Technical Paper: Dust Control in Continuous Mine Section

Scott Klima

MINERALS COUNCIL
SOUTH AFRICA

Biography

Scott Klima is a Mining Engineer with NIOSH's Pittsburgh Mining Research Division in their Health Hazards Prevention Branch. He graduated from The Pennsylvania State University with a degree in Mining Engineering and has been with NIOSH for over nine years working on the Respirable Hazards Team. His research at NIOSH focuses on reducing exposures to harmful respirable dust through use of engineering and administrative controls to improve the health and safety of underground mining personnel.

Controlling Respirable Dust on Continuous Mining Sections

Scott Klima

Mining Engineer

Centers for Disease Control and Prevention (CDC)

National Institute for Occupational Safety and Health (NIOSH)

Pittsburgh Mining Research Division (PMRD)

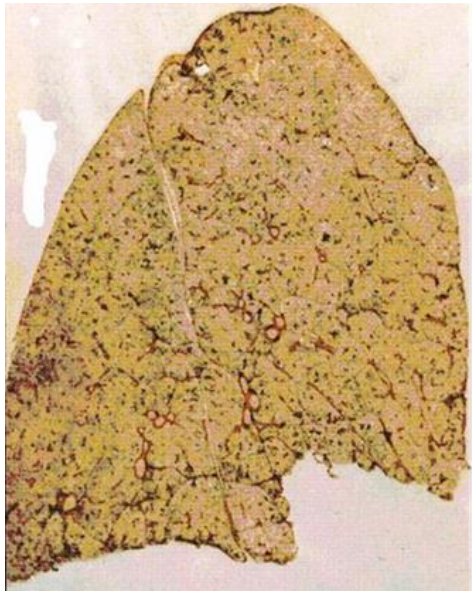
Introduction – Dust Control Research

- Respirable dust, defined as minus 10 µm in size, can be inhaled into the lungs and has long been known to be a serious health threat to workers in many industries
- In coal mining, overexposure to respirable coal mine dust can lead to coal workers' pneumoconiosis (CWP), commonly known as black lung
- CWP is a lung disease that can be disabling and fatal in its most severe form, progressive massive fibrosis (PMF)
- Additionally, miners can be exposed to high levels of respirable silica dust, which can cause silicosis, another disabling and/or fatal lung disease
- The goal, therefore, is to limit worker exposure to respirable dust to prevent development of these lung diseases

Health Effects of Overexposure to Respirable Coal and Silica Dust

Coal Workers' Pneumoconiosis (CWP) – Black Lung Disease

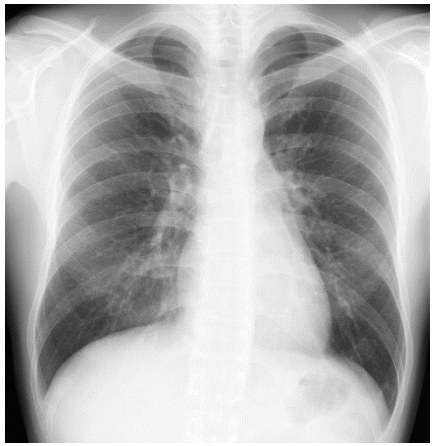
- Chronic lung disease that results from the inhalation and deposition of coal mine dust in the lung
- With continued exposure to coal mine dust, the lungs undergo structural changes that are eventually seen on a chest x-ray
- In the early stage of disease (simple CWP), there may be no symptoms.
- If a person has inhaled too much coal mine dust, simple CWP can progress to progressive massive fibrosis (PMF)
- PMF is the formation of large tough, fibrous scar tissue deposits in the areas of the lung
- This ultimately interferes with the lung's normal exchange of oxygen and carbon dioxide and breathing becomes very difficult.

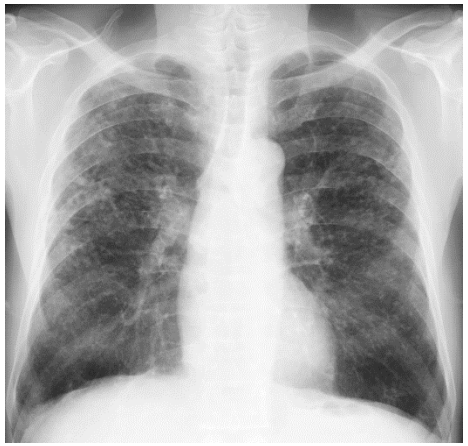


Normal Lung

Simple CWP

PMF



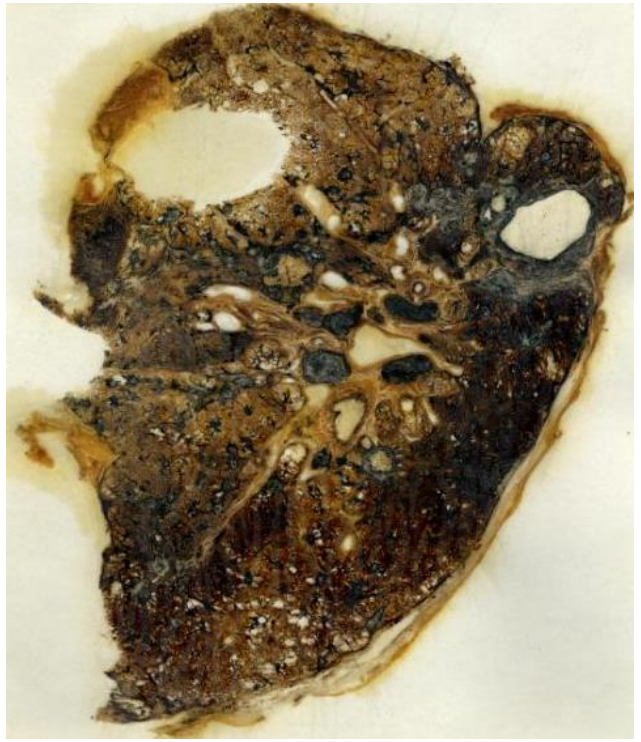


Health Effects of Overexposure to Respirable Coal and Silica Dust

Silicosis

- Underground mine workers are potentially exposed to quartz dust when rock within or adjacent to the coal seams is cut, crushed, and transported
- Exposures to respirable crystalline silica are associated with the development of silicosis, lung cancer, pulmonary tuberculosis, and airway diseases
- A worker may develop one of three types of silicosis:
  - Chronic Silicosis: usually occurs after 10 or more years of exposure at relatively low concentrations.
  - Accelerated Silicosis: develops 5–10 years after the first exposure
  - Acute Silicosis: develops after exposure to high concentrations of respirable crystalline silica and results in symptoms within a period of a few weeks to five years after initial exposure

