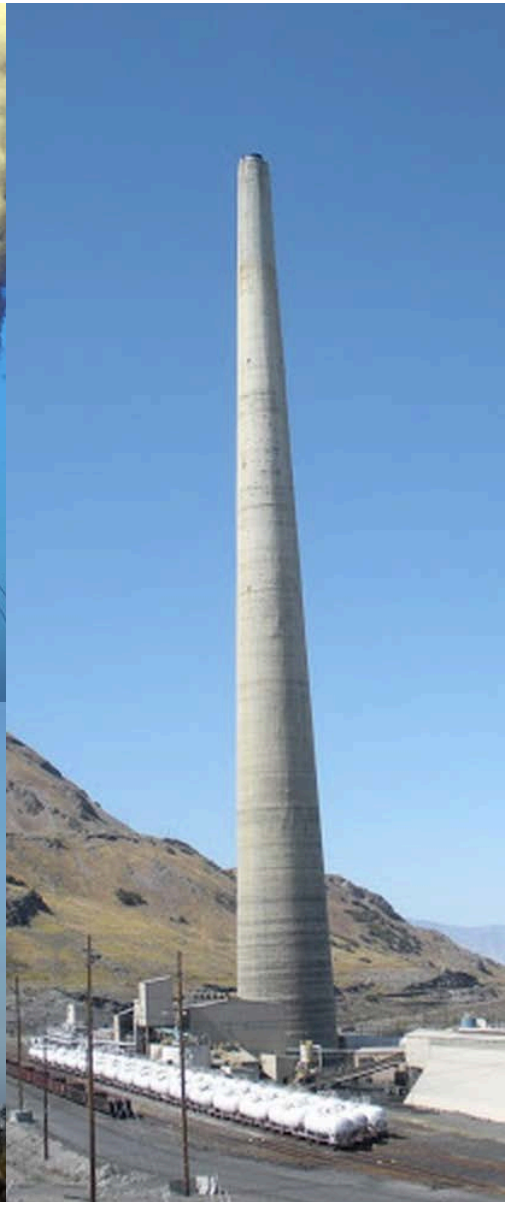
# ChEn 374
# Fluid Mechanics

Environmental Considerations

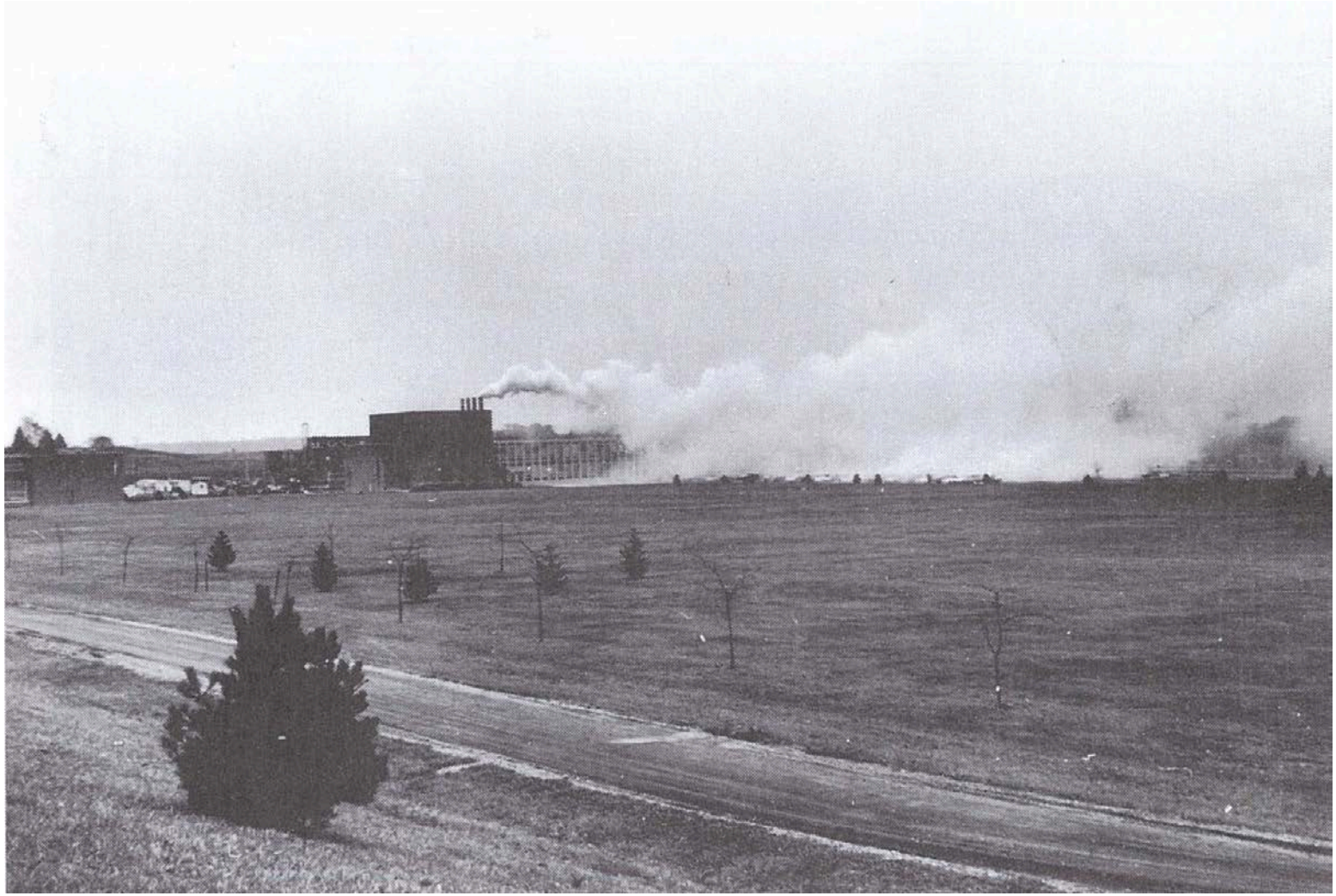
# Environmental Aspects of Fluid Mechanics

- We are stewards of the Earth and should take care of it.
- Several fluid mechanics related issues
  - Pollution
    - Liquid spills
    - Effluents
    - Leaching
    - Air pollution from emitted substances
  - Environment
    - Meteorology
    - Wind for energy
    - Ocean currents

