Performance of the Continuous Personal Dust Monitor

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NAS requested information on:

1) How is the accuracy of individual CPDM units determined?
2) How is the CPDM worn and used?
3) How is the CPDM used to better understand exposures and improve mine conditions?
4) What feedback have you received from coal miners’ using the CPDM?
5) What is the overall CPDM reliability?
6) What have been the main faults and repairs for the CPDM?
7) What are the challenges in making the CPDM smaller?
8) What is the status of development for a real-time silica monitor?
Personal Dust Monitor (PDM) development

Objective: develop a sampler to provide dust exposure information to the mine worker and operator in real time with the goal of preventing overexposures

• 1998 NIOSH issued RFP for development of person-wearable, mass-based sensor for measurement of respirable coal mine dust

• in consultation with stakeholders, NIOSH led the development of new mass-based monitoring technology for coal mining

• stakeholders included BCOA, UMWA, NMA, MSHA, R&P/Thermo Fisher Scientific

• regular meetings were held to keep stakeholders involved with ongoing PDM development

• stakeholders reviewed all sampling protocols and publications and collaborated on development steps
PDM Model 3600 development

- combined cap lamp and gravimetric dust sampler functions into one unit
- provides continuous respirable dust monitoring with real-time feedback to miner
- records dust readings and instrument operating parameters (each minute)
- provides an accurate end-of-shift dust concentration
PDM mass measurement principle

- filter cartridge mounted on end of Tapered Element Oscillating Microbalance (TEOM)
- TEOM oscillates at its harmonic frequency
- frequency changes in direct relation to the mass collected on the filter
- measurement principle does not respond to other particle characteristics such as optical properties, composition, or size distribution
Real-time screen displays

- 30 min exposure
- Cumulative exposure
- Permissible exposure limit (PEL)
- Percent of PEL reached

Graph with each bar representing a 30 minute average
PDM accuracy

- laboratory and mine-site testing completed to show that NIOSH accuracy criteria was met and equivalency to coal mine dust personal sampling unit (CMDPSU) determined
- MSHA and NIOSH certified the PDM design and components; subsequent instruments built to these exact specifications
- KO used in dust determination and each unit has unique K0 value determined by Thermo (calibration weights)
- mine can conduct periodic audits to ensure proper PDM operation

Thermo guidelines

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow audit</td>
<td>Monthly</td>
</tr>
<tr>
<td>KO audit</td>
<td>Annual</td>
</tr>
<tr>
<td>Tilt audit</td>
<td>Annual</td>
</tr>
<tr>
<td>Factory calibration</td>
<td>Annual</td>
</tr>
</tbody>
</table>
PDM accuracy: multiple key operating parameters recorded

- **Flow rate** – measured air flow volume (can identify pinched sampling hose; Status Code = *Flow out of range*)

- **Mass1 total** – measured mass on filter (can identify large gain/loss of mass which may result from inlet falling into dust pile or dropping PDM which knocks dust off of filter; Status Code = *Mass offset*)

- **TE heater temp** – measures temperature control (ensures accuracy of dust mass measurement; Status Code = *TE temp out of range*)

*(MSHA uses this information to help determine validity of samples)*
PDM Model 3600 vs. Model 3700

- cap lamp, battery, power take-off removed
- sampling inlet moved from cap lamp to lapel
- weight reduced to 4.4 pounds (2 kg)
- Model 3700 certified by MSHA and NIOSH in 2014
New respirable dust rule for coal mining
(Lowering Miners' Exposure to Respirable Coal Mine Dust, Including Continuous Personal Dust Monitors - 2014)

2016: CPDM & 1.5 mg/m³
CPDM use in new rule

• CPDM sampling required for underground mines but optional for surface mining

• quarterly sampling required for designated occupation “DO” and “ODO”

• 15 consecutive valid sampling shifts required for each occupation

• DO and ODO cannot be sampled concurrently

• secure data file transmitted to MSHA with WinPDM software

• CPDM worn on belt, in pouch on belt, in backpack, or with binocular harness
PDM programming with computer

![PDM programming interface](image)

- **Wear ID**: 90543
- **Mine ID Number**: 4534532
- **Contractor Code**: 546
- **Sample Start Time**: 7/28, 14:38
- **Sample Time (hrs:min)**: 01:00
- **Sample Time (minutes)**: 0
- **Average Expected Temperature**: 73 - 85°F (23 - 29°C)
- **Respirable Dust Standard**: 1.0 mg/m³

