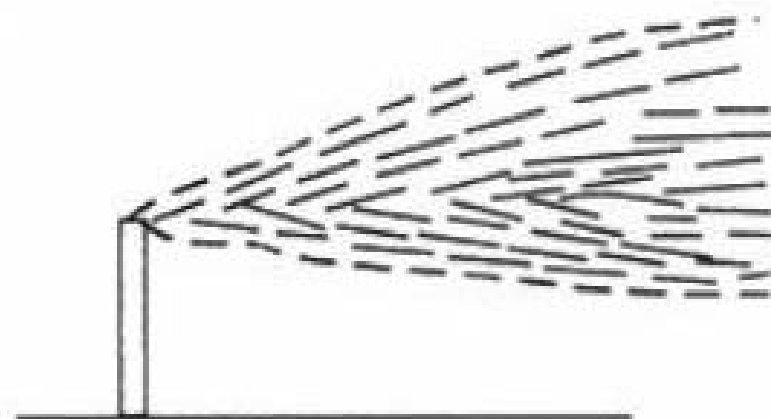
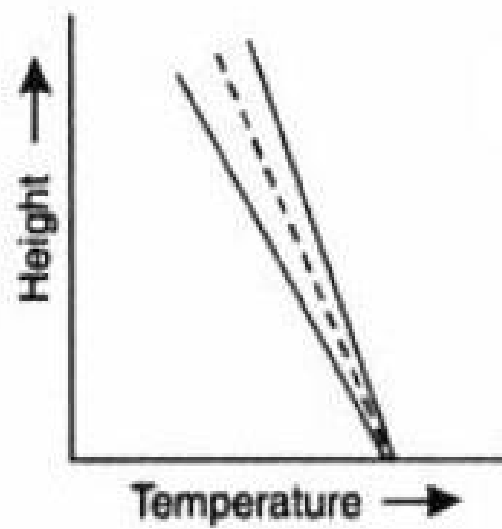
- “ Is it at stable or unstable condition? **Unstable**
- “ High or low wind speed? **Low wind speed.**
- “ Does it happen during the day or night? **Day**
- “ Is it good for dispersing pollutants? **Yes**

Coning Plume

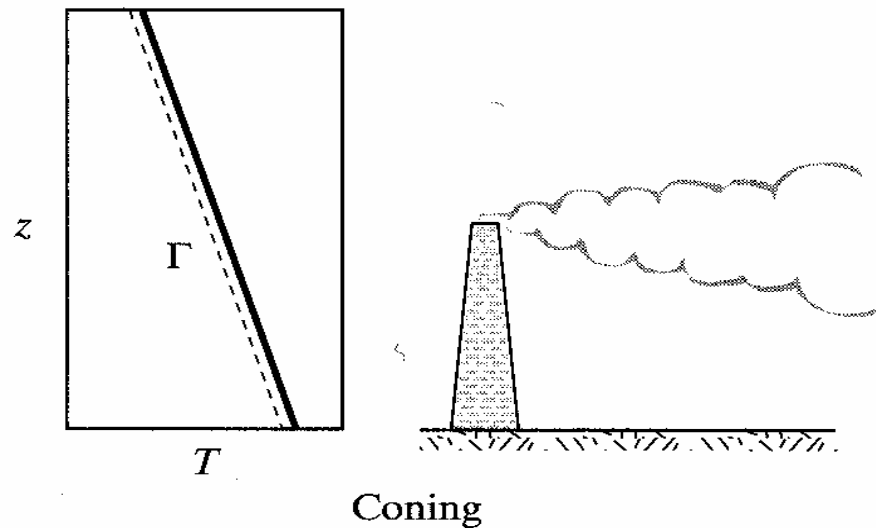


- Occurs under cloudy skies both during day and night when the lapse rate is neutral.
- Plume shape is vertically symmetrical above the plume line
- Stable with small-scale turbulence
- Associated with overcast moderate to strong winds
- Roughly 10° cone
- Pollutants travel fairly long distances before reaching ground level in significant amounts
- Occurs in neutral atmospheric conditions

(dry adiabatic lapse rate - - -, ambient lapse rate —)



Near neutral stability (coning)



- ” Standard Plume: Moderate wind speed
- ” Moderate radiation, night time
- ” Horizontal dispersion at a right angle to the wind is due to turbulence and diffusion, which occurs at the same rate as the vertical dispersion, which is not being opposed nor encouraged by the stability (or lack of it) in the atmosphere.
- ” Plume spreads equally in the vertical and horizontal as it propagates downstream, forming a coning plume



- “ Is there good vertical mixing? **OK**
- “ On sunny or cloudy days? **Partly cloudy**
- “ Good for dispersing pollutants? **OK**