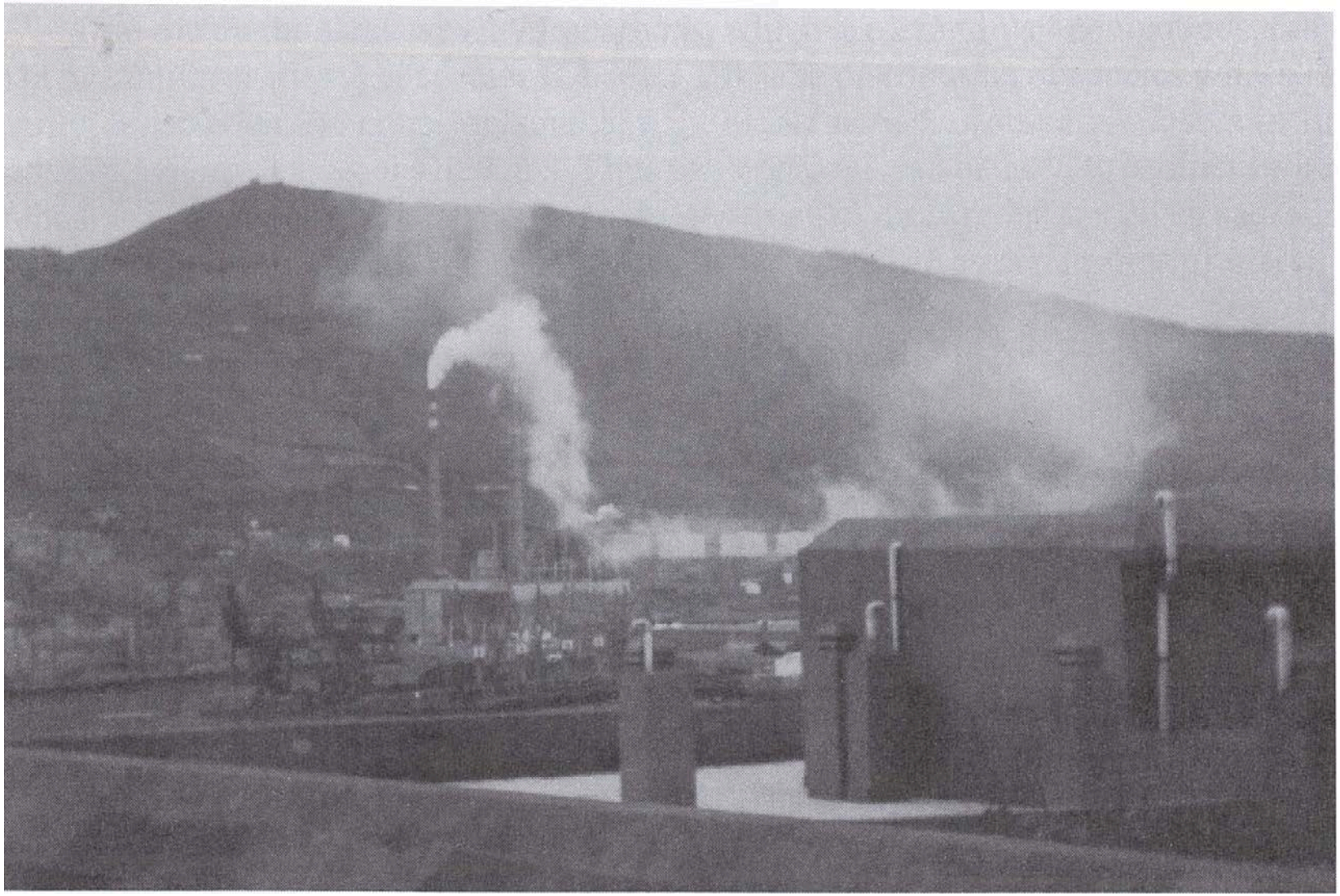
# Smokestacks



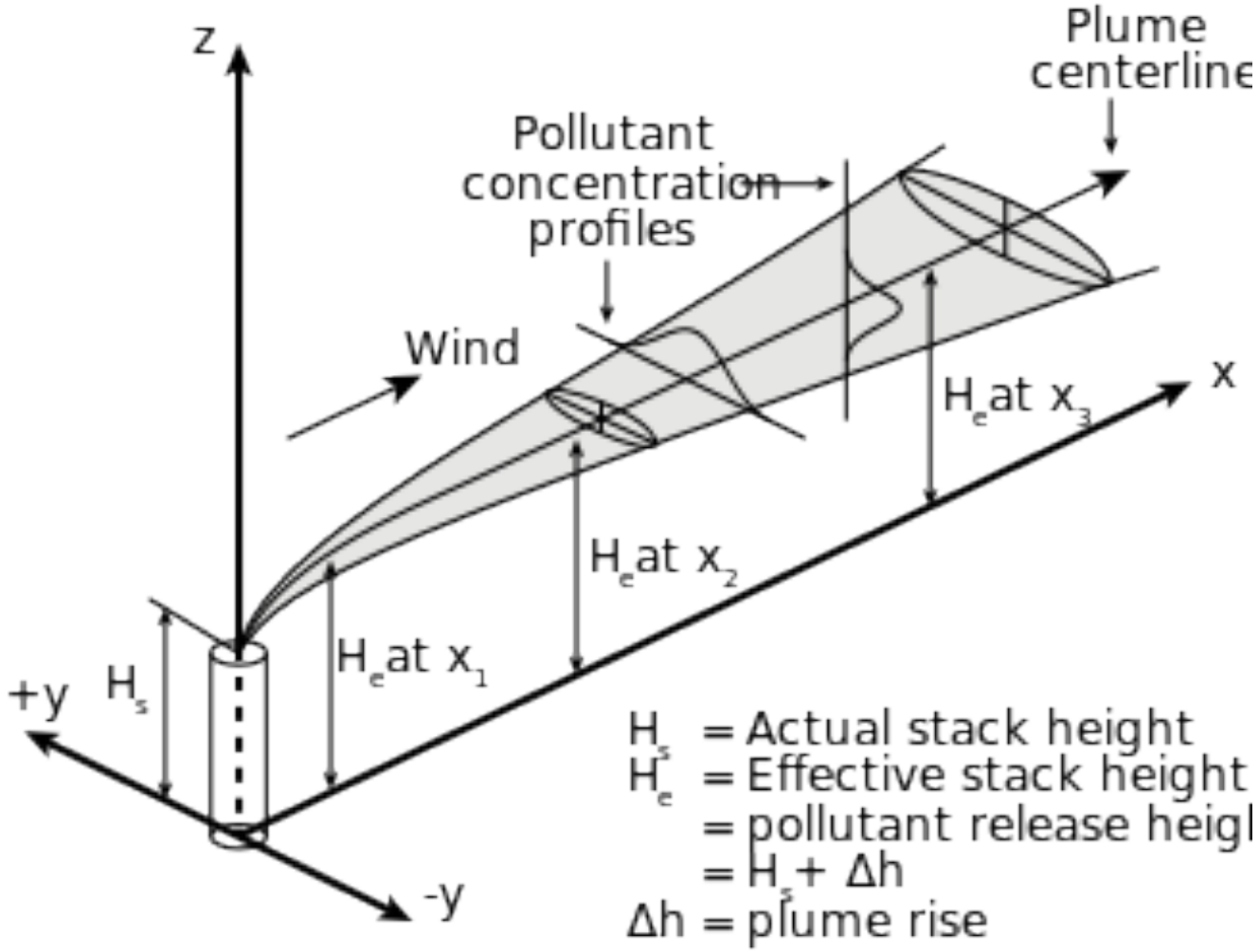
# Air pollutant dispersion



# Fumigation



# Plume Dispersion



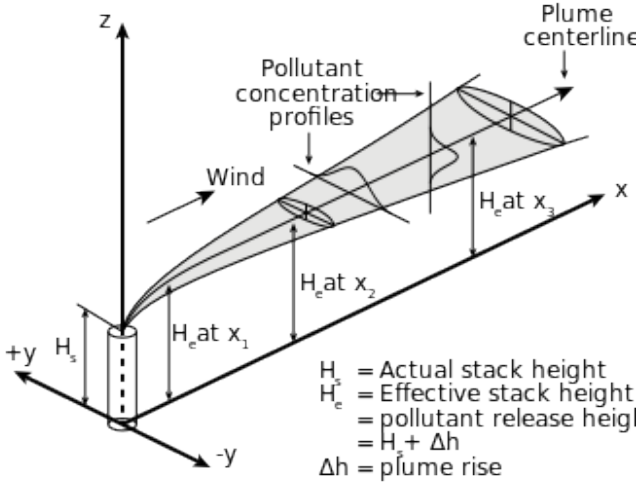
# Plume dispersion

- Model as a Gaussian plume
- Pollutants emitted are convected downstream and spread by turbulent eddies
- Diffusion equation

$$\frac{\partial c}{\partial t} = \mathcal{D}_x \frac{\partial^2 c}{\partial x^2} + \mathcal{D}_y \frac{\partial^2 c}{\partial y^2} + \mathcal{D}_z \frac{\partial^2 c}{\partial z^2}$$

  - Use turbulent diffusion coefficients
- Solution: ignoring streamwise dispersion:

$$c = \frac{Q}{2\pi u \sigma_y \sigma_x} \exp - \left( \frac{y^2}{2\sigma_y^2} + \frac{(z-H)^2}{2\sigma_z^2} \right)$$

