- **Carbon Dioxide (CO_2):** Primary combustion product; elevated levels cause increased respiration rate and reduced egress capability
- **Carbon Monoxide (CO):** Toxic gas produced under oxygen-limited conditions; interferes with oxygen transport in blood
- **Oxygen Depletion:** Combustion consumes oxygen, potentially reducing O_2 concentration below safe breathing levels
- **Smoke Particulates:** Reduce visibility and cause respiratory irritation

4.4 Fire Growth and Development

Fire growth typically follows characteristic phases:

- **Incipient Phase:** Initial ignition and slow growth
- **Growth Phase:** Accelerating fire development (often following t^2 growth for design fires)
- **Fully Developed:** Peak heat release rate
- **Decay Phase:** Fuel-limited reduction in HRR

For performance-based analysis, design fires are often characterized by t-squared growth curves:

$$Q(t) = \alpha t^2$$

Growth rates (α):

- Slow: $\alpha = 0.00293$ kW/s^2 (600s to 1055 kW)
- Medium: $\alpha = 0.01172$ kW/s^2 (300s to 1055 kW)
- Fast: $\alpha = 0.0469$ kW/s^2 (150s to 1055 kW)
- Ultra-fast: $\alpha = 0.1876$ kW/s^2 (75s to 1055 kW)