**NOTICE**: Knowingly making any false statement, representation, or certification on this document is a violation of the federal criminal code, which may be punished by a fine or by imprisonment or both.
End-of-shift respirable dust level and recorded information

- the PDM records data each minute during the sampling period
- the data are stored in the instrument and can be downloaded (CSV file) and analyzed at the end of the shift
- the stored data provides a time-related record of dust exposures. When coupled with operational information, dust sources can be identified and the impact of worker positioning and/or control technologies can be evaluated.
PDM recorded dust concentrations can identify exposures

PMRD longwall dust gallery test data

Respirable dust concentration, mg/m³

Time

Cumulative concentration
30-minute concentration
Feedback from mine workers using CPDM

- Emily Haas, PhD – Behavioral Scientist, Human Factors Branch

- CPDM intervention studies at 3 mines with a total of 35 miners interviewed
  - initial visit and then follow-up visit
  - interview DO and ODO persons
  - 2 mines in West Virginia and 1 mine in Virginia

- one-time visits at 3 low coal mines in Virginia

- 2 publications
  - “Using CPDM dust data.” Coal Age, February 2016
  - “How miners in low coal respond to the CPDM.” scheduled to be published in the May issue of Mining People Magazine
Positive feedback from miners using CPDM

- “...I always like looking at my readout. It’s nice to see what the feedback was so you can prevent exposure later.”

- “It does change your habits. You think more where you should be to minimize exposure. It’s kind of on your mind more.”

- “I actually changed where I’m eating lunch. I used to eat lunch right on my bolter. I realized how much dust I get just sitting there by the machine...So now I walk a ways and sit and eat my lunch in a less dusty area. I feel better about that.”

- “We make sure to watch where and when we’re rock dusting in terms of people being around. We used to not really give the bolters a heads up that we’d be rock dusting. But now we make sure to tell them so they can get up in fresh air before we start. The CPDM has made us more aware and look out for each other in that regard.”
Initial/ongoing concerns from miners using CPDM

➢ “…we didn’t know what to expect so it’s very scary at first. It wasn’t until our supervisors went over the information with us that we knew we were okay during certain spikes on the job. But seeing that number [3.0] when the regulation is 1.5 really gets you thinking.”

➢ “…I have found myself a little distracted or preoccupied with the CPDM...just always wanting to check it to make sure it’s not too high...”

➢ “I’ll be honest I am constantly swinging my belt to look at the thing and make sure I’m okay. But if there was some type of warning it would put me more at ease in terms of compliance issues and where my levels are at. I think right now I’m so distracted by it that it’s not exactly safe when I’m running the miner to always be swinging around to see my levels.”
Feedback from miners using CPDM – low coal

- **Dust technician to CM operator:** “I showed him his initial readings with the CPDM that were over 1.0 mg/m³ because we don’t want anything over 1.0 mg/m³. He experimented with it and he moved himself to different areas. He’s in a better range now, he learned a lot, and he feels better.”

- **CM operator:** “I know I should move but I just don’t because it’s pretty difficult to resituate and still do my job.”

- **Management to RB operators:** To minimize dust liberation from clogged drills, management said that drilling the first four inches more slowly is crucial. Several managers discussed relaying this message to their bolters to help reduce their exposure to respirable dust.

- **Management:** ....at first, everyone liked to look at their dust data readouts. ....miners experience complacency after reading and analyzing so many dust data cards and become less interested in time.
Industry-reported issues with PDM sampling

- **Battery charging**
  - charger indicates full charge but PDM does not last full shift
  - Thermo reports faulty charger cables, weak batteries, or charging units as primary causes of problems
  - Thermo issued Technical Bulletin on cleaning procedures for charging contacts to promote proper charging conditions

- **Temperature selection**
  - MSHA requires PDM to be in temperature control during first and last minute of shift for sample to be considered valid
  - mines gaining experience with operating PDMs and Temperature-Out-of-Range codes have dropped over the last year

- **WinPDM software locks up (multiple windows open)**
PDM reliability (MSHA data through Dec 31, 2016)

- CPDM sample void rate (24.2%) within 1.4% of void rate for gravimetric sampler (22.8%)