Silicosis



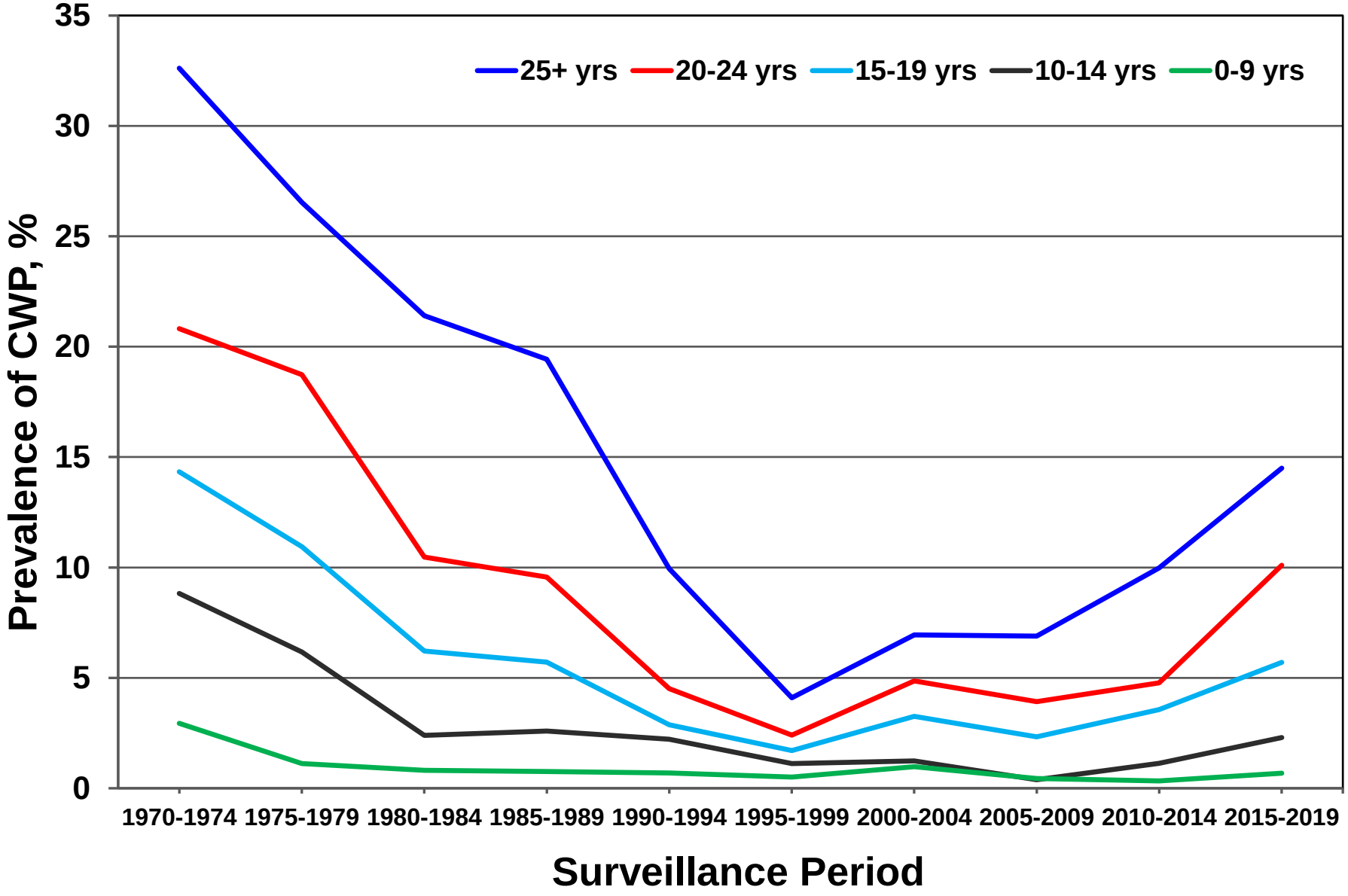
PMF

Health Effects of Overexposure to Respirable Coal and Silica Dust

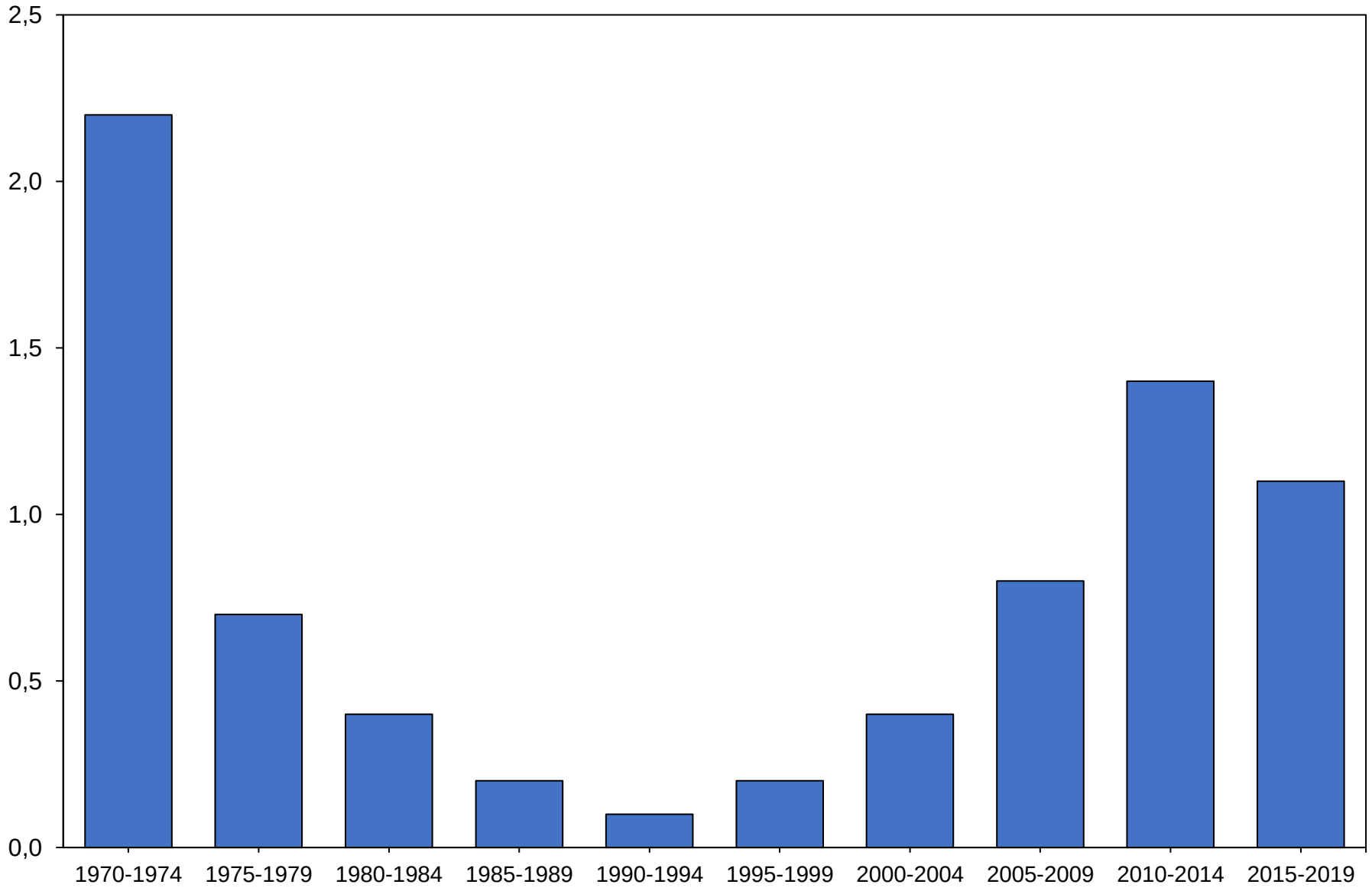
Federal Coal Mine Health and Safety Act of 1969

- The Mine Safety and Health Administration (MSHA) enforced regulations designed to limit mine workers' exposure to respirable coal mine dust to a maximum of 2 mg/m^3 of air
- Continuous miner (CM) operators and roof bolter (RB) operators are occupations with greater potential for exposure to excessive levels of respirable coal mine dust
- As part of this program, underground coal miners are required to have an initial chest x-ray when they begin employment.
- Underground coal miners can voluntarily receive periodic chest x-rays to detect the presence of CWP at its earliest stage of development

