8th International Conference on Geoscience and Earth Resources Engineering (ICGERE) 2026

Development of a Laboratory-Scale Physical Goaf Model for Methane Distribution in Longwall Mining

Utin Tasya Awliya [1], Ahmad Ihsan [2], N.P. Widodo[2]

[1] Master's Program of Mining Engineering, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Indonesia 40132,
[2] Mining Engineering Research Group, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Indonesia 40132.

Introduction

Methane (CH_4) is a major hazard in underground coal mining because it can accumulate under certain ventilation conditions. In longwall mining, methane distribution is influenced by ventilation airflow and the porous characteristics of the goaf, where direct measurements are difficult due to limited accessibility.

A laboratory-scale physical goaf model provides a controlled platform to investigate methane transport and distribution under defined ventilation conditions. **This study evaluates methane distribution under different exhaust fan power levels using controlled methane injection.**

Objective

To develop a laboratory-scale physical goaf model and investigate methane distribution under different exhaust fan power levels with a constant methane injection rate.

Materials and Methods

Laboratory-Scale Physical Goaf Model

A laboratory-scale physical goaf model was developed at an approximate scale of **1:30** to represent the main gate, working face, tail gate, and goaf of a longwall ventilation system. The goaf zone was filled entirely with gravel to represent the porous broken-rock mass. The model was equipped with ten methane concentration sensors (**M1–M10**), four air velocity sensors (**V1–V4**), a methane injection system, an exhaust fan, and a ventilation regulator.

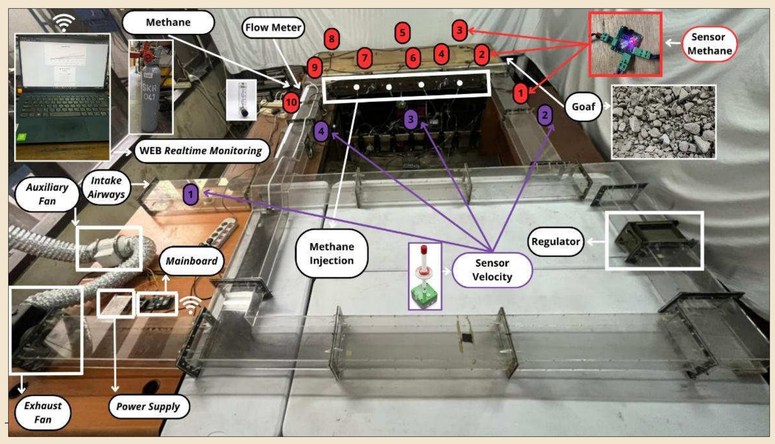

Figure 1. Laboratory-scale physical goaf model and experimental setup for methane distribution measurement.

Key specifications:

Goaf: **189 × 60 × 10.5 cm**

Working-face effective area: **0.0085 m²**

Gravel permeability: **7.48×10^{-13} m²**

Experimental Conditions

Four experimental scenarios were conducted using different exhaust fan power levels: **8.30 W (50.98%), 13.26 W (66.67%), 23.98 W (82.35%), and 38.06 W (100%)**. Methane was injected at a constant total flow rate of **300 cc/min through four injection points at the working face**. Before each test, the sensors were calibrated. Methane concentration and air velocity data were continuously recorded **for 8 minutes at 3-second intervals**. All sensors were connected to a mainboard serving as the central data acquisition unit, with measurement data displayed and monitored **in real time through a web-based interface**.

Table 1. Experimental scenarios and methane injection configurations.

Scenario	Injection Position	Fan Power	Methane Injection Flow Rate	Test Duration
1	4 Injection Points at the Working Face	8.30 W (50.98%)	300 cc/min	8 min
2	4 Injection Points at the Working Face	13.26 W (66.67%)	300 cc/min	8 min
3	4 Injection Points at the Working Face	23.98 W (82.35%)	300 cc/min	8 min
4	4 Injection Points at the Working Face	38.06 W (100%)	300 cc/min	8 min

Results and Discussion

Airflow Characteristics

Table 2. Average airflow rate (m^3/s) at Sensors V1–V4 under different exhaust fan power levels.

