

			
			
			
<h2>A Real-Time, Wearable Elemental Carbon Monitor for Use in Underground Mines</h2> <p>Larry Takiff¹ & Geoffrey Aiken²</p> <p>1: ICx Nomadics, 215 First St., Suite 104, Cambridge, MA 02142, larry.takiff@icxt.com, 617-441-8871 x3117</p> <p>2: ICx Biodefense, 1001 Menaul Blvd. NE, Albuquerque, NM 87107, Geoffrey.aiken@icxt.com, 505-314-8104</p>			

		
<h2>Abstract</h2>		
<p>ICx Technologies has designed and is currently testing a real-time, wearable elemental carbon monitor designed primarily to determine exposures of workers in underground mines to diesel particulate material (DPM). Diesel particulates are composed primarily of elemental and organic carbon, and have been classified as a potential carcinogen. DPM levels can be high in workplaces where diesel equipment and vehicles are used, especially in underground mines due to the enclosed workspace. Consequently, in the U.S. the Mine Safety and Health Administration, an agency of the federal government, regulates personal exposure to DPM in underground metal and nonmetal mines, determined as total submicron carbon exposure, with a relation to elemental carbon established. The most common current method of measuring personal exposure to elemental or total carbon nanoparticles involves capturing the particles on a filter followed by a thermo-optical laboratory analysis, which effectively integrates the exposure spatially and in time, thus removing any information on exactly when and where high personal exposures occurred. In addition, the multiple-week turn-around time of the test makes it difficult for the workplace to implement and test exposure reduction mechanisms, and does not serve to prevent over-exposures, only to determine that they have occurred after the fact. The ICx monitor, based on a design developed and tested by Dr. James Noll's group at the NIOSH Pittsburgh Research Laboratory, uses a real-time particle capture and light transmission method to yield elemental carbon values that are displayed for the wearer and are stored internally in a compact device. Both current concentrations and eight-hour time weighted averages are displayed. The results have been found to agree well with the established laboratory method (NIOSH Method 5040) for elemental carbon emissions from a diesel engine. The monitors are compact (< 1 kg) and powered by a rechargeable Li-ion battery, and the filter cartridges and battery can operate the device for at least a full shift in environments typical of underground mines. ICx and NIOSH are examining the use of the monitor for other applications and types of workplaces, which have lower concentrations of elemental carbon or different sources of carbon.</p>		
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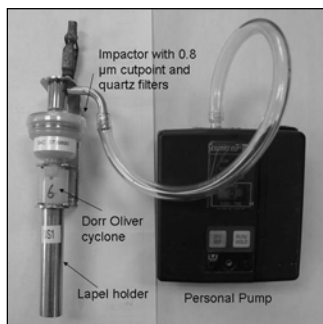
Diesel Particulate Matter (DPM)

- Possible human carcinogen
- Composed of elemental carbon (EC) and organic carbon (OC), sum is total carbon (TC = EC + OC)
- Generated by diesel engines including those used in mines
- U.S. federal regulations on DPM in mines
- Total carbon is regulated, derived from EC measurement
- TC now measured with sampler/filter/off-site lab analysis, multi-week turn around complicates engineering solutions
- NO commercial real-time personal exposure monitor that accurately measures DPM

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Current DPM Measurement in Mines



- Procedure
 - Sample → Send to lab → Results to mine → Action?
- Value
 - Established method
 - Accurate
- Issues
 - Time consuming
 - Cost & effort
 - Not real time: single # for a full shift

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Problem with Current Method

- 2-3 week cycle time to assess effect of changes in ventilation or equipment
- No way to tell when in time, or where in mine exposure occurred
- Overexposure detected but not prevented
- Cost of lab test



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The ICx Diesel Particulate Monitor

- Developed by NIOSH Pittsburgh Research Laboratory (Dr. James Noll), commercial version by ICx
- Pump, size selector, & filter with laser transmittance measurement of filter darkening for EC
- Operates > 10 hours with rechargeable battery
- Real time LOD: 15 $\mu\text{g}/\text{m}^3$ for 5 minute average at 1.7 lpm
- 8 hr TWA dynamic range
 - 9 – 300 $\mu\text{g}/\text{m}^3$ @ 1.7 lpm
 - 18 – 600 $\mu\text{g}/\text{m}^3$ @ 0.85 lpm



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Easy to use . . .