Percentage of examined underground coal miners with CWP by tenure in mining



Percentage of examined underground coal miners with PMF

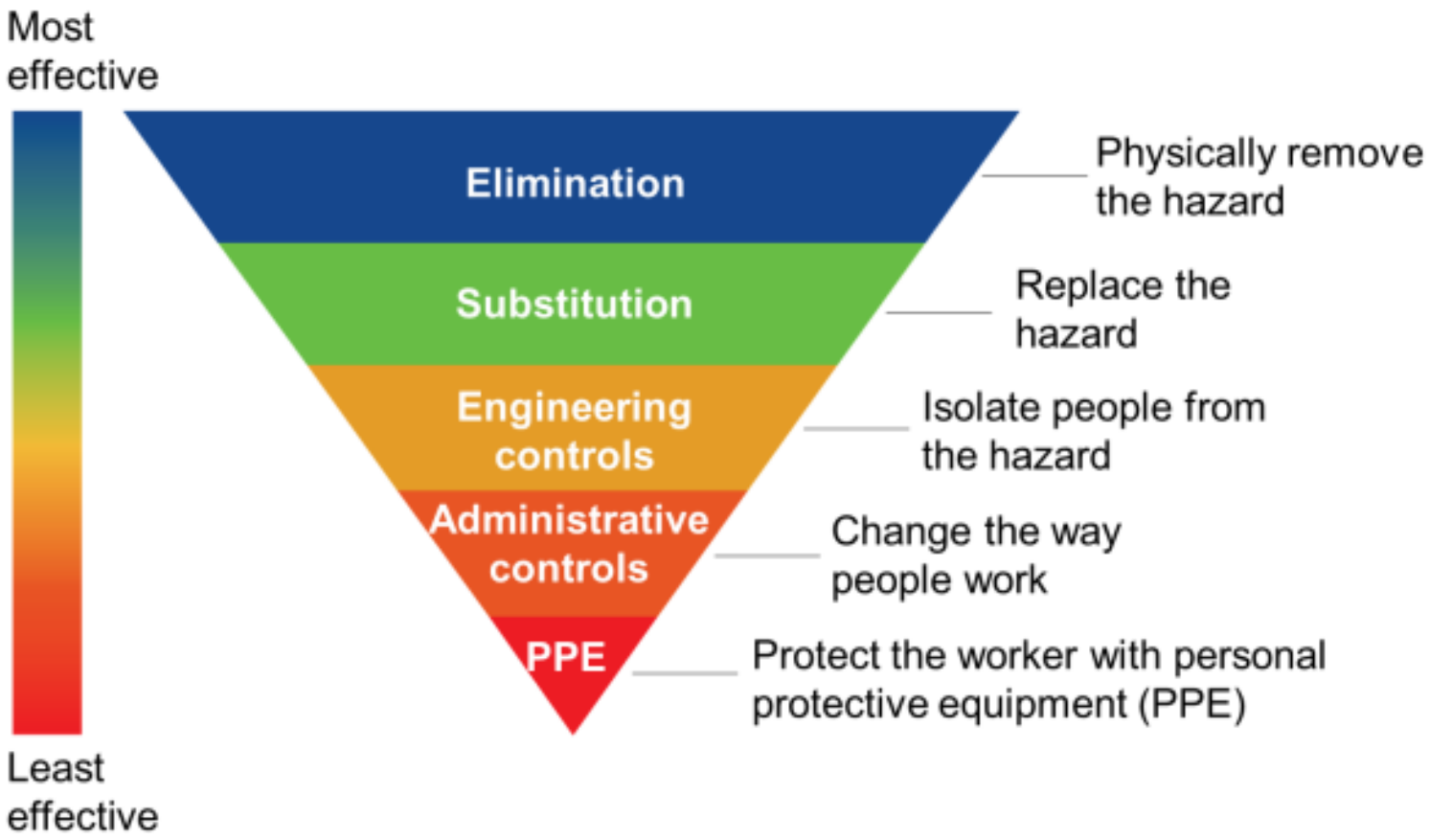


Health Effects of Overexposure to Respirable Coal and Silica Dust

Updated Dust Rule

- The unexpected increases in CWP and PMF contributed to MSHA creating a new dust rule in 2014
- The respirable dust standard was lowered to 1.5 mg/m^3
- Implementation of these new dust standards began on August 1, 2016
- This rule also requires occupational compliance sampling to be conducted with a continuous personal dust monitor and to encompass the entire work shift regardless of length (previously compliance sampling was only conducted for eight hours regardless of shift length)
- The new rule provides an opportunity to gain a more realistic measure of the full-shift dust exposure of coal mine workers

Hierarchy of controls approach for reducing workplace hazards



Methodology for controlling respirable dust generations and worker exposure

Step	Goal—approach (examples)
1	**Minimize the quantity of respirable dust generated** —employ efficient cutting (drum and bit design, cutting method)
2	**Prevent respirable dust from getting into the ventilating air** —wet dust at generation point (water sprays) —enclose the dust source (stageloader, belt transfers)
3	**Remove respirable dust from the ventilating air** —dust collectors (flooded bed scrubbers, vacuum collectors) —water sprays (nozzle type, operating parameters)
4	**Dilute remaining airborne dust** —ventilation quantity (maximize) —increase distance from dust source (shield advance, continuous miner cuts)
5	**Prevent respirable dust from reaching workers' breathing zones** —ventilation velocity (quickly move dust) —move air with water sprays (directional sprays, blocking sprays) —physical barriers (belting, enclosed cabs)
6	**Regular maintenance of controls to retain effectiveness**

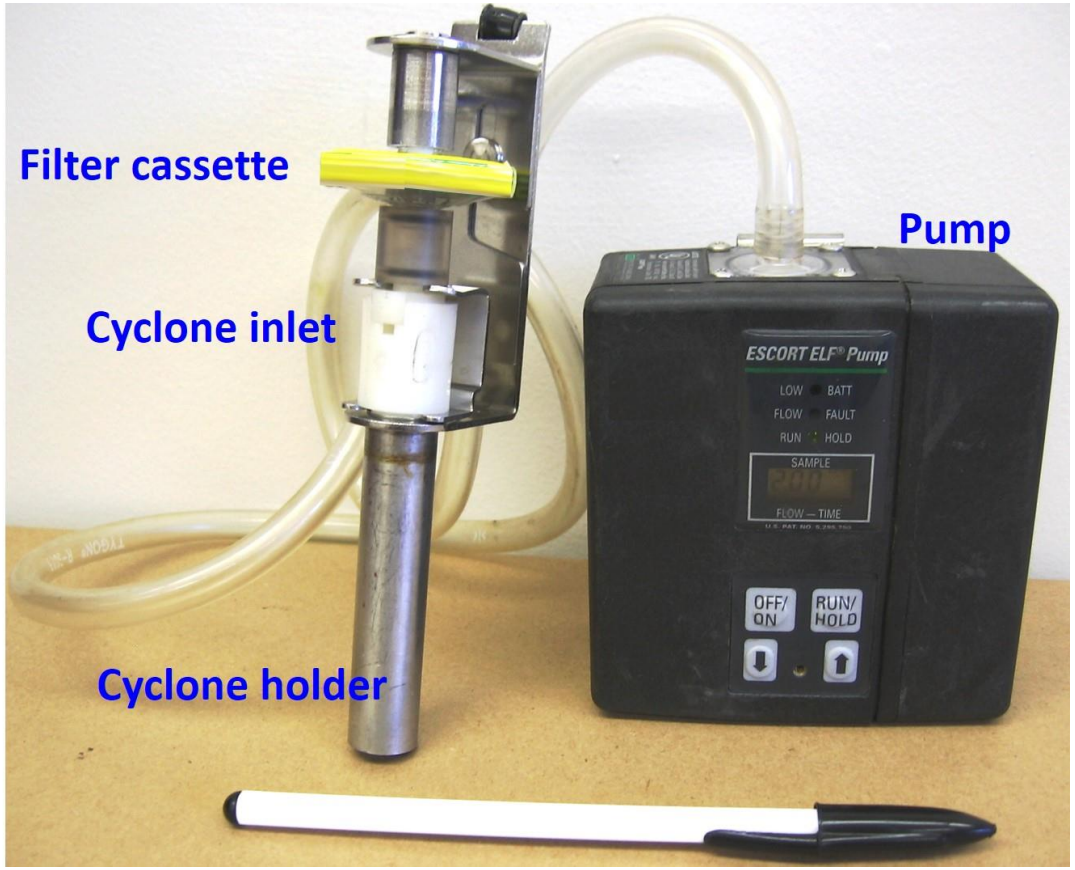
Sampling to Quantify Respirable Dust Generation

- To accurately quantify the amount of potentially harmful respirable dust in the mine air, sampling instrumentation must be used
- Accurate respirable dust sampling is important to quantify worker exposures, identify dust sources, and evaluate the effectiveness of control technologies
- Three types of samplers:
  - gravimetric sampler
  - continuous personal dust monitor
  - light-scattering instrument
- These samplers can be worn by miners to quantify personal exposures or can be placed at specific locations to quantify area dust levels

Sampling to Quantify Respirable Dust Generation

Gravimetric Sampler

- Used by mine operators and MSHA inspectors to collect all compliance samples from the 1969 health and safety act until MSHA passed the new dust rule
- Consists of:
  - 10-mm Dorr-Oliver cyclone
  - 37-mm PVC filter
  - Zefon sampling pump (2 L/min)
- Cyclone separates the oversize dust from the respirable fraction
- Filter is weighed to determine the mass of respirable dust collected during sampling
- Filter can also be analyzed for silica content



Sampling to Quantify Respirable Dust Generation

Continuous Personal Dust Monitor (CPDM)

- NIOSH developed a personal dust monitor that provides near real-time respirable dust exposure information during the shift and the average shift concentration at the end of sampling
- Respirable dust is collected through a lapel-style inlet and deposited onto a filter and is used to calculate a respirable dust concentration
- Beginning on February 1, 2016, underground coal mine operators have used the CPDM to obtain compliance dust samples on specified occupations