- 20,907 voided CPDM samples
  - 44.8% invalid production
  - 22.4% CPDM void codes* = EFI (21.3%) and FOR (1.1%)
  - 12.2% excess sample
  - 9.2% invalid time

- Large industry variation: 30 mines with lowest and highest void rates
  - average void rate for lowest 30 mines = 7.8% (EFI = 2.1% of total samples collected)
  - average void rate for highest 30 mines = 40.8% (EFI = 8.6% of total samples collected)

* EFI – effective functioning impaired (TE not detected, Mass offset error, CPU fault, TE frequency, PDM CPU reset, Power low shutdown, TE temp out of range)
  
  FOR – flow out of range
• Service cycle time goal of 5 work days to support the PDM3700

• 1445 PDM3700 units returned to Franklin Depot Center for service
  – Services included repairs, preventive maintenance, and scheduled annual certified calibrations
  – 741 Warranty Services, average cycle time of 8 work days
  – 537 Annual Protection Plan Services, average cycle time of 10 work days
  – 167 Billable Time and Material Services, average cycle time of 10 work days

• Repair Center layout improvement in October 2016
  – Redesigned work cell to U shaped design, increasing testing capacity from 10 to 20 units, with expansion available for additional test stations

• 9 MSHA-certified Repair Technicians and Field Service Engineers
  – 5 active to meet current demand
  – flexing additional personnel as workload requires
Impact of CPDM: DO samples exceeding the standard have declined

<table>
<thead>
<tr>
<th>Dust sampler</th>
<th>Sampling period</th>
<th>Dust standard</th>
<th>Number of valid samples</th>
<th>Percent greater than standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravimetric</td>
<td>August 1, 2014 to March 31, 2016</td>
<td>2.0 mg/m³</td>
<td>28,101</td>
<td>1.9%</td>
</tr>
<tr>
<td>CPDM</td>
<td>April 1, 2016 to July 31, 2016</td>
<td>2.0 mg/m³</td>
<td>13,176</td>
<td>0.1%</td>
</tr>
<tr>
<td>CPDM</td>
<td>August 1, 2016 to December 31, 2016</td>
<td>1.5 mg/m³</td>
<td>9,372</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

(94.7%)

(78.9%)
Challenges for next generation PDM

Physical requirements
• mass-based dust measurement
• minimum 12-hour operation
• conventional size selector (known performance facilitates implementation)
• ability to dissipate moisture
• ability to sample in-mine dust concentrations/shift lengths without overloading

Testing requirements
• must meet NIOSH accuracy requirements in 30 CFR Part 74
• must be tested in 20% of MMUs
• must pass MSHA intrinsic safety testing

May be difficult to achieve all requirements in a substantially smaller size?
Real-time silica monitor

- no available instrument offers real-time silica monitoring
- true “real-time” silica analysis may be hindered by need for sufficient silica mass (e.g., 30 minute accumulation time)
- Thermo Fisher Scientific not currently researching a real-time silica monitor
- NIOSH not currently researching a real-time, compliance-grade silica monitor
- NIOSH is researching two end-of-shift silica analysis methods
  - Fourier Transform Infrared (FTIR) spectroscopy analysis of gravimetric filters
  - X-ray Fluorescence (XRF) analysis of alternate PDM filter
Development of field-based, end-of-shift silica monitoring approach

**Method: FTIR spectroscopy**
- direct-on-filter analysis
- no sample preparation or removal of dust from filter
- non-destructive so lab analysis can also be performed
- portable instrument
  - small footprint (< 18 in by 12 in)
  - easily lifted (< 30 lbs)
- analysis time: 3 minutes

**Preliminary findings**
- transmission FTIR can be used for dust samples collected in coal and non-coal mines
- bias of silica estimation might be affected by mineral confounders – especially for samples collected in non-coal mines
XRF analysis of PDM filters

- initial stages of research
- analyze sample without removing filter from TEOM
- alternate filter must be used in PDM
- coal mine dust does not have many confounders
  - coal/carbonaceous material
  - silica (SiO₂)
  - kaolin (Al₂Si₂O₅(OH)₄)
- XRF measures silicon; calculate silica mass by correcting for kaolin based upon the XRF signal for aluminum
Thank you....

Questions???

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