Insert a filter cassette



Close and lock the cassette door



And turn the unit on

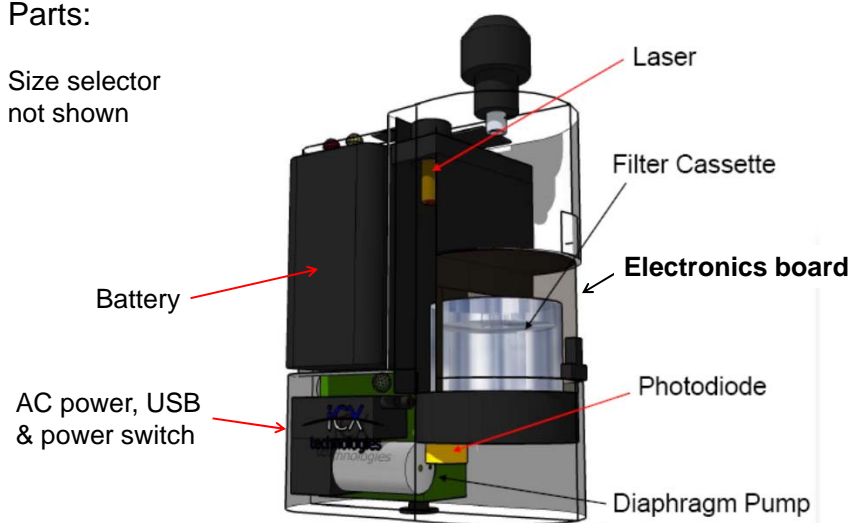


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Parts:

Size selector
not shown



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Output

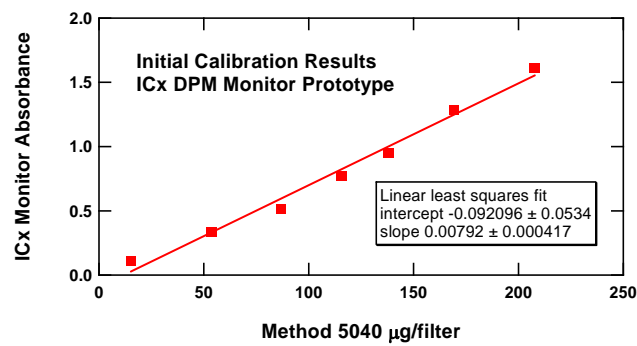
- Real-time EC level ($\mu\text{g}/\text{m}^3$)
- 8-hour time-weighted average EC
- TC using mine-specific conversion
- Exposure limit alarm
- Filter saturation alert
- Sensor & battery voltage
- EC level vs time internally logged



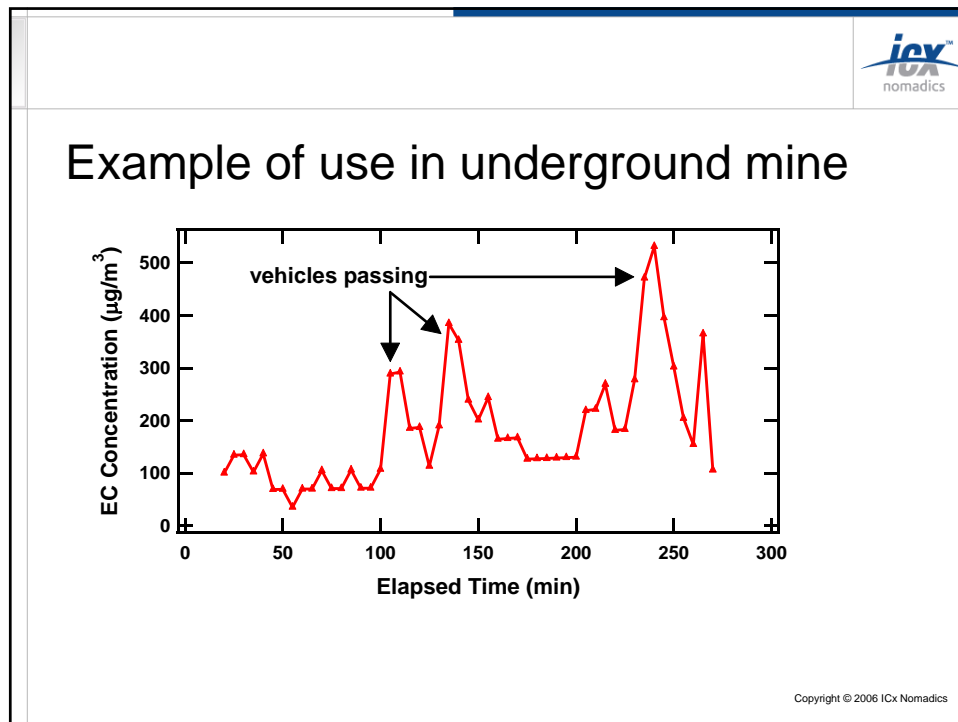
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Agreement with NIOSH Method 5040