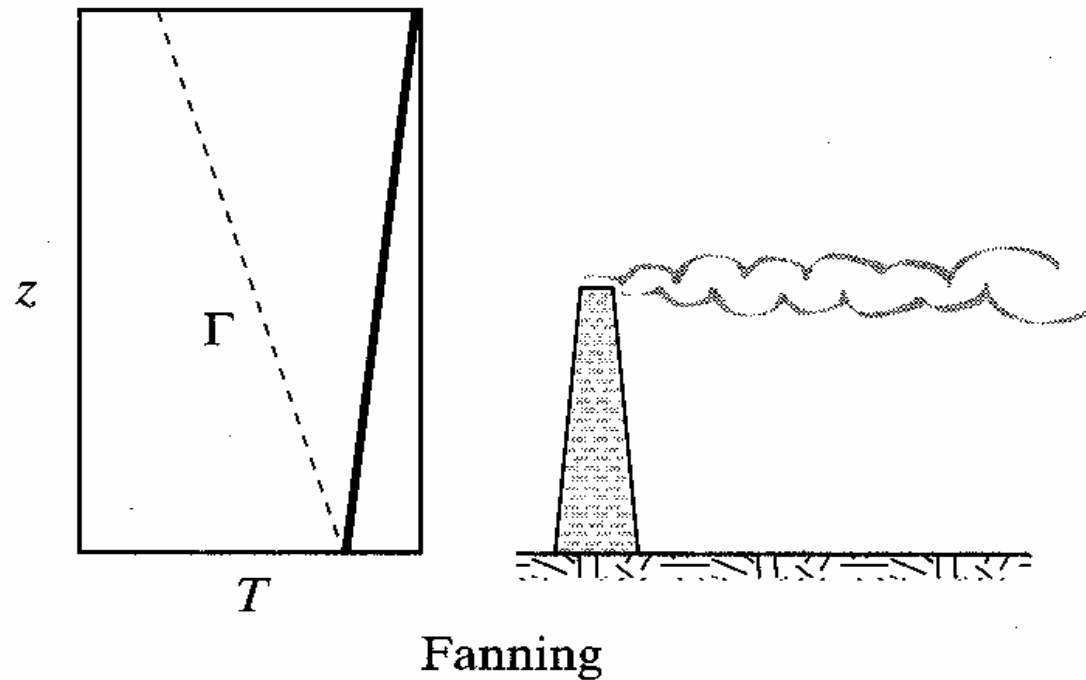
Fanning Plume

- “ Occurs under large negative lapse rate
- “ Light wind & Strong inversion at a considerable distance above the stack
- “ Extremely stable atmosphere
- “ It suppress the vertical mixing , but not horizontal mixing
- “ Little turbulence
- “ If plume density is similar to air, travels downwind at approximately same elevation may be for 10 to 20 km.
- “ For high stacks, fanning is considered a favorable condition because pollution does not contribute to ground pollution.
- “ A fanning plume is often observed at height and & in early morning in all season





- “ High wind speed: Night time, High horizontal dispersion, Vertical dispersion is suppressed by stable atmosphere.
- “ In the vertical, dispersion is suppressed by the stability of the atmosphere, so pollution does not spread toward the ground. This results in very low pollution concentrations at the ground

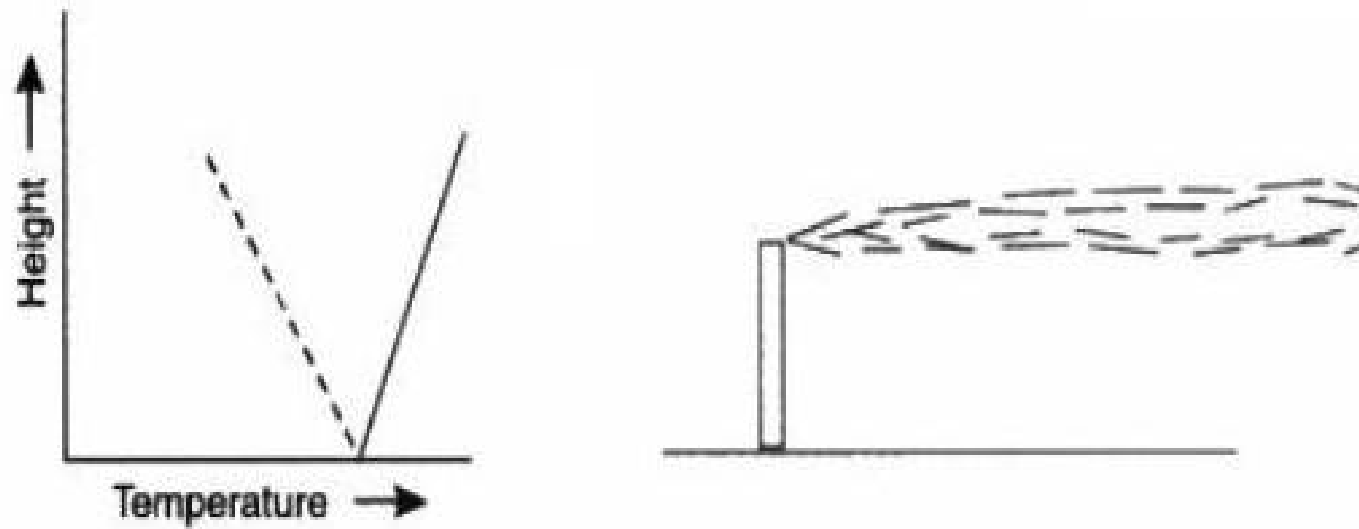


Fanning Plume:

Usually occurs at night, or 1200m-1800m above ground. There is high ground concentration if stack is short or if plume moves through rugged terrain. Occurs in stable inversion atmospheric conditions.



(dry adiabatic lapse rate - - -, ambient lapse rate —)



Surface inversion (fanning)