

Measured Values of Coal Mine Stopping Resistances

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Objective

- A quantitative analysis of the resistance for stoppings in underground coal mines for various construction materials and measurement methodologies.
- Analysis developed realistic stopping resistance values to be used in development of ventilation models.

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Background

- Subsurface coal mines have inherently expanding working areas driving further from mine portals and shafts.
- Adequate engineering and modeling of the ventilation systems needs to be represented.

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Methodology of Measurements

- Two Methods
 - Single Stopping Resistance Technique
 - Developed by the former United State Bureau of Mines (USBM)
 - Average Stopping Resistance Technique
 - Technique employed by Mine Ventilation Services, Inc. (MVS)

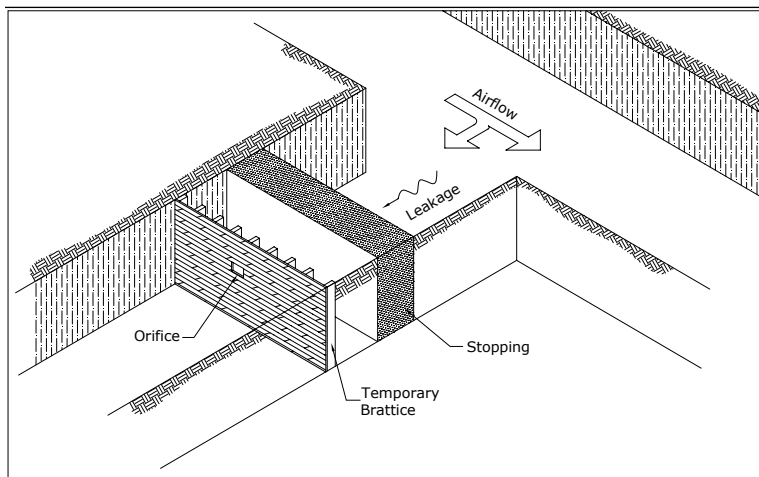
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Single Stopping Resistance Technique (USBM)

- Defines the resistance of an individual stopping.
- Airflow leakage is measured through the stopping.
- The measured leakage is used to define a resistance for a single stopping.
- This measurement technique requires the construction of a temporary brattice and is labor intensive.
 - A small orifice area in the constructed brattice is used to consolidate the airflow.

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Single Stopping Resistance Technique (USBM) cont.



USBM Method of Measuring a Single Stopping Resistance.

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Average Stopping Resistance Technique

- This technique utilizes measurements taken throughout the mine incorporating multiple stoppings.
- It can be used to determine the resistance for stoppings constructed of different materials in various stages deterioration.

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Average Stopping Resistance Technique cont.

Two equations are used to calculate average stopping resistance:

Equation 1:
$$R = \frac{P}{Q^2}$$

Where: R = resistance to leakage (Ns^2/m^8)
 P = average pressure differential (Pa)
 Q = leakage (m^3/s)

○ Equation 1: The Square Law is used to calculate the resistance measured between two points.

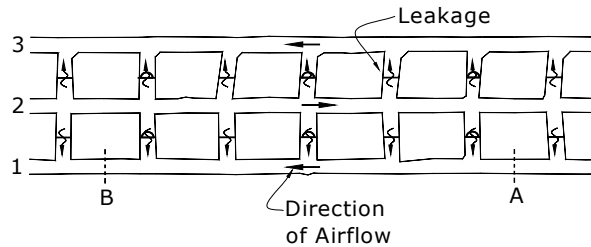
Equation 2:
$$R_s = R \times n^2$$

Where: R_s = average resistance of a single stopping (Ns^2/m^8)
 R = resistance of leakage (Ns^2/m^8)
 n = number of separate parallel leakage paths

○ Equation 2: The resistance to leakage between two points is then equated to an average resistance per stopping for the number of parallel leakage paths between the two entries.

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Average Stopping Resistance Technique cont.



Example of quantifying Average Stopping Resistance technique.

- Pressure differentials between entry 1 and entry 2 are measured.
- Airflow quantities are measured at points A and B.
- 5 stoppings are being evaluated between points A and B.

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Measured Values

o Pressure differentials can be measured across stoppings or man doors.

- Man doors are required to be built into stoppings for egress and access.
- Additional leakage through man doors lower the resistance of stoppings.



Measurement of a differential pressure.