Scenario	Fan Power	Average Airflow Rate (m^3/s)			
		V 1	V 2	V 3	V 4
1	8,30 W (50,98%)	0.0189	0.0155	0.0147	0.0167
2	13,26 W (66,67%)	0.0211	0.0170	0.0162	0.0198
3	23,98 W (82,35%)	0.0244	0.0192	0.0183	0.0243
4	38,06 W (100%)	0.0267	0.0207	0.0194	0.0277

Increasing exhaust fan power increased the measured airflow rate at all four monitoring locations. The highest airflow rates were observed at the highest fan power of 38.06 W (100%).

Methane Concentration Distribution

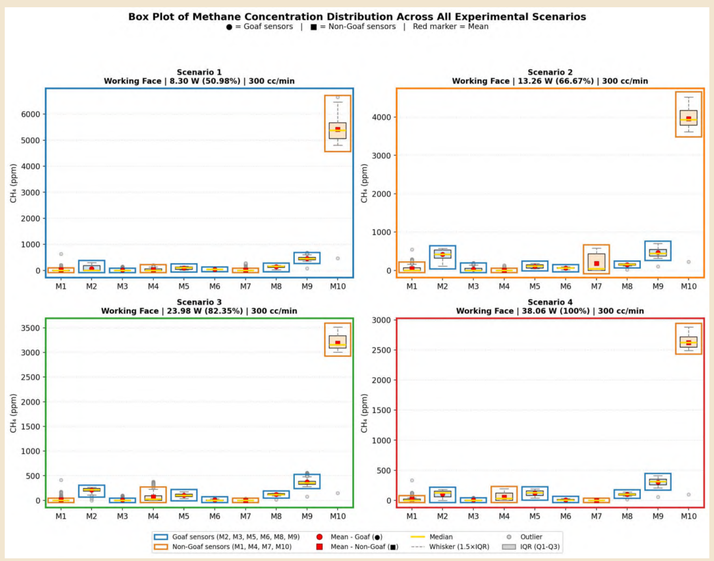

Figure 2. Box plot of methane concentration at Sensors M1–M10 under different exhaust fan power levels.

Methane concentration generally decreased with increasing exhaust fan power.

The highest mean methane concentration was observed at Sensor M10, decreasing from **5442.44 ± 463.69 ppm at 8.30 W to 2640.46 ± 100.68 ppm at 38.06 W.**

Goaf vs Non-Goaf Methane Concentration

Table 3. Comparison of mean methane concentrations between goaf and non-goaf monitoring locations.

Scenario	Goaf (ppm)	Non-Goaf (ppm)	Difference (ppm)
1	137.39	1376.53	1239.14
2	207.51	1052.48	844.97
3	138.82	823.20	684.38
4	106.74	678.75	572.01

The goaf did not exhibit a higher average methane concentration than the non-goaf monitoring locations under the tested conditions. Both goaf and non-goaf average concentrations decreased as exhaust fan power increased.

q/Q Analysis

Table 4. Methane-to-airflow ratio (q/Q) under different exhaust fan power levels.

Scenario	Fan Power	q CH_4 (cc/min)	QV_2 (m^3/min)	q/Q (ppm)
1	8.30 W (50.98%)	300	0.92723	323.54
2	13.26 W (66.67%)	300	1.01795	294.71
3	23.98 W (82.35%)	300	1.15139	260.55
4	38.06 W (100%)	300	1.24286	241.38

The methane-to-airflow ratio decreased from **323.54 to 241.38 ppm** as exhaust fan power increased. Because the total methane injection flow rate remained constant at 300 cc/min and was supplied through four injection points, the decrease in q/Q reflects the increasing ventilation airflow relative to the methane supply.

Conclusion

- Increasing exhaust fan power increased ventilation airflow and generally reduced methane concentration at the monitoring locations.
- The highest mean methane concentration was observed at sensor **M10**, **decreasing from 5442.44 ± 463.69 ppm at 8.30 W to 2640.46 ± 100.68 ppm at 38.06 W.**
- The goaf did not exhibit a higher average methane concentration than the non-goaf monitoring locations under the tested conditions.
- The methane-to-airflow ratio (q/Q) decreased **from 323.54 to 241.38 ppm** with increasing exhaust fan power.

Organized by

FTTMTB Fakultas Teknik Pertambangan dan Perminyakan Institut Teknologi Bandung

Sponsored by

LAPI ITB · DRI Direktorat Riset dan Inovasi · IJE Indonesian Journal of Energy · The Purnomo Yusgiantoro Center · PT. LAPI ITB Delivering Solutions and Innovations that Matter