

STUDYING LONGWALL VENTILATION WITH PHYSICAL MODELING

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Ventilation is the primary method for controlling gas and dust during longwall mining. It is not only important for controlling dust particulates, but also for maintaining permissible levels of methane. Historically, most methane-related mining disasters occurred or originated at or near the active production or development faces.

More recently, methane ignitions and explosions have occurred in mines using the longwall mining method. Therefore, designing and maintaining an efficient ventilation system for a longwall mine is of utmost importance for mine operators. However, the complex and dynamic nature of coal mine ventilation systems makes it difficult to conduct accurate and detailed field assessments.

To study longwall ventilation in a controlled environment, researchers from the National Institute for Occupational Safety and Health (NIOSH) built a unique physical model called the Longwall Instrumented Aerodynamic Model (LIAM) in a laboratory on the Pittsburgh Mining Research Division (PMRD) campus.

In addition to its research applications, LIAM also serves as a dynamic tool for demonstrating longwall ventilation to

mining industry stakeholders and the research community. This article discusses the development, applications and findings from LIAM.

LIAM is a 1:30th scale physical model geometrically designed to simulate a single longwall panel with a three-entry headgate and tailgate configuration, along with three back bleeder entries (See Figure 1). It has a footprint of 8.94 m (29 ft) by 4.88 m (16 ft). The longwall face length in LIAM is 7.31 m (24 ft), which represents a 220-m (720-ft) longwall face in full scale. In LIAM's current setup, the gob is not "squared up," meaning the width of the gob is less than the length of the gob. This configuration allows researchers to study the near-face airflow characteristics in greater detail.

The concept of physical modeling has been applied widely in industrial and environmental fluid flow studies, especially in the aeronautics, automotive and construction industries. In mining, however, the complex and dynamic nature of underground mines has made modeling studies more complicated and difficult when studying ventilation problems. Two particular challenges in developing

a physical model include geometric and aerodynamic scaling.

To ensure good geometric scaling, LIAM is built with very high attention to detail, right down to the shields, cribs, 3D printed shearer, regulators and curtains (See Figure 2). NIOSH used two types of materials to represent different porosities of the gob: broken pieces of Styrofoam (52% porous, shown in green) to simulate a more porous zone behind the shields, and gravel (33% porous, shown in grey) to simulate a more caved zone in the gob.

For aerodynamic scaling, a set of similarity relationships were developed to compare the important physical properties of the flow in the model with the flow in full scale. More detail on the scaling factors can be found in the peer-reviewed paper, which can be requested from the author, whose contact details are mentioned at the end of the article.

For quantification of ventilation parameters such as velocity, pressure and temperature, NIOSH equipped LIAM with 50 hotwire anemometers, differential pressure sensors and thermocouples. These sensors are connected to a data acquisition system for recording and visualizing the data in real time. In addition to the data from the sensors, all tests were also recorded using a ceiling-mounted wide-angle camera. The camera records airflow patterns that are visualized by using theatrical smoke in the LIAM.

The objectives of tests conducted in the LIAM were to measure the air velocities within the gob and to observe the gob-face interaction and movement of air in a longwall panel. Two comparable tests are discussed in this article — one for a bleeder and the other for a bleederless ventilation configuration.

The benefit of LIAM is that it offers a unique opportunity to easily modify and compare different ventilation systems. To simulate a bleeder system, a bleeder exhaust was used on the tailgate side to sim-

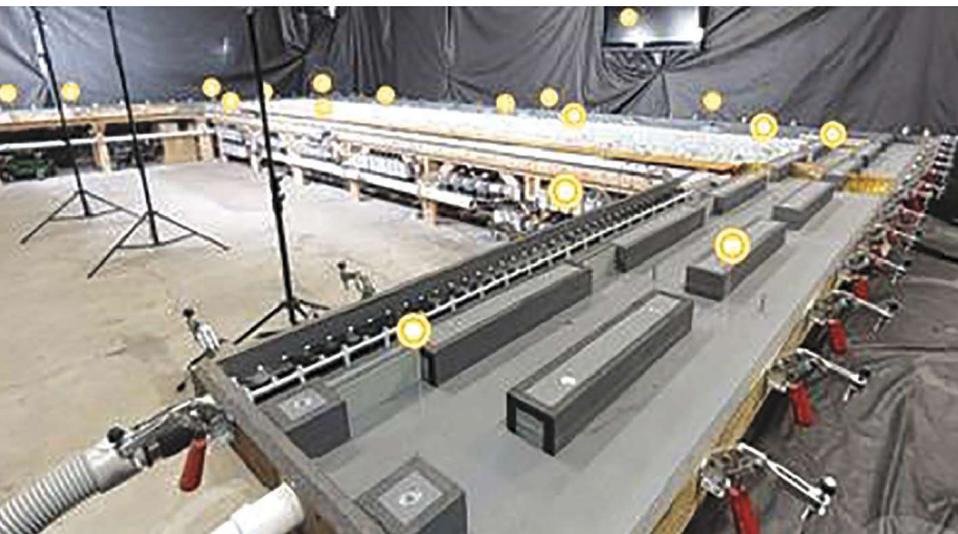


Figure 1—Screenshot representing a virtual tour of the LIAM, available at go.usa.gov/xnahw.

ulate a bleeder shaft. To simulate a bleederless system, stoppings were added around the gob between the gob and back entries, and the back bleeder exhaust was closed.

Bleeder vs. Bleederless Configurations

For both bleeder and bleederless configurations, NIOSH researchers observed that airflow streams were formed within the gob. Airflow was highly turbulent on the face, especially on the headgate side. Figure 3 shows the measured parameters on the face and airflow patterns in the gob.

