A Real-time, Wearable Elemental Carbon Monitor for Use in Underground Mines

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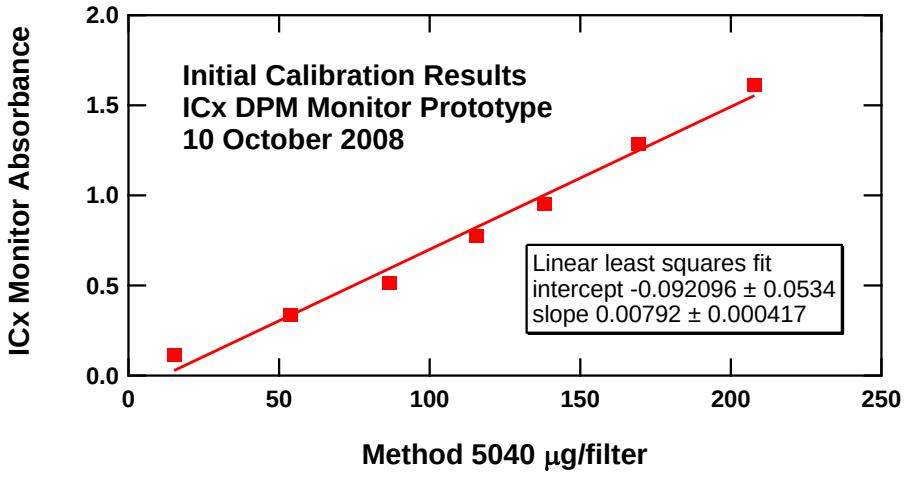
ICx Technologies has designed and is currently testing a real-time, wearable elemental carbon monitor designed primarily to determine exposures of workers in underground mines to diesel particulate material (DPM). Diesel particulates are composed primarily of elemental and organic carbon, and have been found to present a health hazard. The submicron particles themselves are respiratory irritants and the adsorbed organic components include polycyclic aromatic hydrocarbons such as nitropyrenes which are probably human carcinogens. DPM levels can be high in workplaces where diesel equipment and vehicles are used, and this hazard is particularly severe in underground mines due to the enclosed workspace and difficulty and expense of ventilation. 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 quartz 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. Existing real-time particle monitors are either not sufficiently sensitive for measuring hazardous DPM levels, are too large or costly for routine use in mines, or are subject to interference from other materials commonly present in mines, such as water vapor, oil mist, cigarette smoke, and dust. The ICx monitor, based on a design developed and tested by Dr. James Noll's group at the U.S. National Institute of Occupational Safety and Health (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. Air is pumped into the monitor by a flow-controlled pump and the submicron particles are selected using an industry-standard cyclone and impactor unit. The submicron particles are adsorbed onto a filter and the optical transmittance of the filter is measured, which decreases as the filter is loaded with black carbon particles. Appropriate calibration is applied to convert the measured transmittance to an elemental carbon filter loading and air concentration. 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.



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ABSTRACT

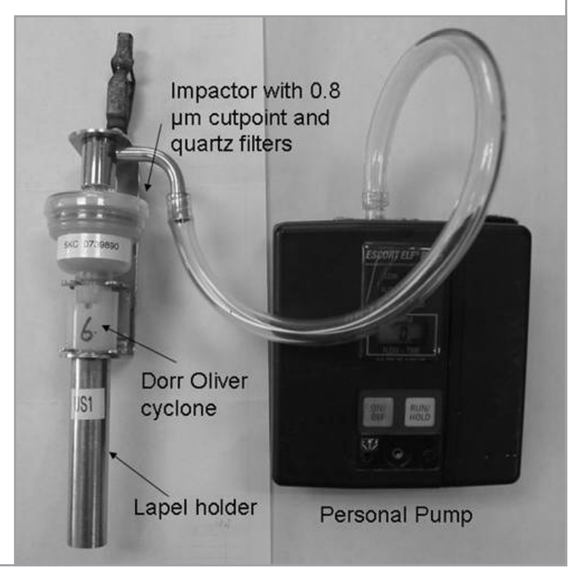
ICx Technologies has designed and is currently testing a real-time, wearable elemental carbon monitor designed primarily to determine exposures of workers in underground mines to diesel particulate material (DPM). Diesel particulates are composed primarily of elemental and organic carbon, and have been found to present a health hazard. DPM levels can be high in workplaces where diesel equipment and vehicles are used, and this hazard is particularly severe 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.

