Control of Gases Underground

- Identify contaminant gas
- Locate its source and nature of occurrence
- Determine release rate
- Plan control method

Control Techniques in Preferred Order

Prevention

- Use proper blasting procedures
- Adjust and maintain IC engines
- Avoid open flames, welding fumes, etc.

Removal

- Drain in advance of mining
- Drain by bleeder system
- Local-exhaust ventilation
- Water infusion in advance of mining

Absorption

- Chemical reaction in IC engine conditioner
- Solution by air-water spray in blasting

Isolation

- Sealing off abandoned workings
- Restricted blasting or off-shift blasting
- Design isolated panels

Dilution

- Local dilution by auxiliary ventilation
- Dilution by main ventilation
- Local dilution by diffusers and water sprays
Control of Strata Gases

- Most common and most serious problem
- Emissions may develop:
  - oxygen deficiency
  - explosive atmosphere
- Layering dangerous with methane

Control of Strata Gases

Leach and Thompson => empirical indicator of layering, layering number $N_l$:

$$N_l = \frac{V_u}{Q_g} \left( \frac{b}{41} \right)^{1/3} \quad \text{(Eq. 3.7)}$$

- $V_u$ – air velocity in upper half of airway, fpm
- $Q_g$ – methane inflow, cfm
- $b$ – airway width, ft

Control of Layering

Tests show that layering can be controlled with the following values for $N_l$:

- 5 in a horizontal airway,
- = 5 in in an airway with uphill flow (8 if steep),
- 3 in an airway with downhill flow (5 if steep)

Control of Methane

- Draining in advance of mining (first done in Ruhr in 1943)
- Auxiliary ventilation at working face (line brattice or fans; blowing or exhausting, sometimes both)
- Diffusers and venturi water sprays sometimes used to assist

Control of Blasting Gases

- Proper selection of explosives
- Proper blasting techniques
- Proper stemming is essential
- Local-exhaust or auxiliary ventilation
- Air-water sprays in a drift (create a mist to absorb $SO_2$, $H_2S$, $NO_2$)
- Restricted or off-shift blasting
Control of IC Engine Exhaust
- New, electronically controlled engines
- Low-sulfur fuel (< 50 ppm)
- Catalytic converters (for CO, NO₂)
- Particulate filters (ceramic, fiber)
- Particulate filters (paper with water cooling system)
- Scrubbers (new dry scrubber system)
- Good maintenance

Control of Fires & Explosions
- Prevention is most effective
- Isolation needed after incident
- More details in Chapter 15 later

Control of Battery Gas
- Isolation of charging station
- Adequate ventilation on a separate split of air

Dilution Ventilation
- Most common and useful method
- Limiting factors:
  - Volume required sometimes impractical with high % of gas
  - Location of workers may be a problem
  - Contaminant must have low toxicity
  - Generation of contaminant must be reasonably uniform

Calculating Dilution Ventilation
- Function of the following factors:
  - The Maximum Allowable Concentration (MAC) for the contaminant
  - The rate of flow of the contaminant into the mine
  - The concentration of the contaminant in the incoming air
  - MAC may be lower than the TLV (by choice)
  - Permissible exposure limit (PEL) is mandated legally (say, MSHA)

Calculating Dilution Ventilation
Steady-State Dilution

\[ Q \geq \frac{Q_g}{(1 \times MAC) - B} \]  \hfill (Eq. 3.8)

MAC – as defined before, fraction
B – concentration of the gas in the incoming air, fraction
\(Q_g\) – inflow rate of the gas into the mine atmosphere, cfm
\(Q\) – inflow rate of the incoming air, cfm
Calculating Dilution Ventilation

Steady-State Dilution

When the concentration of the contaminant gas in the incoming air is very small compared to the MAC (~ 0), then:

\[ Q \geq \frac{Q_g}{(\text{MAC} - B)} - Q_g \]  
(Eq. 3.9)

Note: \( Q \) is calculated as the average velocity, \( V \), fpm, flowing in the airway with cross-sectional area, \( A \); \( Q = VA \)

Calculating Dilution Ventilation

Steady-State Dilution

When two or more contaminants are involved, the dilution requirement for each must be calculated.

