CONTROL OF EXPLOSIVE ZONES AND OXYGEN PENETRATION IN LONGWALL GOBS THROUGH NITROGEN INJECTION

Jürgen Brune, Greg Bogin, Richard Gilmore, John Grubb, Jon Marts, Saqib Saki
Outline

- Project Design
  - Research Goals
  - Model Description and Assumptions
  - Model Validation
  - Hazardous Gas Mixtures

- Hazard Mitigation
  - Modeling Parameters
  - N₂ Injection and Explosive Mixtures
Research Goals

- Modeling of stratigraphy of longwall panel to establish gob resistance to gas flow
- Modeling of sealed longwall panel – sealed, progressive nitrogen inertization, and gob vent boreholes
- Validation of model utilizing available measurements
- Explosive zones identified in the ventilated areas and gob
- Partnerships with mines
FLAC 3D Modeling

- FLAC 3D used to model permeability and porosity in the gob.
- Potential flow of gases in overlying strata – used as methane source in FLUENT.

Assumed and Simplified Methane Source

Vertical cross section of bed displacement and gob formation
• FLAC 3D Model takes into account overburden material strengths to determine stress and strain distribution in gob.

• Converts stress and strain to porosity and then permeability distribution.
Model Validation

- Quantity and gas concentration readings at ventilation network evaluation points (intake, face, return)

- Sampling ports at seals ($O_2$, $N_2$, CO, $CO_2$, $CH_4$)

- Gob ventilation boreholes ($O_2$, $N_2$, CO, $CO_2$, $CH_4$, flow)

- Tracer gas studies (NIOSH)
Gob Gas Explosibility Color Coding

O2 Concentration

CH4 Concentration

Plan View
Hazard Mitigation Parameters

- Face Ventilation Rates
  - Hazardous Gas Mixture
  - Oxygen Ingress and Spon Com Risk Assessment

- Nitrogen Injection Studies
  - Hazardous Gas Mixture
  - Oxygen Ingress and Spon Com Risk Assessment

- Gob Caving Characteristics
Face Ventilation Quantity Impact

40,000 cfm

70,000 cfm
Higher Face Quantities Increase Explosive Mixture Volume in the Gob

**Graph:**
- **Y-axis:** Relative Hazardous Mixture Volume
- **X-axis:** Flow Rate at Face (cfm)
- **Legend:**
  - ▲ Volume of Hazardous Gas Mixtures
  - ✗ Methane at Tailgate Return

**Chart Details:**
- The volume of hazardous gas mixtures increases with the flow rate at the face.
- Methane at the tailgate return decreases as the flow rate increases.

**Data Points:**
- At a flow rate of 40,000 cfm, the volume of hazardous gas mixtures is 0.00, and methane is 1.2%.
- At a flow rate of 75,000 cfm, the volume of hazardous gas mixtures is 1.00, and methane is 0.2%.

**Analysis:**
- Higher face quantities lead to an increase in the volume of explosive mixtures in the gob, which poses a greater risk for explosions.
- Adjusting the flow rate at the face can help in reducing the hazardous gas mixtures and methane at the tailgate return, thereby decreasing the risk of explosions.

**Conclusion:**
- It is crucial to monitor and manage the flow rates at the face to ensure safe and controlled mining operations.
Oxygen Ingress – Face Quantity

- 70,000 cfm (33 m³/s)
- 400 cfm (0.19 m³/s)

Diagram showing oxygen ingress with color-coded percentages and distances in meters and feet.
Oxygen Ingress – Face Quantity

Face Ventilation Quantity of 40,000 cfm (19 m³/s)

40,000 cfm (19 m³/s)

400 cfm (0.19 m³/s)

Gob Vent Boreholes

North

HG

TG

N₂

N₂ 400 cfm (0.19 m³/s)

0m 152m 305m

30.5 m

100 ft
Nitrogen Injection Effect

- Base case used 70,000 cfm of face ventilation and 400 cfm of nitrogen injection HG and TG
- Evaluated impact of nitrogen injection
  - Quantity (200 – 1600 cfm)
  - Location (HG vs. TG)
- Purpose is to minimize volume of explosive methane–air mixture
Nitrogen Injection Rate Study

200 cfm HG & TG

800 cfm HG & TG
Nitrogen Injection Location Study

800 cfm N2 Injection  200 cfm

200 cfm N2 Injection  800 cfm
Oxygen Ingress – Nitrogen Injection Rates

Headgate ONLY Nitrogen injection – HG = 200 cfm (0.09 m³/s)

Nitrogen Injection Rates

- Headgate (HG) = 200 cfm (0.09 m³/s)
- Oxygen Ingress

Diagram showing nitrogen injection rates and oxygen ingress with depth and location markers.
Oxygen Ingress – Nitrogen Injection Rates

Headgate ONLY Nitrogen injection – HG = 800 cfm (0.38 m³/s)

- Nitrogen Injection Rates
- Oxygen Ingress
- Gob Vent Boreholes

North

0% 3.5% 7% 10% 14% 17.5% 21%

HG

70,000 cfm (33 m³/s)

N² 800 cfm (0.38 m³/s)

0 cfm (0 m³/s)

30.5 m

100 ft
Oxygen Ingress – Nitrogen Injection Rates

Headgate ONLY Nitrogen injection – HG = 1600 cfm (0.75 m³/s)

- Nitrogen injection rates:
  - 70,000 cfm (33 m³/s)
  - 1600 cfm (0.75 m³/s)
  - 0 cfm (0 m³/s)

- Oxygen ingress:
  - Headgate (HG)
  - Nitrogen injection (N₂)
  - Gob and vent boreholes

- Grid map:
  - North direction
  - Height markers: 0 m, 152 m, 305 m
  - Distance markers: 30.5 m, 100 ft
High Nitrogen injection rate – HG = 800 cfm (0.38 m³/s), TG = 800 cfm (0.38 m³/s)
High Nitrogen injection rate – HG = 1600 cfm (0.75 m$^3$/s), TG = 800 cfm (0.38 m$^3$/s)

Oxygen Ingress – Nitrogen Injection Rates
Conclusions

‣ Increasing the face ventilation quantity pushes oxygen further into the gob
  – This may increase the volume of explosive gases
  – This may increase spon com tendencies

‣ Injecting nitrogen to inertize is most effective from the headgate but some nitrogen should also be injected on the tailgate side
  – Nitrogen will reduce explosive gas volume
  – Nitrogen will reduce spon com hazard
Thank You

- Dr. Jürgen F. Brune
  Research Professor
  COLORADO SCHOOL of MINES

- 303–273–3704
- jbrune@mines.edu