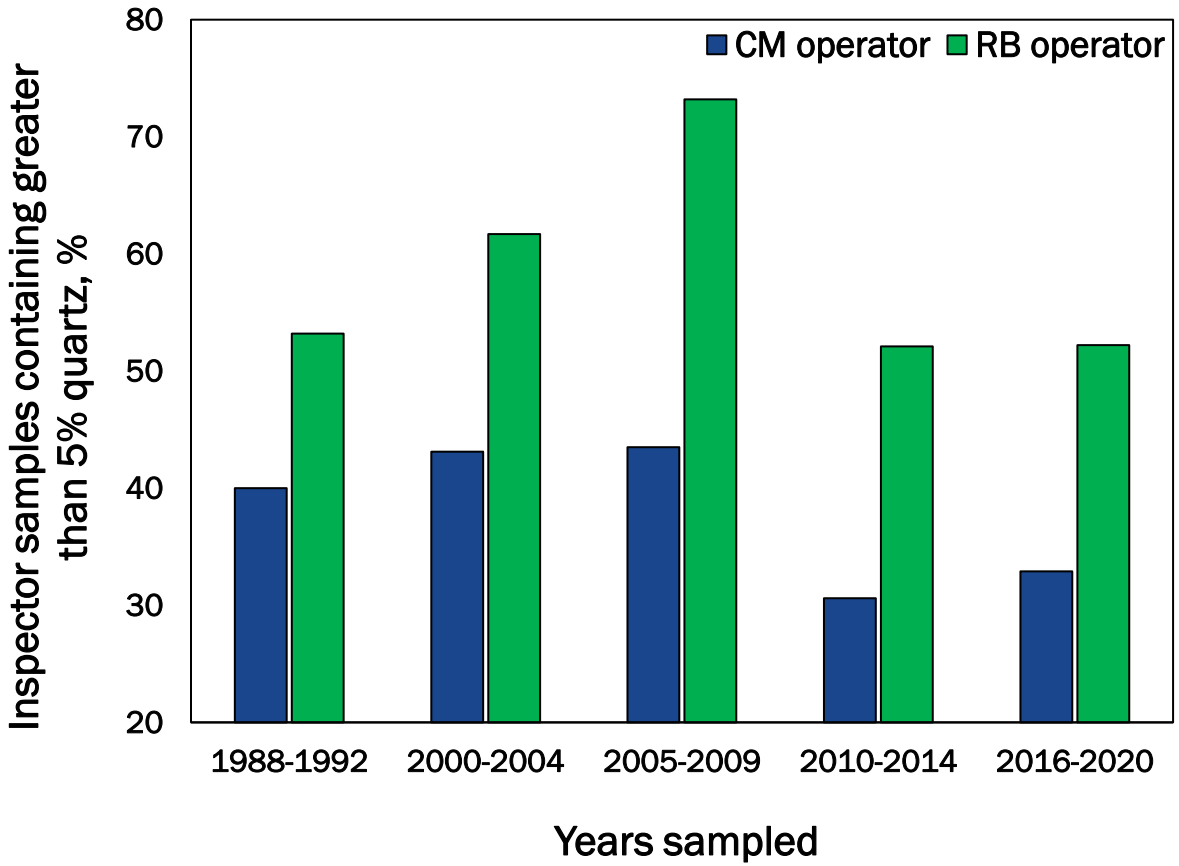
Sampling to Quantify Respirable Dust Generation

Light-Scattering Real-Time Dust Monitor

- Personal DataRAM (pDR)
- Dust-laden air enters a sensing chamber where a light beam passes through the dust
- A sensor measures the amount of light scatter caused by the dust and relates this scatter to a relative dust concentration
- Used in conjunction with gravimetric samplers for proper calibration
- A benefit of using the pDR is that data for short-term dust events can be collected and analyzed (ex: dust exposure for shuttle car operators during loading)

Controlling Respirable Dust on Continuous Mining Sections

- Exposure to respirable crystalline silica (quartz) dust is a major concern on continuous mining sections, with the largest source of this quartz typically being the rock strata overlaying
- For continuous mining operations, extraction of this rock is often needed for equipment clearance but can lead to increased dust generation
- Roof bolter operators must drill into roof rock to anchor roof supports
- In MSHA's 2014 dust rule, the CM operator and RB operator were specified as designated occupations that must be sampled by mine operators on CM sections



Controlling Respirable Dust on Continuous Mining Sections

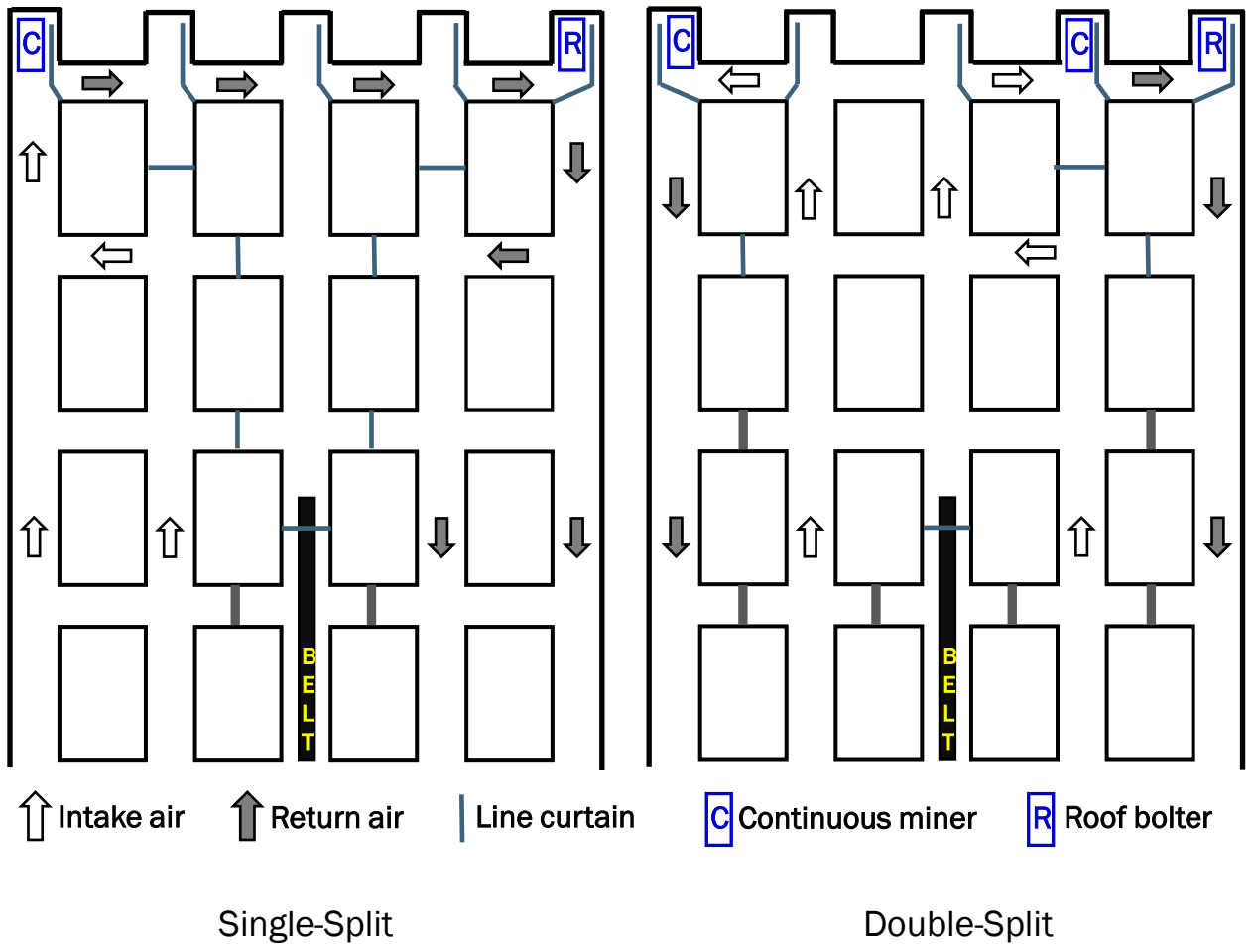
Section Ventilation – for CM sections, federal regulations require a minimum air quantity at each working face of 3,000 cfm, with a minimum quantity of 9,000 cfm required at the last open crosscut

Single-Split Ventilation

- Intake air is brought in on one side of the section and sweeps across all faces before exiting in the return on the other side
- When the CM is operating in the main intake entry, all faces downwind would be in the dusty return air from the miner

Double-Split Ventilation

- Intake air is brought in the center entry or entries and split into two branches
- One branch will ventilate the left-side while the second branch will ventilate the right-side entries.



