Vent Lab. #5
Leakage Through Mine Stoppings
February 16, 2000

Introduction

It is wasteful enough to operate against a high mine resistance, but far more wasteful is to handle a large volume of air of which only a small percentage is actually reaching the working areas. In operating mines today, it is not uncommon to lose between 60 to 80 percent of the air between the fan and the last open cross-cut due to air leaking directly into return airways.

Fugitive air losses as a result of poorly maintained stoppings and overcasts will cause shortage of fresh air at working sections where workers need more fresh air and where the major job of diluting and carrying away gases and dusts is conducted. Furthermore, in order to compensate for these losses, additional air has to be handled at the fan. This will not only cause dust problems in airways due to higher velocities within the ventilation system, but will also increase power costs.

Unfortunately, all the control devices are subject to natural deterioration over time, mainly caused by strata convergence and damages (vehicles running into stoppings and overcasts blasting underground), both of which will result in increased air leakage. As a matter of fact, the majority of air leakage in underground coal mines are happening at or near the bottom of the slope where the pressure differential is the highest, the control devices are the oldest.

Air leakage problems have been around for a long time. For example, survey results from sixteen mines by Montgomery in 1936 showed that on the average only 19 percent of the air handled by the fan reached the last open cross-cuts, the rest of fresh air has leaked through stoppings, doors, and overcasts directly into return airways. It was also reported in 1955 that the first half of the ventilation circuit contributing about 75 percent of the total loss. Another ventilation survey of 22 coal mines in the Central Basin in U.S. conducted in 1952 concluded that the percentage of air losses due to leaky stoppings, trap doors, and overcasts varies between 8.9 and 70.7 percent. In the worst case, only 29.3 percent of the fan quantity reached the active workings.

Brattice Window Method

The purpose of this lab is to familiarize the students with the concept of leakage through a stopping and to determine the amount of such leakage through the use of the Brattice Window Method as described as follows.

The procedure is a simple one. A second stopping, called the temporary test stopping (TTS), is erected in the same entry as the leaking permanent stopping (see figure below). The TTS is made of an impervious fabric, such as plastic mine brattice, and is fastened to the roof, floor, and sides of the entry with spads or similar fasteners. The TTS also will leak, as air will pass through gaps around the edges. A rectangular opening, window 1, is cut into the TTS. The cross-sectional area of this window and the velocity of air passing through it are measured and the volume flow calculated from
\[ Q_1 = V_1 A_1, \]

where \( A \) = cross-sectional area of window 1, \( \text{ft}^2 \),
\( V \) = air velocity through window 1, \( \text{fpm} \),
and \( Q \) = air volume through window 1, \( \text{cfm} \).

Next, a second rectangular opening, window 2, is cut into the TTS. Its area \( A_2 \) and the velocity of air through it \( V_2 \) are measured and used to calculate the air volume \( Q_2 \) through it.

\[ Q_2' = V_2' A_2, \]

the decreased air velocity \( V_1' \) through window one is also measured and a new lower air volume \( Q_1' \) is calculated from

\[ Q_1' = V_1'A_1 \]
These values are used in the brat/ice-window-method equation to calculate the total volume of air \( Q_{TL} \) in cfm passing through the permanent stopping as follows:

\[
Q_{TL} = 0.82 \left[ Q_1' + Q_2' + \frac{Q_1' + Q_2'}{V_1/V_1'} - 1 \right]
\]

The 0.82 window correction factor is necessary because of the vena contracta created by the airflow through the windows.

The last term of the equation, \( \frac{Q_1' + Q_2' - Q_1}{V_1/V_1' - 1} \), is the “leakage” term which gives the total volume of air leaking around the TTS.

**Procedure**

1. Meet at the mine classroom to discuss the lab.
2. Close all temporary stoppings.
3. Install the Test Temporary Stopping (TTS) and prepare it for the Brattice Window Method experiment.
4. Turn the mine fan on low speed.
5. Take the necessary readings with the vane anemometer.
6. Turn the mine fan on high speed and repeat step #5.