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 curately measures DPM

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



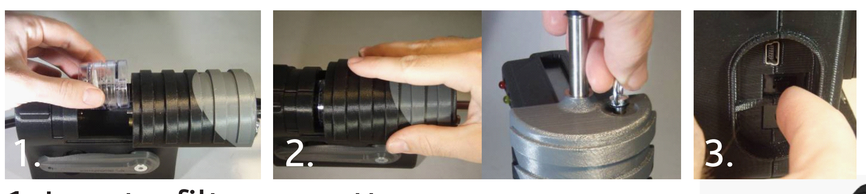
PROBLEM WITH CURRENT METHOD

- 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

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 rechargable battery
- Real-time output of DPM levels @ 50-1000 mg/m3

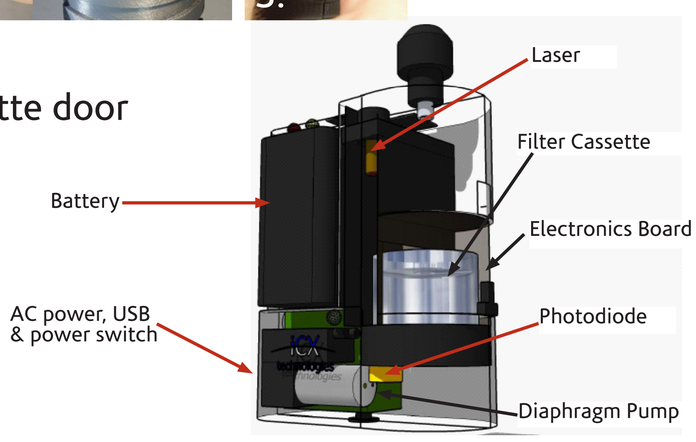
EASY TO USE



1. Insert a filter cassette
2. Close and lock the cassette door
3. And turn the unit on

PARTS

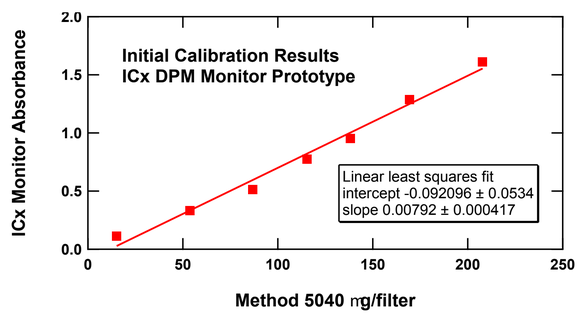
Size Selector
Not Shown



OUTPUT

- Real-time EC level (mg/m3)
- 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

AGREEMENT WITH NIOSH METHOD 5040



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 interferrents:
- Dust
- Oil mist
- Water vapor
- Cigarette smoke
- Ability to use to collect 5040 samples

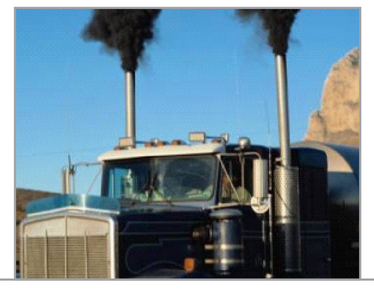
MONITOR FOR METAL/STONE MINES

Coal & 'gassy' mines

Intrinsically safe certification

Non-mine diesel workplaces

railyards, truck depots, fire stations, loading docks...



Add other gasses & functionality

ICx gas measurement: NO, NO2, CH4, CO, CO2