Controlling Respirable Dust on Continuous Mining Sections

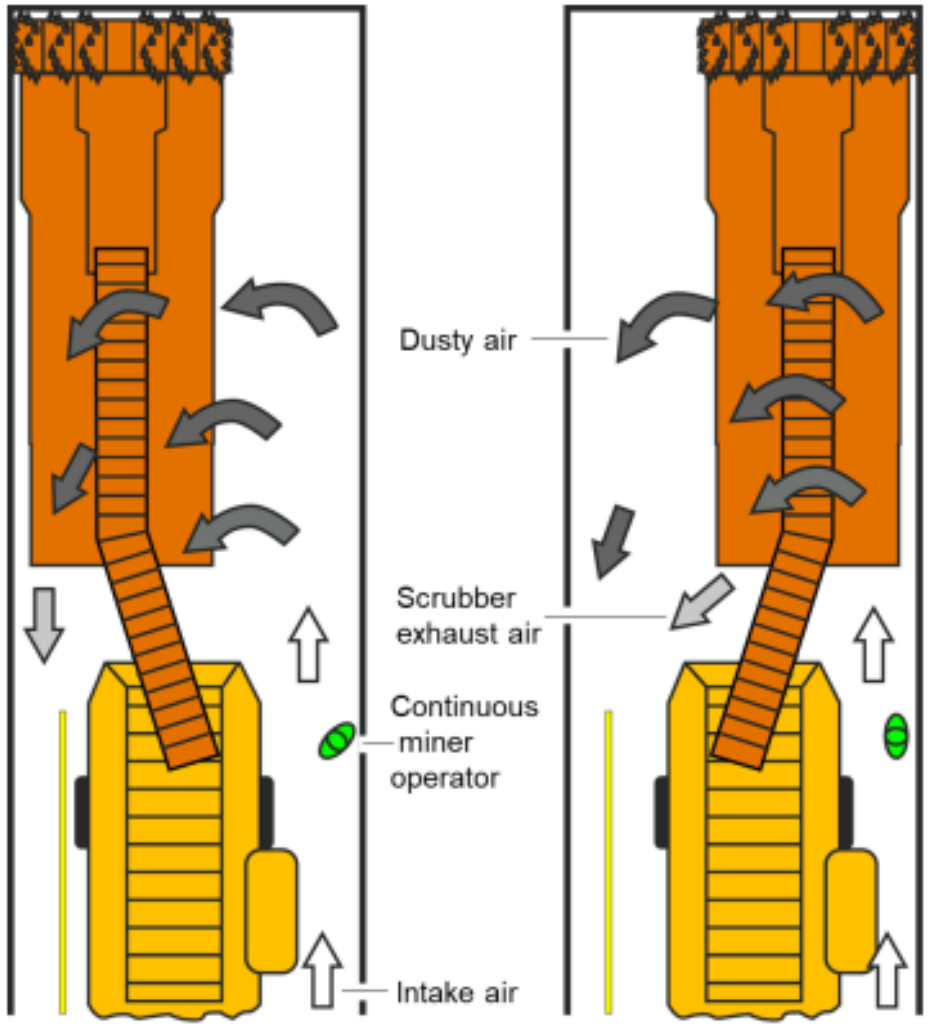
Intake Air Dust Control

- MSHA requires the average concentration of respirable dust in intake air to be maintained at or below 0.5 mg/m^3 within 200 ft outby the working faces.
- Typically, high levels of intake dust are sporadic and result from activities in the intake entries that may take place over the course of a working shift. These activities can include:
  - Delivery of supplies and/or personnel
  - Moving equipment in intake entries
  - Rock dusting
  - Construction activities
- To eliminate these sources of dust generation, these outby activities should be completed on nonproduction shifts when possible
- Feeder-breaker operations can contribute an undesirable amount of respirable dust into the mine air. The following are some basic controls for reducing dust at the feeder-breaker:
  - MSHA recommends using full cone sprays at the feeder-breaker to wet coal and silica dust and hollow cone sprays to knock down airborne dust
  - Dust levels can be decreased by using automated sprays at the feeder-breaker that activate during shuttle car unloading to wet the coal before it enters the breaker

Controlling Respirable Dust on Continuous Mining Sections

Exhausting Face Ventilation

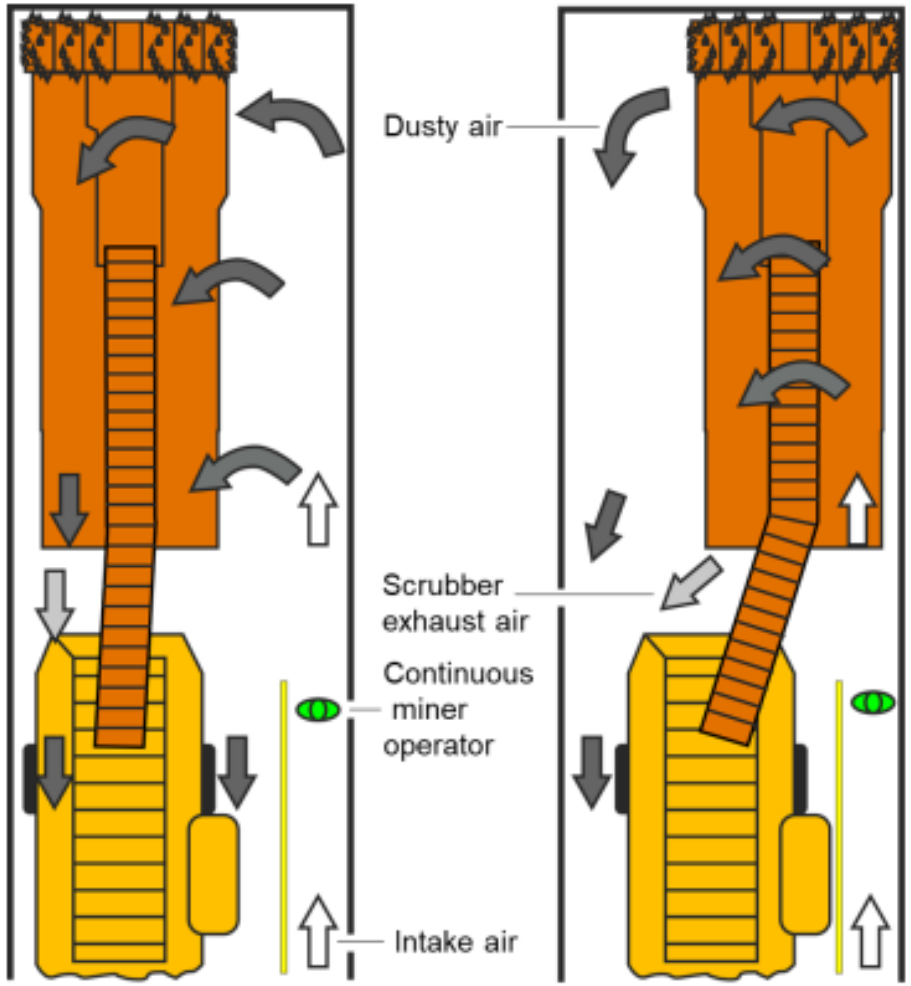
- The intake air sweeps the face and the dust-laden air is then drawn behind the return curtain or through exhaust tubing and carried away
- This system allows most of the mining entry to be in intake air, which is beneficial for the respirable dust exposure for all personnel in the face entry.
- Exhaust face ventilation airflow does not penetrate as deeply into the face as blowing ventilation, particularly as curtain setback distance increases – concern for controlling methane emissions in gassy operations
- Exhaust face ventilation allows haulage car operators to remain in intake air while the car is being loaded behind the continuous miner



Controlling Respirable Dust on Continuous Mining Sections

Blowing Face Ventilation

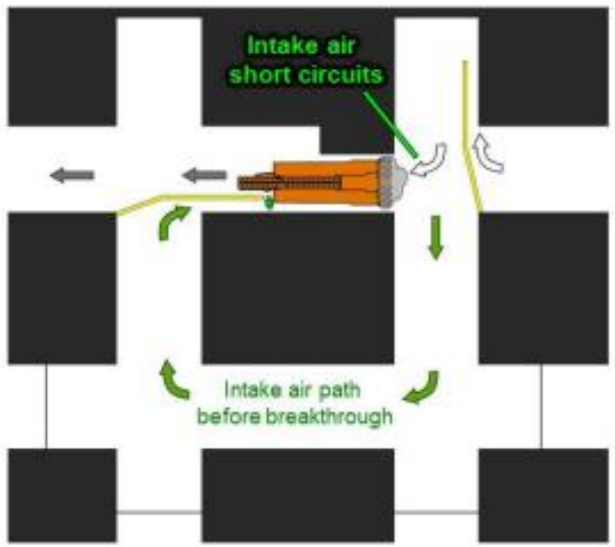
- The clean air is blown toward the face and sweeps dust-laden air into the return entry, which is the widest portion of the working entry
- This system allows the CM operator to reduce dust exposure by being positioned in the intake air at the inby end of the blowing curtain or tubing
- However, this limits the operator's movement without being in return air
- Blowing ventilation positions shuttle car operators in return air, resulting in elevated dust exposures when compared to shuttle car operators working in exhaust ventilation