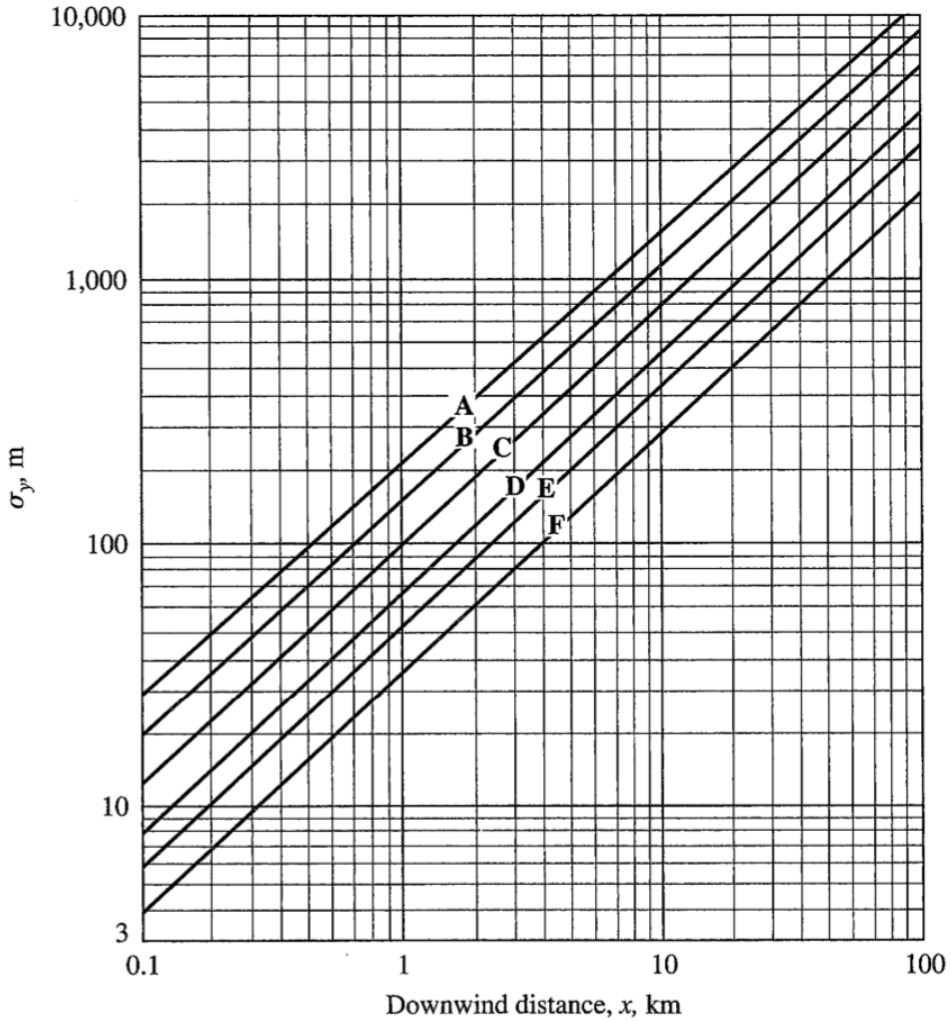


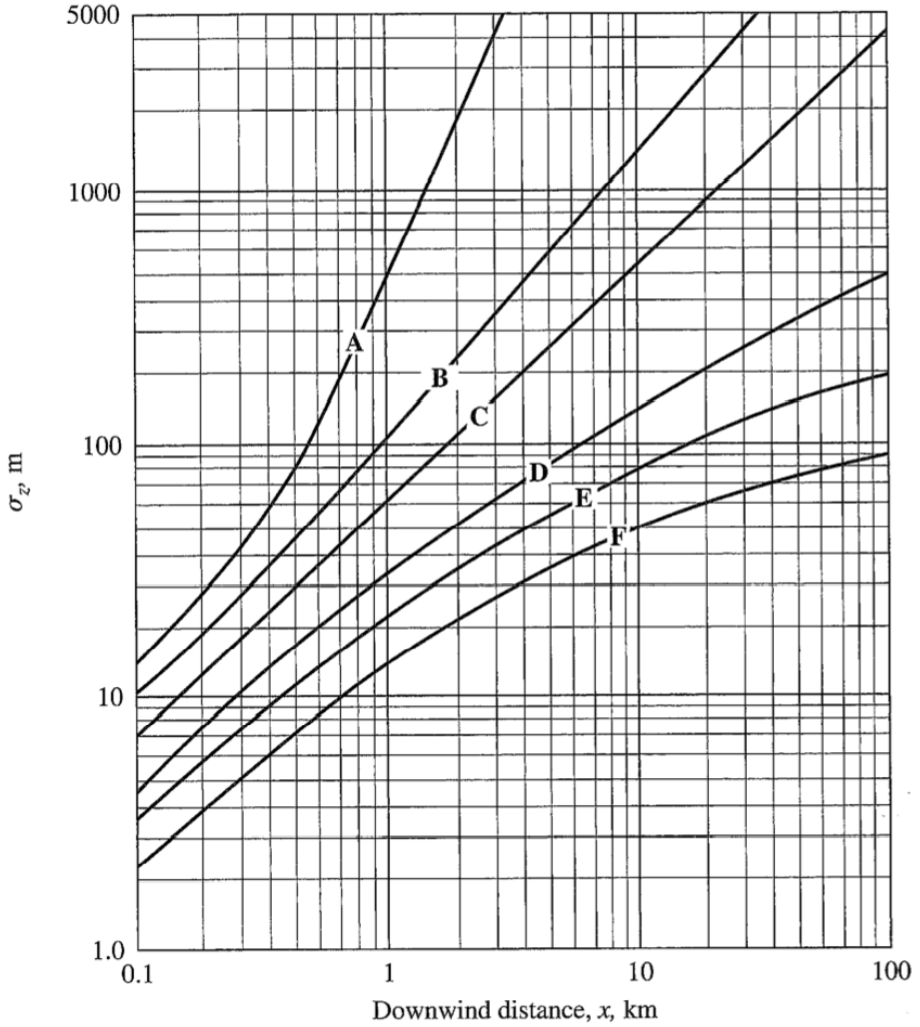

- H is stack height
- Q is emission rate (kg/s)
- u is wind speed
- c is concentration (kg/m$^3$)
- σ are dispersion factors

# Plume dispersion

$$c = \frac{Q}{2\pi u \sigma_y \sigma_x} \exp - \left( \frac{y^2}{2\sigma_y^2} + \frac{(z-H)^2}{2\sigma_z^2} \right)$$

*From de Nevers Fluid Mechanics for Chemical Engineers, 3rd ed.*



# Plume Dispersion

| Stability category | | $x \leq 1$ km | | | $x \geq 1$ km | | |
|---|---|---|---|---|---|---|---|
| | $a$ | $c$ | $d$ | $f$ | $c$ | $d$ | $f$ |
| A | 213 | 440.8 | 1.941 | 9.27 | 459.7 | 2.094 | −9.6 |
| B | 156 | 106.6 | 1.149 | 3.3 | 108.2 | 1.098 | 2.0 |
| C | 104 | 61 | 0.911 | 0 | 61 | 0.911 | 0 |
| D | 68 | 33.2 | 0.725 | −1.7 | 44.5 | 0.516 | −13.0 |
| E | 50.5 | 22.8 | 0.678 | −1.3 | 55.4 | 0.305 | −34.0 |
| F | 34 | 14.35 | 0.740 | −0.35 | 62.6 | 0.180 | −48.6 |

$$\sigma_y = ax^{0.894}$$

$$\sigma_z = cx^d + f,$$

**Key to stability categories**

| Surface wind speed (at 10 m), m / s | Day* | | | Night* | |
|---|---|---|---|---|---|
| | Incoming solar radiation | | | Thinly overcast or ≥4 / 8 low cloud | ≤3 / 8 Cloud |
| | Strong | Moderate | Slight | | |
| 0–2 | A | A–B | B | — | — |
| 2–3 | A–B | B | C | E | F |
| 3–5 | B | B–C | C | D | E |
| 5–6 | C | C–D | D | D | D |
| ≥6 | C | D | D | D | D |

*The neutral class, D, should be assumed for overcast conditions, day or night.

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