

COAL MINE VENTILATION EFFICIENCY: A COMPARISON OF US COAL MINE VENTILATION SYSTEMS

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Abstract

With ever rising energy costs, it is increasingly important for mines to operate with energy efficiency. As a large portion of a mine's energy consumption is often attributed to the operation of mine ventilation fans, maintaining an efficient ventilation system is a critical pro-active way for mining companies to reduce power costs. A common way to measure a mine's ventilation system efficiency is to calculate the volumetric efficiency, which is simply a calculation of the percentage of total mine air that is usefully employed for production. The purpose of this study is to document a nationwide comparison of the volumetric efficiency of U.S. underground coal mining operations. The results will aim to show just how efficient today's coal mine ventilation systems are and what factors may be causing their various efficiencies and inefficiencies.

Definition of Volumetric Efficiency

Mine ventilation volumetric efficiency is defined as the percentage of total mine air that is "usefully employed" for production. There can be room for discrepancies when considering what constitutes being "usefully employed" for air in a mine. McPherson defines air that is usefully employed as "the sum of airflows reaching the working faces and those used to ventilate equipment such as electrical gear, pumps or battery charging stations" (McPherson, 1993). Hartman considers usefully employed ventilation air to be the sum of air at the last open crosscut and belt air (Hartman, 1997).

For this study, mine air that is considered to be usefully employed consists of air that is used for ventilating working faces as well as air that is used for equipment that is critical to production (such as electrical gear, pumps, battery charging stations). After determining the total mine air quantity at the main fans and calculating the summation all air that is usefully

employed in a mine, the following equation can be used for calculating ventilation volumetric efficiency:

Equation 1. Volumetric Efficiency

$$\text{Volumetric Efficiency} = \frac{\text{Airflow Usefully Employed}}{\text{Total Airflow through Main Mine Fans}} \times 100 \text{ percent}$$

Values for ventilation volumetric efficiency fall in a wide range. McPherson states values may range from 75% down to 10% (McPherson, 1993). In this study, mines had efficiency values which fell within the range of 14.5% to 71.6% (shown below in Table 2). Mines with efficiency values in the lower part of this range indicate that large volumes of air are not being employed effectively, creating a potentially large and wasteful energy expense.

Factors Affecting Efficiency Loss

The two most significant factors that can cause lower volumetric efficiency include losses from leakage as well as the use of ventilation air to ventilate old workings, pillared/gob areas, or seals.

Leakage through stoppings and doors can be minimized through good construction and maintenance. However, leakage is certainly inevitable when large numbers of stoppings are present in a mine, no matter how well-constructed. Additionally, the potential for leakage naturally increases with fan pressure, so mines with high operating pressure are more prone to leakage. A reliable method for avoiding leakage in a mine is to minimize connections between entries having flows in opposite directions. This can be accomplished by dividing intake and return entries with a neutral entry or entries, or by geographically separating intake and return entries with barrier pillars (McPherson, 1993). This, of course, requires incorporation of ventilation design at the mine planning stage, but such planning can save future fan power costs.

Young mines often have a volumetric efficiency advantage over mines that have been in operation for a longer period of time. In older mines, not only do stoppings deteriorate over time, creating leakage, but more mined-out areas inherently exist. When dealing with previously pillared or longwalled areas, legally speaking, a mine must either ventilate these areas with bleeder entries or seal them. Since air dedicated to ventilating old workings and seals does not count as usefully employed air; mines with large amount of bleeder entries or seals tend to have a lower ventilation efficiency value.

Data Analysis

Ventilation data was gathered from 23 mines from all regions of the country: Central and Northern Appalachia, Western Kentucky, Illinois Basin, Western Mountains and the San Juan Basin. Of the 23 mines, 11 are longwall operations and 12 are Room and Pillar operations. Not only are the studied mines diverse in location, but also in size, as the total mine airflow values range from 139,700 cfm for a small room and pillar mine to 1,150,000 cfm for a large longwall operation. These data are tabulated below in Table 1.

Table 1. Total Mine Intake Air Statistical Data by Mine Type

Mine Type	Total Number of Mines	Total Mine Intake Air (kcfm)		
		Min.	Mean	Max.
Longwall	11	270.0	686.6	1150.0
Room and Pillar	12	139.7	332.1	525.0
Total/Combined	23	139.7	551.2	1150.0

The following information was gathered from all mines; including the necessary data for calculating ventilation efficiency:

- mine type
- main mine fan airflows
- airflows at last open crosscuts or headgates
- airflows at battery charging stations, electrical equipment and pump stations, etc.

Noticeable differences were discovered between ventilation efficiency values for longwall mines versus room and pillar mines. The data analysis shows that, on average, room and pillar mining operations tend to have higher ventilation efficiencies. The average room and pillar operation usefully employs 44.4% of its total air, as opposed to 33.9% for longwall operations. These results are shown below in Table 2.

Table 2. Volumetric Efficiency Statistical Data by Mine Type

Mine Type	Total Number of Mines	Volumetric Efficiency (%)		
		Min.	Mean	Max.
Longwall	11	14.5%	33.9%	65.0%
Room and Pillar	12	23.1%	44.4%	71.6%
Total/Combined	23	14.5%	38.3%	71.6%

The following graph (Figure 1) represents the distribution of mines in the various ranges of volumetric efficiency. For example, the chart shows that there are a large number (8) of mining operations between the range of 20% and 30%.