**Instructions and Equipment**

The outline of the Brattice Window Method for determining the amount of leakage through a mine stopping, which is included in the lab handouts, will be followed as closely as possible in this experiment. Once the Test Temporary Stopping has been put in place and the test holes in the stopping have been cut and measured, the fan will be turned on low speed. Subsequently, after hole #2 is taped shut, the air velocity through hole #1 will be measured. Once this has been accomplished, hole #2 will be opened (both will now be open) and velocity readings through #2 will be recorded. Finally, the velocity of the air through hole #1 will be measured while hole #2 remains open.

After the aforementioned tests are completed, the fan will then be turned on high speed and the procedure repeated.

**Report**

The report will consist of calculations relating to the determination of air leakage through the test temporary stopping using the Brattice Window Method. Included in the discussion should be an analysis of the difference in leakage for the two fan speeds; an explanation of any deviation from expected results; the various problems and advantages of the Brattice Window Method; and finally, the reasons why leakage determination for a mine's stoppings is so important.
Additional Information

Air Leakage Underground

Unfortunately, a lack of empirical data and knowledge of the condition of individual stoppings makes an exact analysis of underground stopping leakage impossible. Generally, leakage is most severe through the old stoppings outby the circuit. These are also subjected to higher pressure differential than the newer inby stoppings. Therefore, the circuit air volume diminishes at a decreasing rate progressing from outby to inby the circuit.

The amount of leakage depends on the stopping material and pressure differential across the stopping, and can be expressed as

\[ Q = \dot{a} H^n, \text{ in cfm} \]

where \( \dot{a} \) is the leakage at 1” W.G. and \( n \) is a constant which varies with stopping materials. Values of \( \dot{a} \) range from 5 cfm for a coated stopping to 1,400 cfm for stoppings built of hollow-slag concrete blocks; and values of \( n \) range from 0.3 for a hollow-core, dry-wall blocks to 1.1 for a foam-coated concrete stopping.

Effect of Leaky Stoppings

The main effect of leaky stoppings is to increase the pressure which, in turn, the power requirements for ventilating a particular area with a specified amount of air. It can be shown theoretically and proved experimentally that the pressure increase that results from presence of leaky stoppings is approximately directly proportional to the total leakage air through the stoppings expressed as a percentage of the air volume delivered to the area to be ventilated.

Example 5-1 is a numerical example showing the effect of a leaky stopping. Assuming mine resistance are 1.00 x 10^{-10} lb.min^{-2}/ft^{4} in all sections, then the total fan pressure for a mine with perfect stoppings is,

\[
H_T = H_{AB} + H_{BC} + H_{CD} + H_{DE} + H_{EF} + H_{FG} + H_{GH} \\
= (0.5)^2 + (0.5)^2 + (0.5)^2 + (0.5)^2 + (0.5)^2 + (0.5)^2 + (0.5)^2 \\
= 1.75 \text{ in. W.G.}
\]

![Figure 5-1 Mine panel with perfect stopping line](image-url)
If 25,000 cfm of air leaks through Point I, an additional 25,000 cfm of air must enter the section to compensate for leakage (Figure 5-2).

![Figure 5-2 Mine panel with 25,000 cfm air leaking in the stopping line](image)

In this case,

\[
H_T = H_{AB} + H_{BC} + H_{CD} + H_{DE} + H_{EF} + H_{FG} + H_{GH} \\
= 1(0.75)^2 + 1(0.75)^2 + 1(0.5)^2 + 1(0.5)^2 + 1(0.5)^2 + 1(0.75)^2 + 1(0.75)^2 \\
= 3.00 \text{ in. W.G.}
\]

Difference = 3.00 in. W.G. – 1.75 in. W.G. = 1.25 in. W.G.

Because the fan operates 24 hours a day, 365 days a year. For a fan having an 80% efficiency, 1.25 in. W.G. loss caused by the leaky stoppings with leakage of 25,000 cfm is equipment to:

\[
\text{Brake Horsepower} = \frac{1.25 \times 25000}{6345 \times 0.8} = 6.156 \text{ hp}
\]

or roughly $2,414 per year, based on 6¢/kwh or 392.10/hp/year.