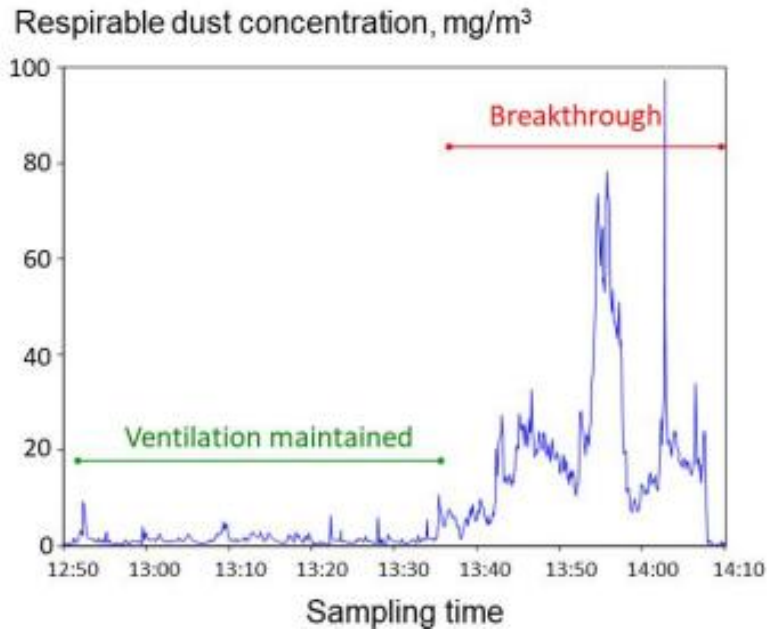


Controlling Respirable Dust on Continuous Mining Sections

Crosscut Breakthroughs

- Extracting crosscuts is a necessary part of the mining cycle but presents challenges for dust control
- When initiating a crosscut, the angle of the CM and positioning of the haulage car behind the miner for loading can result in the miner operator needing to reposition from the desired location from a dust control perspective
- It may be difficult to initially establish face ventilation that prevents dust from rolling back toward the operator
- If the breakthrough occurs into the section ventilation, the intake air short-circuits and carries dust directly toward the equipment operators
- If the crosscut breakthrough occurs with the section ventilation, dust-laden air is quickly carried away from the face personnel.





Controlling Respirable Dust on Continuous Mining Sections

Continuous Miner Dust Control - cutting by the CM represents the greatest source of dust generation on CM sections, which can be a concern for the CM operator and other workers downwind of the miner.

Efficient Cutting

- If the minimum quantity of respirable dust is generated during mining operations, then a lesser quantity of respirable dust must be controlled through other technologies
- To minimize the amount of respirable dust generated, efficient cutting by the CM should be a primary goal

Cutting Bits

- Cutting bit selection can greatly affect respirable dust concentrations generated during cutting
- CM bits designed with large carbide inserts and smooth transitions between the carbide and steel shank typically produce less dust

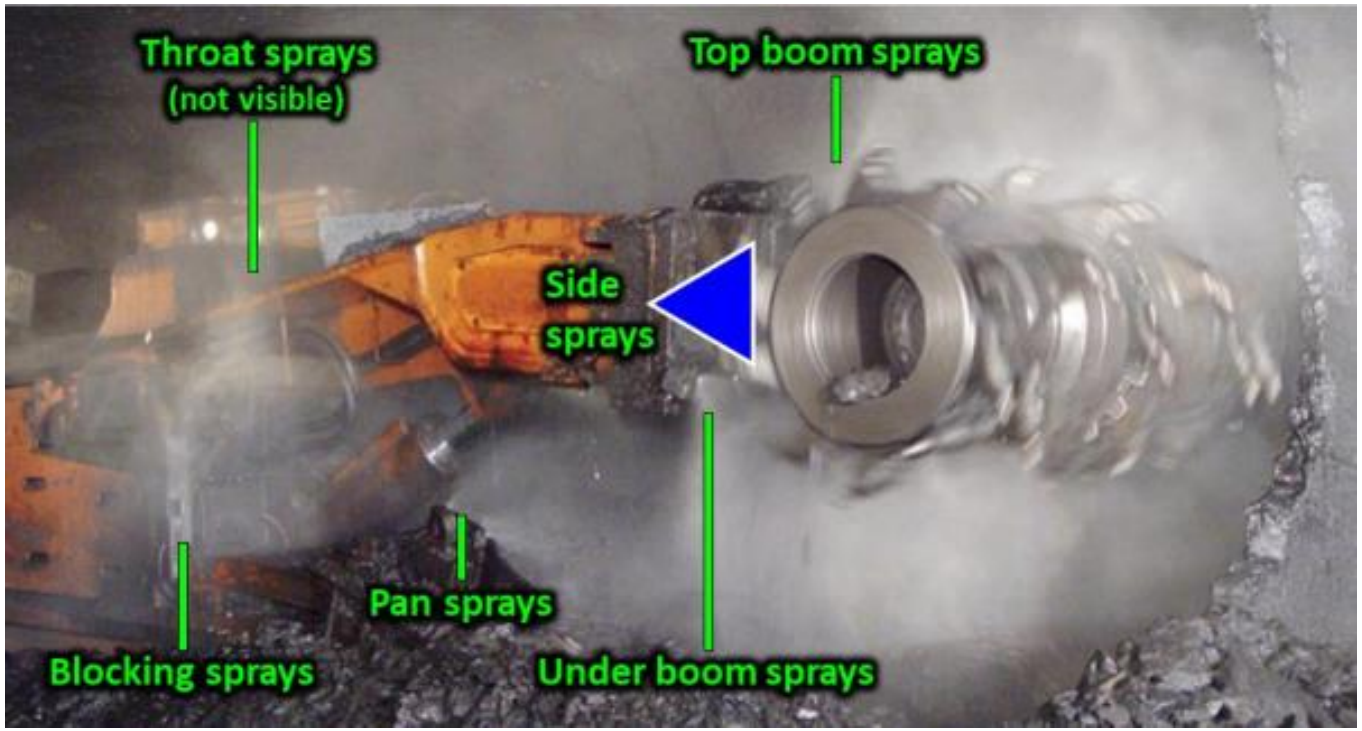
Modified Cutting Method

- If roof rock must be cut, it can be beneficial to cut the coal beneath the rock for several feet and then back the CM up to cut the remaining rock
- This cutting method leaves the rock in place until it can be break out to a free, unconfined space, which creates less respirable dust

Controlling Respirable Dust on Continuous Mining Sections

Water Sprays

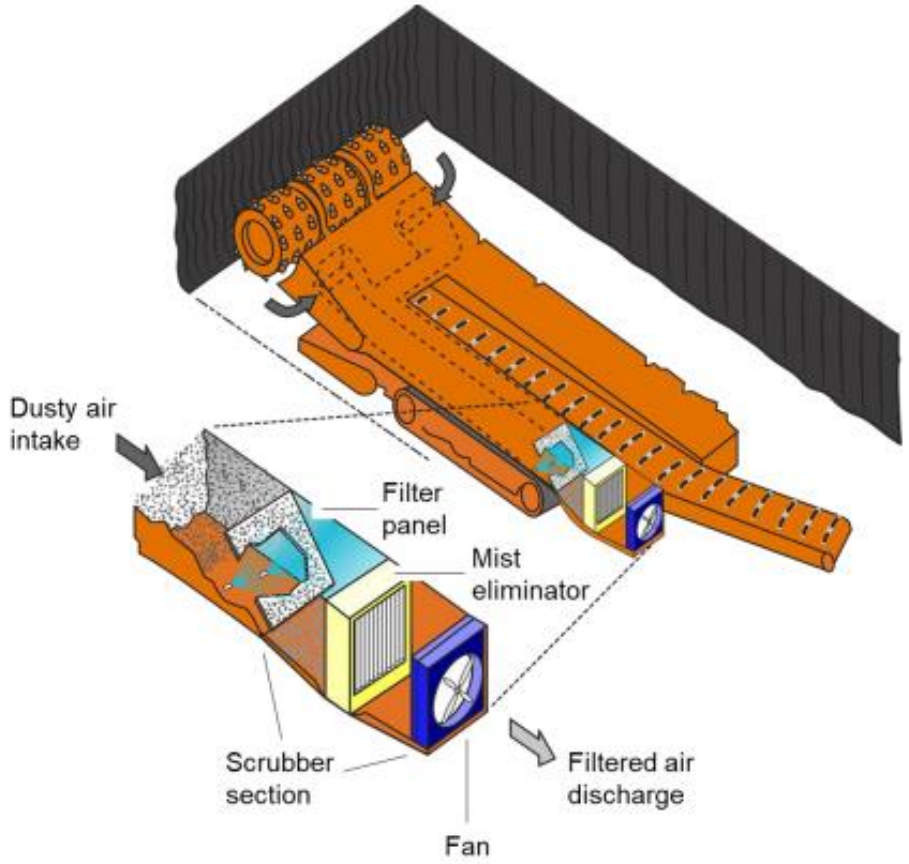
- Most CMs operate with water sprays located at multiple locations in order to achieve the desired dust control
  - Cutting boom
  - Loading pan
  - Conveyor throat
  - Sides of the miner (side and blocking sprays)
  - Cutting drum