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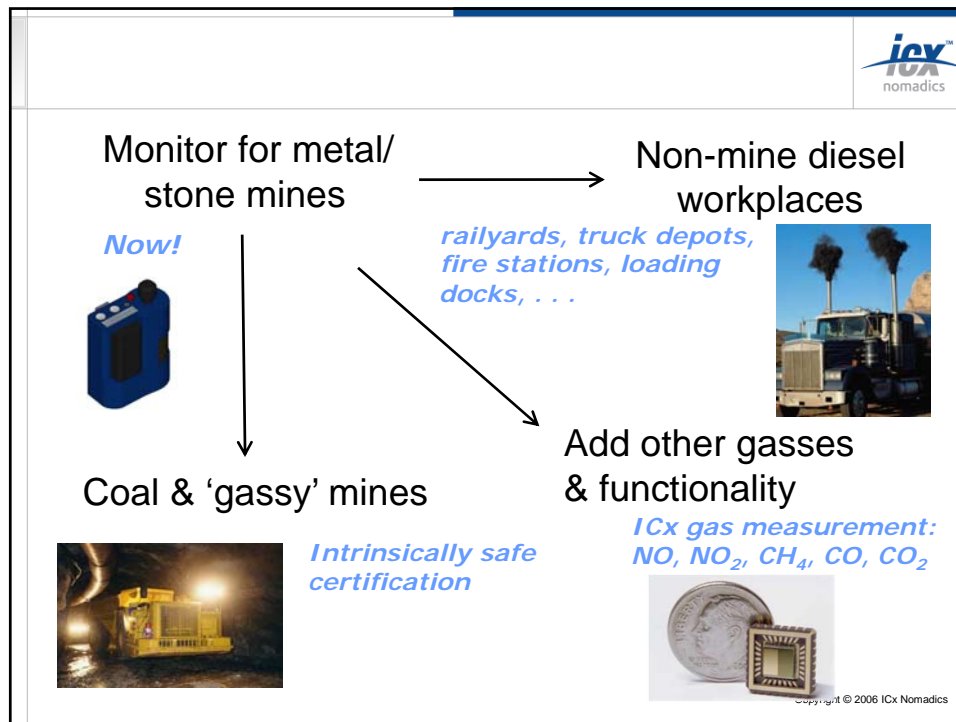


Advanced Features

- Adjustable pump speed: 0.85 or 1.7 lpm
- Adjustable averaging time: 1 – 60 minutes
- AC power and mount to collect area samples
- Size selector removes interferences:
 - Dust
- Can be used to collect 5040 samples



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Mine Monitor Prototype Status

- Beta prototypes tested in mines
 - PA, CO, MT, AK done or in progress
 - ON, NV, ID, more PA planned or possible
- Design changes for commercialization & manufacturability scheduled for September
- Commercial sales in 1Q2010

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Beyond the Mine Market . . .

- Ambient & other workplace monitoring
 - Sensitivity to EC levels at or below 1 $\mu\text{g}/\text{m}^3$ necessary
- Other types of black carbon
 - $\text{PM}_{2.5}$
 - Tailpipe emissions
- Unattended operation and networking
 - Much greater interval between filter & battery change
 - Wireless networks of monitors with active (ventilation?) control and software

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Acknowledgement

- Dr. James D. Noll, NIOSH Pittsburgh Research Laboratory, 626 Cochran's Mill Rd., Pittsburgh, PA 15236, JIN1@cdc.gov, 412-386-6828

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