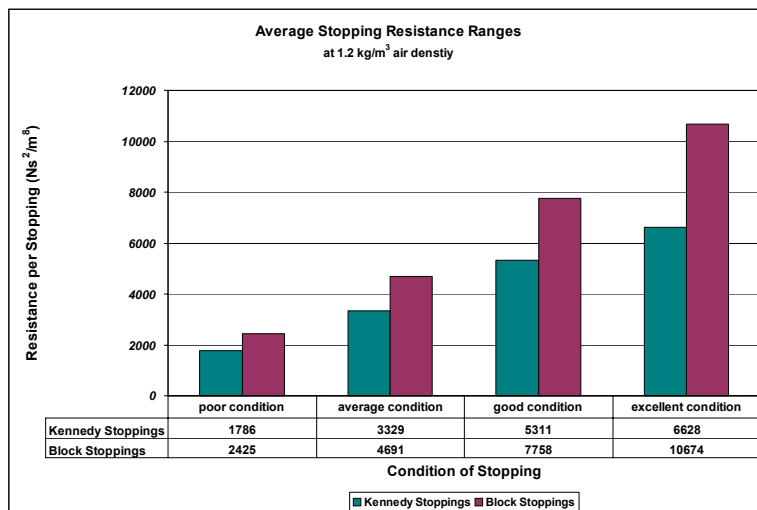
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Measured Values cont.

- The Average Stopping Resistance technique has been used by MVS since starting to perform full ventilation surveys.
 - Analyzed data compiled from 20 different coal mines
 - Data collected between 1999-2007
- Two Types of Stoppings
 - Concrete Block
 - Kennedy
- All Data has been standardized to an air density of 1.2 kg/m^3

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Measured Values cont.



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Stopping Condition Characteristics

Stopping Condition	Description
Excellent	Plaster is free of cracks or flaking. Edges between the stopping and the roof and walls are sealed. Man doors closes tightly.
Good	Plaster is cracking and chipping.
Average	Plaster is slaking. Visible cracks and signs of wear to the stopping.
Poor	Significant cracks and holes in the stopping for leakage. Stopping material and man doors show visible signs of deterioration.

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Concrete Block Stopping



Concrete Block Stopping in Excellent Condition.

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Concrete Block Stopping



Concrete Block Stopping in Good Condition.

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Concrete Block Stopping



Concrete Block Stopping in Average Condition.

- Cracks are visible in the stopping plaster.
- Sealants have been added to reduce leakage.

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Concrete Block Stopping



Concrete Block Stopping in Average Condition.

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Concrete Block Stopping



Concrete Block Stopping in Average to Poor Condition.

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Concrete Block Stopping



Concrete Block Stopping in Poor Condition.

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Kennedy Stopping



Kennedy Stopping in Excellent Condition.

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Kennedy Stopping



Kennedy Stopping in Good Condition.

21

Kennedy Stopping



Kennedy Stopping in Average Condition.

22

Kennedy Stopping



Kennedy Stopping in Average Condition.

23

Kennedy Stopping



Kennedy Stopping in Poor Condition.

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Application of Average Stopping Resistances

- Resistances are used to model leakage paths for current and future mine ventilation designs.
- Selecting a stopping resistance is based on two conditions:
 - Stopping construction material
 - Expected condition of stopping
- Use the parallel rule to reduce the number of modeled leakage paths.
 - Parallel rule extrapolates the resistance for a single modeled stopping to represent multiple stoppings.

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Application of Average Stopping Resistances cont.

Equation 3:

$$R_{avg} = \frac{R_s}{n^2}$$

Where: R_{avg} = resistance of modeled stopping (Ns^2/m^8)
 R_s = average resistance of a single stopping (Ns^2/m^8)
 n = number of separate parallel leakage paths

- Equation 3: Parallel rule is used to extrapolate an average stopping resistance for a single modeled stopping to represent multiple stoppings.

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Conclusion

- Two Methods of Measuring Stopping Resistance
 - Single Stopping Resistance Technique
 - USBM method used to calculate resistance of a single stopping
 - Average Stopping Resistance Technique
 - MVS method used to determine an average resistance for multiple stoppings
- Two Types of Stoppings Evaluated
 - Concrete Block
 - Kennedy
- Provides quantitative stopping resistances to be used in current and future ventilation models in the development of airflow leakage paths.

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Questions

- Any questions?

- Thank you!!!

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Sources

- McPherson, M.J., 1993, "Subsurface Ventilation and Environmental Engineering," Chapman and Hall Publishing.
- MVS Archive Records, 1995-2007
- Weiss, E.S. et al. "Strength Characteristics and Air-Leakage Determinations for Alternative Mine Seal Designs" USBM R.I. 9477, 1993, 21 pp. Table 1. Example of a sample table with table caption.