Controlling Respirable Dust on Continuous Mining Sections

Flooded-Bed Scrubbers

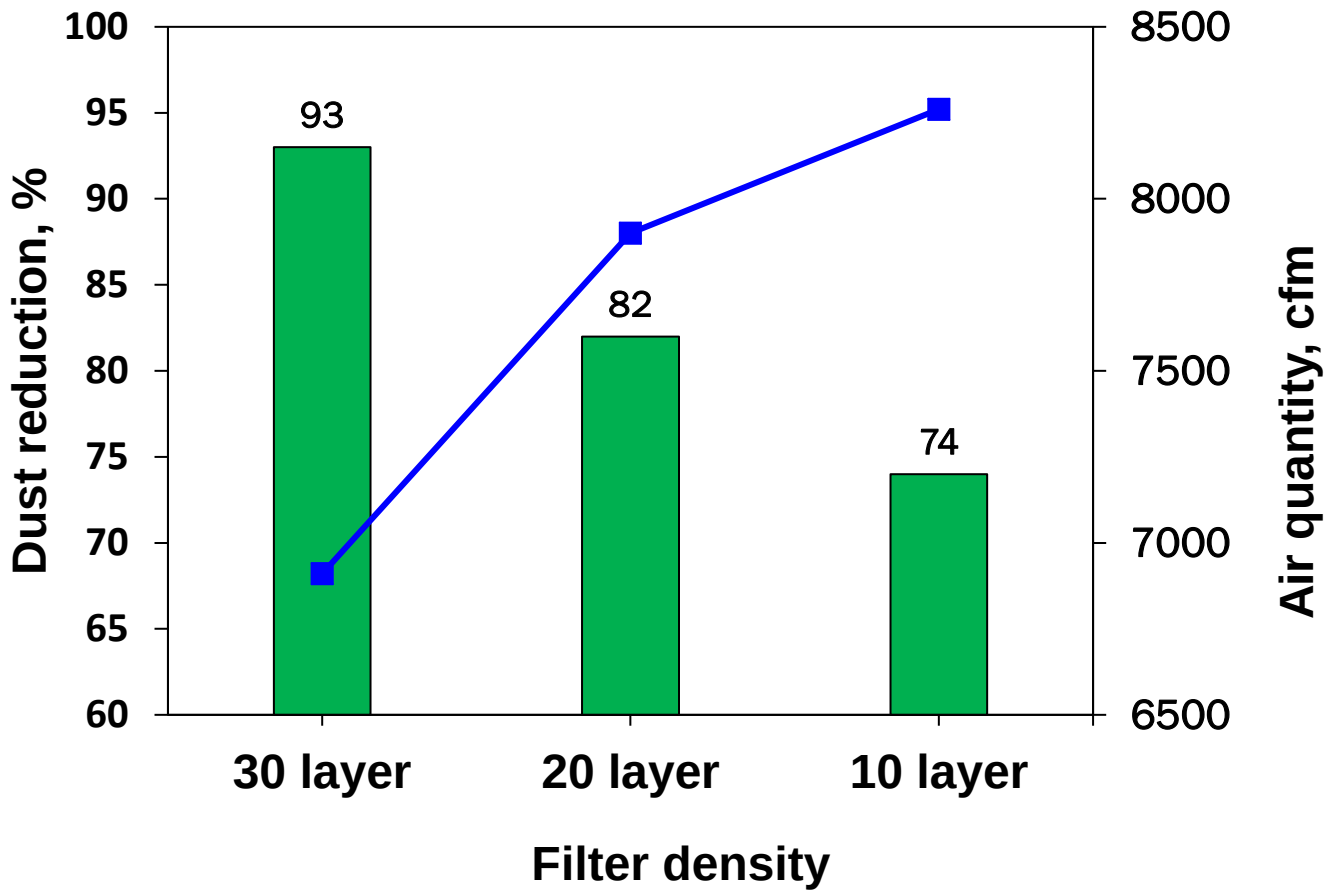
- Fan-powered dust collectors installed on CMs to capture dust-laden air at the cutting face
- This air is drawn into inlets mounted close to the cutting head and through steel ductwork toward the back of the CM, where a multi-layer mesh filter panel is being wetted by a water spray
- As the dust particles and water droplets impact the filter mesh and work their way through the layers, the dust particles become encapsulated in the water droplets
- After exiting the filter panel, these dust-laden water droplets encounter a wave-blade mist eliminator which causes the airstream to make numerous turns through the unit
- The momentum of the dust-laden water droplets causes them to strike the mist eliminator blades and be removed from the airstream
- The relatively clean, dry air is then discharged by the fan back into the mine atmosphere



Controlling Respirable Dust on Continuous Mining Sections

Scrubber Dust Control Effectiveness

- Overall dust reduction achieved with flooded-bed scrubbers is determined by capture and collection efficiencies
- Capture efficiency: quantity of face ventilation air that is captured by the scrubber
- Collection efficiency: percentage of respirable dust entering the scrubber that is removed before discharging into the mine atmosphere
- Optimum flooded-bed scrubber performance: all dust-laden air at the cutting face is drawn into the scrubber and a high percentage (> 90%) of the respirable dust is removed
- Full-scale laboratory and mine-site testing have shown the scrubber can reduce dust levels in the return by 80% to 90%



Controlling Respirable Dust on Continuous Mining Sections

Roof Bolter Dust Control – RB operators have had the highest quartz exposure on CM sections and have multiple sources of dust exposure

Efficient Drilling and Dust Confinement

- Efficient drilling with sharp bits and drilling parameters adjusted for the type of rock being drilled into can decrease dust generated during roof bolting
- Most underground coal mines use roof bolters with tungsten carbide-tipped drill bits
- As the carbide loses its sharp cutting edge, drilling penetration will be reduced, leading to greater dust generation as the bit grinds rather than efficiently cuts into the rock

Dry Vacuum Dust Collector

- These systems are designed to pull dust generated by drilling through a hollow drill steel and rubber hoses back to a pre-cleaner and collector box
- The pre-cleaner is a cyclone designed to remove larger particles from the airstream to reduce dust loading of the collector box
- The collector box has multiple chambers and contains a cyclone and final canister filter, which are used to remove the captured dust from the airstream
- The filtered air is then discharged through a muffler back into the ambient mine air

Controlling Respirable Dust on Continuous Mining Sections

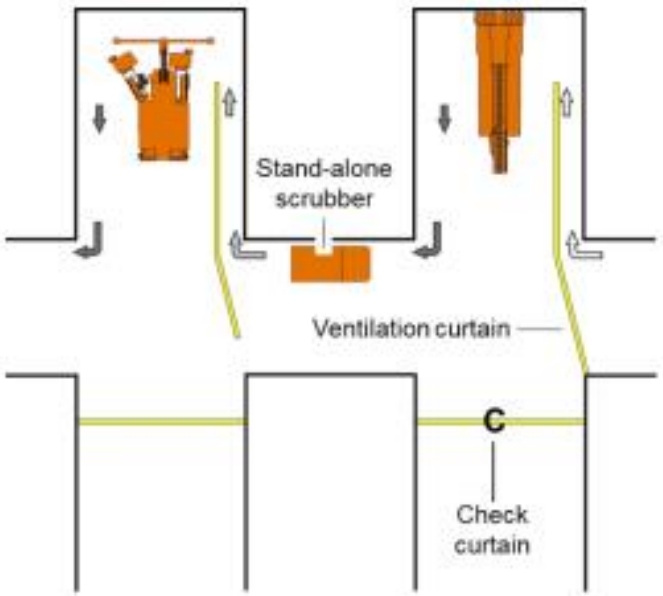
Roof Bolter Canopy Air Curtain

- An engineering control that can be used to provide protection from dust generated during drilling and dust generated by the CM when the RB is located downwind of the CM
- A centrifugal fan draws ambient air from the mining entry through a filter and blows this air down over the RB operator through a plenum mounted on the underside of the canopy
- Protection is provided to the operator while positioned under any portion of the canopy
- Canopy air curtains can be installed as retrofits or incorporated into new machines