In the bleeder configuration, shown in Figure 3 (top), there was a bleeder exhaust in the back. The main return is through the three-entry tailgate entries outby the face. Most of the air traveled along the length of the face from the headgate side to the tailgate side, with some air traveling right behind the shield line. On the face, part of the air enters the gob in front of the shearer (choosing the path of least resistance) and comes back on the face inby the shearer. For the flow in the gob, it was observed that air enters the shield legs on the headgate side of the face and travels from the front of the gob toward the back bleeder entries. The air velocities were higher in the high-permeable Styrofoam region compared to the low-permeable gravel region within the gob.

In the bleederless configuration, shown in Figure 3 (bottom), seals were added around the gob and the back bleeder exhaust was closed. To make sure the bleeder and bleederless configurations are comparable to each other, the intake airflow in the headgate entries was kept similar. Air traveled along the length of the face from the headgate to the tailgate. Overall, there was more air on the face compared to the bleeder system. Similar to the bleeder system, a portion of air traveled right behind the shield line. Both the data and smoke visualization showed that some air came back on the face near the mid-face region. In the gob, there are seals in the back. Therefore, air travels almost parallel to the face from the headgate to the tailgate side.

The results shared in this article represent a scenario where the roof caves right up to the shields. However, depending on the depth of cover, geology and roof control plan, there can be a void behind the shields when the longwall retreats. To further investigate the effect of varying void spaces, researchers tested three caving

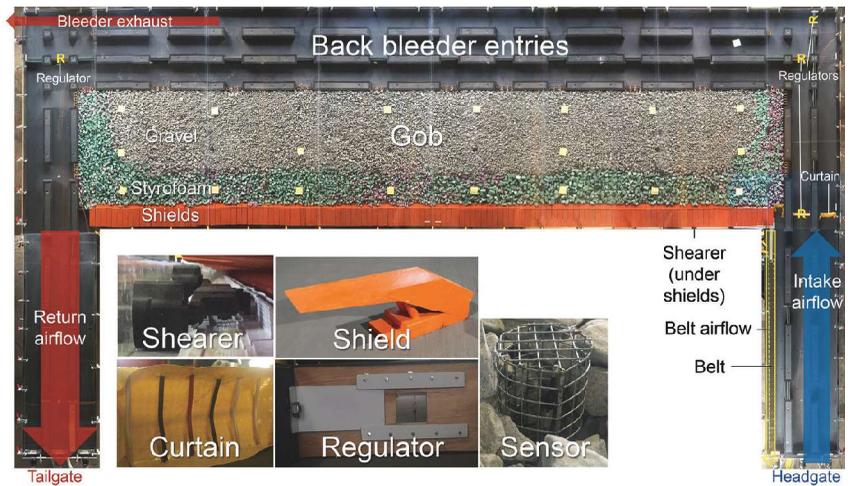


Figure 2—Top view of LIAM showing longwall features and ventilation control.

scenarios with different void spaces behind the shields. The preliminary findings suggest that varying void spaces behind the shields may have a significant impact on longwall ventilation.

Currently, NIOSH researchers are pursuing the development of site-specific simulations with LIAM. The goal is to use the data from field sites to simulate the ventilation of a longwall panel to help address issues related to airflow on the face and gas emissions from the gob.

NIOSH welcomes further collaboration with active longwall mines to help advance this research and to offer mines a better understanding of their site-specific ventilation. Researchers invite mining stakehold-

ers to visit the PMRD campus in Bruceton, Pennsylvania, for a LIAM demonstration.

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Disclaimer

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of NIOSH or the Centers for Disease Control and Prevention.

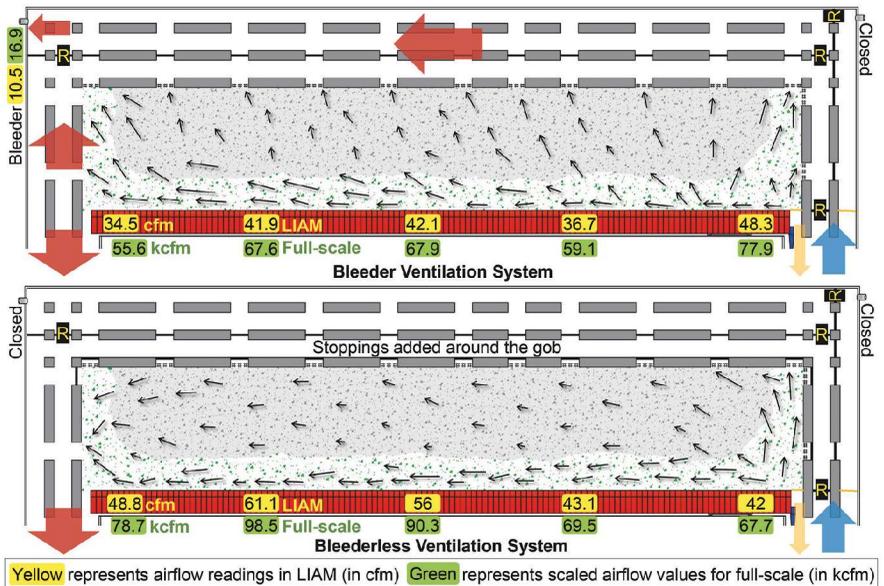


Figure 3—Schematic showing airflow streams in the gob with airflows (in cfm) on the face for a bleeder system (top) and a bleederless system (bottom).