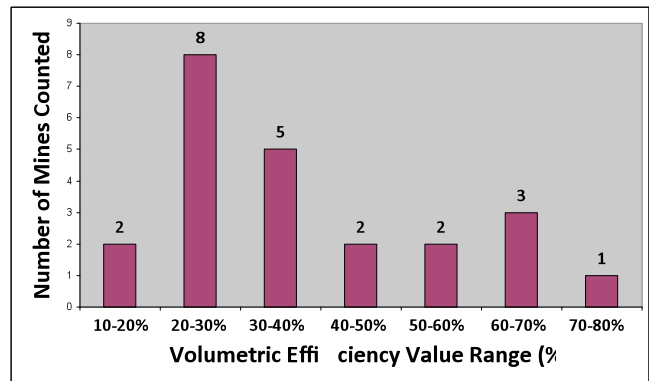


Figure 1. Statistical Distribution of Number of Mines in Each Volumetric Efficiency Value Range

Based on average values for all mines, both longwall and room and pillar, the following chart (Figure 2) was created to illustrate the distribution of ventilation air in mines. As one would expect, the majority of usefully employed air is used to ventilate the working areas, while ventilating supporting equipment is notably less.

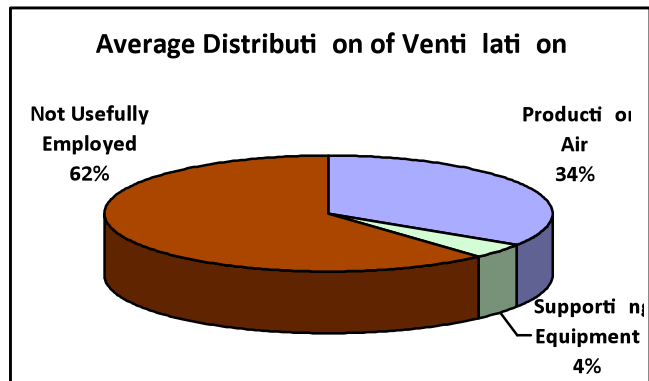


Figure 2. Average Distribution of Mine Air

The following is a list of supporting mine data that was gathered:

- number of longwall and continuous miner production units
- average seam height
- main mine fan operating pressures
- airflows sweeping mine seals (intake to seal to return configuration)
- approximate number of seals in mine

All additional supporting data was gathered with the intention of investigating any possible correlations between volumetric efficiency and other mine performance parameters. The most obvious correlation occurs when plotting volumetric efficiency versus total fan pressure. One would expect that higher fan pressure would create higher volumes of leakage throughout the mine, and reducing volumetric efficiency. The following graph in Figure 3 illustrates this correlation with a power function trend-line.

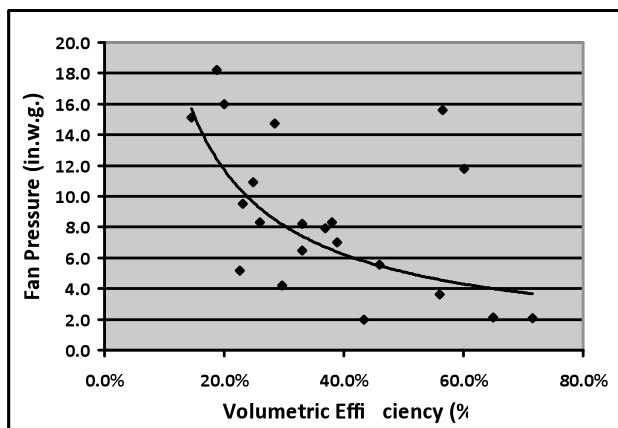


Figure 3. Volumetric Efficiency vs. Fan Pressure

However, one must keep in mind the complexity of the factors behind a low ventilation efficiency value. As just stated, it is well known that higher fan pressure facilitates more leakage and lower ventilation efficiency. But keep in mind the assumption could be made that the mines having the highest fan pressures are most likely the largest mines. It could also be assumed that the largest mines have the largest number of stoppings (creating potential leakage) as well as a potentially high amount of previously mined-out areas, which are required either to be ventilated or sealed. Therefore, it is highly possible that these other factors may have a role in the relationship between fan pressure and volumetric efficiency.

No obvious correlations were discovered between ventilation volumetric efficiency and seam height, number of production units, mine production or number of mine seals. This is not particularly surprising as the

main factors that affect ventilation efficiency, leakage and air ventilating old workings, are not highly affected by the previously stated parameters.

Conclusions

This study illustrates that the average coal mine ventilation system in the United States is operating with reasonable volumetric efficiency, at approximately 38%, but has room for improvement as one mine shows that it is possible to reach over 70% efficiency. Room and pillar mines are operating with slightly higher efficiencies of approximately 44% while longwall mines are operating with an average efficiency of 34%. The lower efficiency value for longwall operations, in combination with the correlation of high main mine fan pressure to lower efficiency, illustrates that larger mines have the greatest challenges to increase their ventilation efficiency.

While safety is the primary concern behind maintaining an efficient ventilation system, it is also important to keep in mind that a good ventilation system and proper ventilation planning is essential to efficient production. Additionally, increasing the efficiency of a ventilation system can often significantly reduce power cost. It is therefore beneficial to a mining operation to keep in mind the factors and practices which can foster an efficient ventilation system.

The factors behind what helps and hinders the efficiency of a ventilation system are numerous and complicated. Upon examination of the data acquired for this study, it was apparent that it is not possible to single out any single factor that solely affects ventilation efficiency. The most common factors include: leakage caused by unmaintained or deteriorating stoppings; increased leakage due to high fan pressures; amount/area of mined-out/gob areas requiring ventilation; and the number of seals requiring ventilation. Ventilation system inefficiencies at every mine are influenced by some combination of the above factors. Therefore, if a mining operation has intentions of increasing volumetric efficiency, it is critical for its ventilation planners to be diligent in recognizing, anticipating and avoiding these complex factors which cause inefficiency in mine ventilation systems.

References

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