Controlling Respirable Dust on Continuous Mining Sections

Stand-Alone Mobile Dry Scrubber

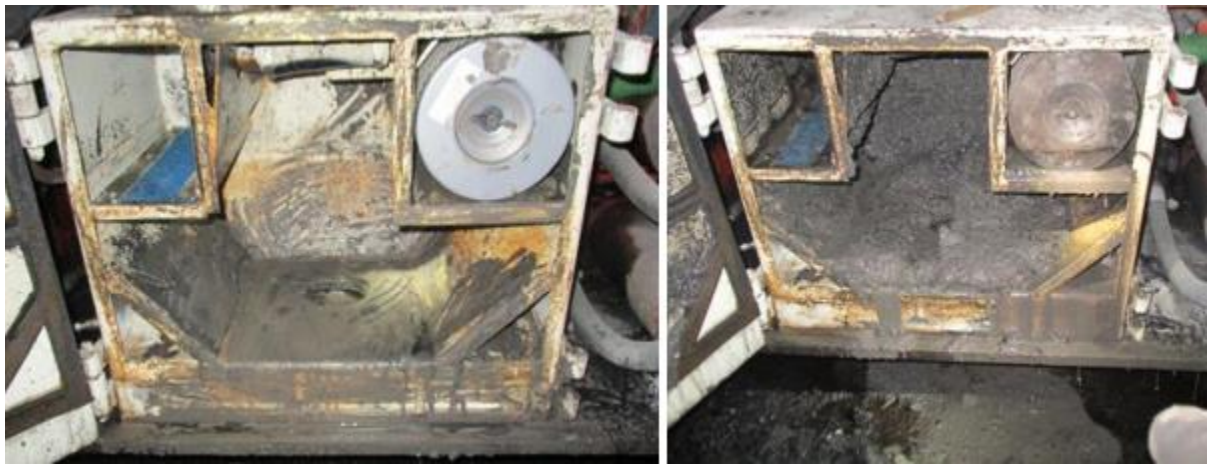
- Positioned to clean the return air from the CM and provide filtered air to the RB operators when working downwind of the CM
- In controlled laboratory tests, the DS averaged over 95% respirable dust removal efficiency at both the low and high airflows
- In field testing, respirable dust sampling conducted upwind of the DS and at the face showed a 50% reduction in respirable dust
- Commercially available for use in underground coal mines



Controlling Respirable Dust on Continuous Mining Sections

Wet Collector Box

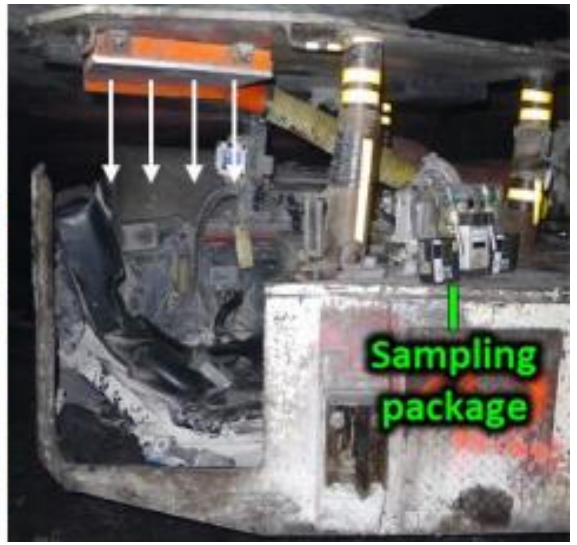
- Dry vacuum dust collection systems are traditionally used on RBs, but cleaning of the dust box is a potential source of dust exposure, which may contain elevated levels of quartz
- The wet box removes the internal cyclone, the lower section of the metal compartment divider, and adds a water spray, drain valve, and angled plates in the bottom panel of the collector box
- After bolting each cut, the RB operator would activate a hydraulically controlled drain valve at the bottom of the collector box to drain the saturated dust
- Remaining material can be rinsed out with a water hose tapped into the water feed to the RB. Since the dust is saturated, little or no dust should become airborne during this cleaning
- Use of the wet collector box reduced operator dust levels during box cleanout by an average of 80% over three shifts, while overall shift dust reductions from the PDM samples averaged over 25%



Controlling Respirable Dust on Continuous Mining Sections

Shuttle Car Canopy Air Curtain

- Intended to lower the dust exposure of haulage car operators, particularly when blowing face ventilation is used
- NIOSH conducted laboratory testing of this air curtain design and then in-mine testing with it installed on the canopy of a ram car (battery hauler)
- Results indicate that an average dust reduction of 65% was observed for the ram car operator when loading behind the CM
- While tramming to the feeder-breaker, unloading, and tramming back to the CM, average dust reductions of 18%, 36%, and 24% were measured, respectively
- These results indicate that a canopy air curtain installed on haulage vehicles can successfully reduce operator dust exposures



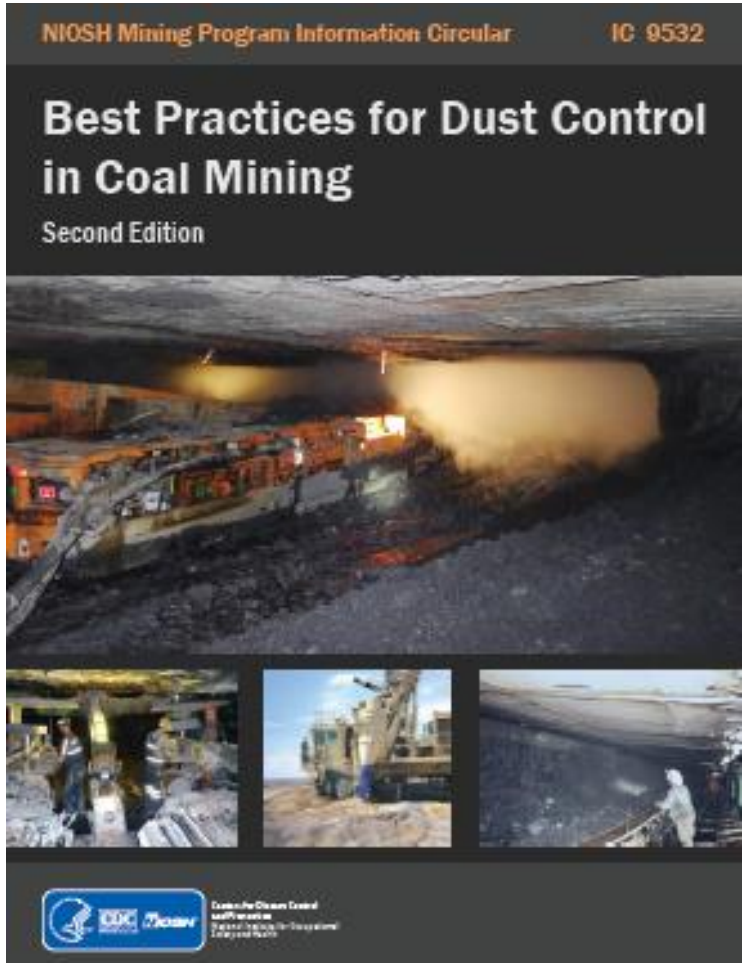
Current Research – Continuous Miner Scrubber Simulator

- Evaluation of a flooded-bed scrubber system to improve operation and develop associated techniques to maintain and/or restore performance when subjected to respirable dust
- Evaluate the dust collection efficiency of different scrubber screens
- Determine methods to improve scrubber dust collection efficiency
- Find solutions to limit clogging of scrubber screen

Current Research – Water Spray Chamber Knockdown Testing

- Evaluation of water spray systems for knockdown performance on respirable dust and the use of additives to improve airborne dust capture
- Water spray comparison testing by varying performance factors
  - Spray type – different water sprays have different performance characteristics
    - Water flow rates
    - Airflow induction ability
  - Operating pressure
  - Dust composition
  - Use of surfactants

Controlling Respirable Dust on Continuous Mining Sections



Scott Klima
SKlima@cdc.gov
412-386-6468