If there are no synergistic effects, the minimum air required will be the maximum quantity calculated.

If a synergism is known or suspected, another calculation is needed.

Calculating Dilution Ventilation

Steady-State Dilution

When synergism is known or suspected, the following summation can be used to determine the condition of an atmosphere:

\[ \sum_{i=1}^{N} \frac{C_i}{\text{TLV}_i} \]

When the summation is < 1.0, the atmosphere is considered safe.

Calculating Dilution Ventilation

Time-Dependent Growth or Decay

The increase in the volume of gas in the workings in time interval \( \tau \) to \( (\tau + d\tau) \) is:

\[ Yd\tau = (QB)d\tau + Q_gd\tau - (Q + Q_g)x d\tau \]  
(Eq. 3.12)

Where:
- \( Y \) – volume of the workings, ft³
- \( Q \) – incoming air, cfm
- \( Q_g \) – gas inflow, cfm
- \( B \) – concentration of contaminant in incoming air, fraction

Rearranging and integrating gives:

\[ \tau = \frac{Y}{Q + Q_g} \ln \left( \frac{QB + Q_g - (Q + Q_g)x_\tau}{QB + Q_g - (Q + Q_g)x_\tau} \right) \]  
(Eq. 3.13)

Where:
- \( x_\tau \) – concentration in the working at time \( \tau \), fraction
- \( x_\tau \) – concentration at time \( \tau \), fraction

Calculating Dilution Ventilation

Steady-state dilution calculations: See examples 3.4 and 3.5, p. 61 of your book.

Time-dependent growth or decay dilution calculations: See examples 3.6 through 3.8, pp. 62-63.

Equations are valid for particulate contaminants as well – watch units.
Methane Drainage Techniques
- Vertical degas system
- Vertical gob degas system
- Horizontal borehole degas system
- Cross-measure borehole system
- Packed cavity system

We’ll cover each one briefly.

Sorption Isotherm Example
- Reservoir pressure needs to be reduced to initiate gas desorption of coal
- Generally this is done through dewatering

Northeast Blanco Unit #403

Relative Efficiencies of Techniques

Note: There have been no reported adverse effects from hydro-fracturing

Vertical Gob Gas Wells
- Height of gas-emission space above seam varies from 300 to 600 ft
- Depth below seam 80 to 300 ft
- Horizontally, dimensions can exceed those of a longwall panel by at least 200 ft
- Gas-emission space for a 500 x 5000-ft longwall panel would be ellipsoid, with a total volume of 0.72 to 1.72 Bcf
Vacuum pumps often added to improve flow or prevent reversal

- 2 or 3 holes generally sufficient for a 5000-ft longwall panel
- First hole within 500 ft; others ~ 2000-ft apart
- Production varies from a few kcf/d to over 1000 kcf/d
- ~ 50% methane purity; 30-50% of methane captured

### Horizontal Borehole Degas System

- Three subsystems:
  - Drill rig
  - Drillbit-guidance system
  - Borehole-surveying instruments
- Drill 3-5 in diameter holes, 2000-ft deep
- Mud circulation system
- Gas and cuttings separation systems

- Borehole-surveying instruments measure the pitch, roll and azimuth of the borehole assembly (some indicate thickness of coal to roof or floor)
- Success of degasification depends highly on permeability
- Gas in coal seam is saturated with water; typical 1000-ft Pittsburgh seam hole produces 1-3 gpm of water
- Permeability improves as water decreases, decreases with depth (ground stress)

### Table 3.12: Methane-Drainage Characteristics of U.S. Coal Seams

<table>
<thead>
<tr>
<th>Seam</th>
<th>Reservoir Pressure (psi/MPa)</th>
<th>Initial Productivity kcf/d/100 ftm³/day-m</th>
<th>Average Productivity kcf/d/100 ftm³/day-m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pittsburgh (WV)</td>
<td>275 (2.0)</td>
<td>25 (12.6)</td>
<td>15 (13.0)</td>
</tr>
<tr>
<td>Beckley (WV)</td>
<td>400 (2.8)</td>
<td>30 (15.3)</td>
<td>15 (13.0)</td>
</tr>
<tr>
<td>Pocahontas (VA)</td>
<td>650 (4.4)</td>
<td>40 (19.3)</td>
<td>10 (8.6)</td>
</tr>
<tr>
<td>Mary Lee (AL)</td>
<td>750 (5.2)</td>
<td>60 (30.6)</td>
<td>10 (8.6)</td>
</tr>
<tr>
<td>Lower Sunnyside (UT)</td>
<td>900 (6.0)</td>
<td>75 (37.5)</td>
<td>10 (8.6)</td>
</tr>
<tr>
<td>Upper Sunnyside (UT)</td>
<td>1000 (6.7)</td>
<td>80 (40.0)</td>
<td>10 (8.6)</td>
</tr>
</tbody>
</table>

Source: Thakur and Dahi (1982).

*Estimated values.*
Horizontal Borehole Degas System
Must be approved by MSHA.

Steel casing grouted in rib. Protect line along route.

Underground Pipeline Installation
- Needs means to remove water and solids
- Need check valve to prevent air intake from surface
- Need lightning and flame protection at surface
- Design some allowance for relative motion among components

Underground Pipeline Installation
- Spring-closed shut-off valve used on each horizontal borehole, held open by pressurized air or nitrogen (in a fragile tube) acting on a pneumatic actuator
- Tube breaks, flow stops
- High-molecular-weight polyethylene pipe used now

Cross-Measure Borehole System
- Popular in deep European mines
- Small diameter (2 to 2.5 in) boreholes are drilled upward, in gate roads, into overlying strata at an angle of 30-40°; inclined over gob
- 120-150 ft deep; spaced 60-90 ft apart
- Exhausters often used to maintain a suction of 2-4 in w.g.

Packed-Cavity System
- Ideal for mines where gobs are packed with solid material to prevent subsidence
- Gas is drawn from corridors left and supported in the gob as the face advances
- Pipes are inserted into the corridors from a mine airway and connected to methane-drainage mains
- Not recommended for coal seams prone to spontaneous combustion

TABLE 3.13
Summary of Methods for Recovering Methane from Underground Mines

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Methane Quality</th>
<th>Recovery Efficiency*</th>
<th>Current Use in U.S. Coal Mines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical wells</td>
<td>Drilled from surface to coal seam several years in advance of mining</td>
<td>Recover mine pars methane</td>
<td>50%</td>
<td>Used or abandoned in about 60 mines</td>
</tr>
<tr>
<td>gob wells</td>
<td>Drilled from surface to a few feet above coal seam just prior to mining</td>
<td>Recover methane that is sometimes uncontaminated with mine air</td>
<td>50%</td>
<td>Used by over 10 mines</td>
</tr>
<tr>
<td>Horizontal boreholes</td>
<td>Drilled from inside the mine to degas the coal</td>
<td>Recover mine pars methane</td>
<td>50%</td>
<td>Used by 10 mines</td>
</tr>
<tr>
<td>Cross-measure boreholes</td>
<td>Drilled from inside the mine to degas the surrounding rock strata</td>
<td>Recover methane that is sometimes uncontaminated with mine air</td>
<td>20%</td>
<td>Not widely used in the United States</td>
</tr>
</tbody>
</table>

Source: Knotig (PNG)

*Percentages of methane recovered that would otherwise be emitted.
Ventilation Regulations

See pages 474-475 for relevant ventilation regulations (Part 75.3XX) for underground coal mines.

See page 530 for ventilation regulations (Part 57, Subparts D & G) for underground metal-nonmetal mines.

That’s it this time.