

Emissions Assisted Maintenance Program

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**Workshop on Diesel Aerosols and Gases in
Underground Metal and Nonmetal Mines
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The Emission-Assisted Maintenance Program is based on two beliefs

- An improperly maintained diesel engine can emit higher and undesirable emissions compared to a well-maintained diesel engine
- Onsite emission tests can be employed to determine if and where there is the need for maintenance.
- *Recorded historic data of any engine and aftertreatment performance are crucial for the success of the EAMP.*



Coal mines requirements: Weekly loaded-engine undiluted emission tests on all engines in diesel-powered equipment approved under part 36 and heavy-duty nonpermissible diesel- powered equipment (30 CFR 75.1908 ; 30 CFR 75.1914). The undiluted carbon monoxide concentration shall not exceed 0.25% (2500 ppm) (30 CFR 75.1914).

Metal/non metal mines requirements: They do not have the requirement to perform periodic emission tests on diesel-powered equipments but MSHA in his Best Practice Guide encouraged metal/non metal mines operators to perform weekly CO checks

Monitoring tools for tailpipe measurement

- A exhaust gas analysis system
- A manometer for measuring exhaust backpressure
- A temperature probe
- A diagnostic tool (Scan tool) that communicates to the engine ECM.



Gases monitoring in the tailpipe

Exhaust gas analysis system characteristics:

- **Sampling port** – No special requirements for the sampling port in the tailpipe. When it is possible, the sampling inlet should be located far from an elbow or change of diameter and in the middle of the tailpipe.
- **Sampling line** – For a correct measurement of the listed gases, the sampling line should be heated (at least 100 C). The measurement of NO₂ can be jeopardized by the use of a non-heated line
- **A pre-conditioning unit** – It's crucial to consider the presence of water (vapor) and DPM in the exhaust. Most of the time the water is removed by a chiller or water-trap. In this case the measurement of gases concentration is defined “dry” and it should be converted back to “wet” by assuming the water content in the exhaust. Many monitors do automatically this conversion. The DPM is removed by filters.



Gases monitoring in the tailpipe (2)

Exhaust gas analysis system characteristics:

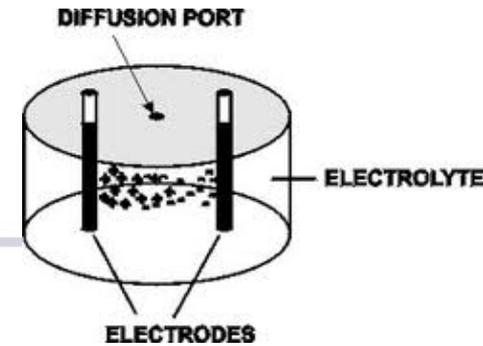
- **Cross-interferences removal** – At high concentration CO, NO, NO₂ and SO₂ can play active role in cross-interferences effects. A converter for NO, NO₂ and SO₂ is necessary ahead of any CO monitor device.
- **Range of operability** – In order to properly measure the concentration of the listed gases the analyzer should have the following ranges of measurement

CO ₂	0-15	%		NO	0-1000	ppm
CO	0-5000	ppm		NO ₂	0-1000	ppm

- **Future limits** – Necessity to measure other gases (N₂O and NH₃) in the tailpipe.



Gas monitors



Electrochemical sensors

- The most used gas monitoring technique used in underground metal/non metal mines.
- Technique for **atmospheric monitor** and **tailpipe monitor**.
- Active or passive sampling.

How it works:

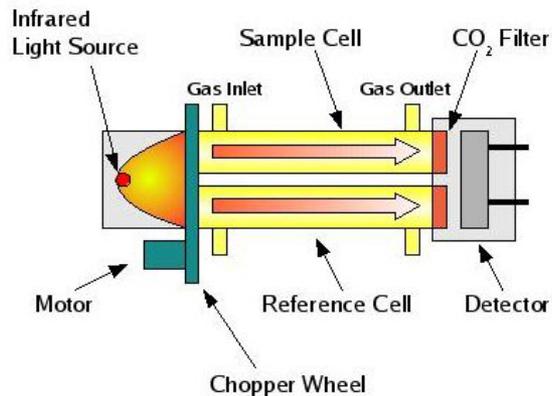
- The gas of interest comes into contact with a sensor specific for this gas, a chemical reaction occurs which creates an electrical signal that can be measured
- The amount of gas of interest supplied to the sensor is limited by diffusion - the output from the sensor is linearly proportional to the gas concentration.
- High sensitivity and selectivity, a wide linear range, minimal space and power requirements, and low-cost instrumentation.



Gas monitors

Non dispersive Infrared analyzer (NDIR)

- The main components are an infrared source (lamp), a sample chamber or light tube, a wavelength filter, and the infrared detector.
- The gas is pumped into the sample chamber, and the gas concentration is measured electro-optically by its absorption of a specific wavelength in the infrared (IR).
- Largely used in laboratory settings. Some portable systems too.
- Each cell is suitable for a single gas only. It is an expensive monitor (\$30,000).
- Interferences are open issues.
- Method for **atmospheric monitor** and **tailpipe measurement**.
- Only active sampling.



Source: esrl.noaa.gov



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Advanced gas monitor techniques

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR detects gaseous compounds by their absorbance of infrared radiation. All gases—with the limited exception of compounds such as nitrogen (N_2) and oxygen (O_2)—absorb in the infrared spectral region and can, in principle, be detected.

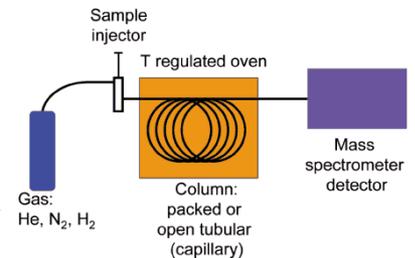


Gas Chromatography Mass Spectroscopy (GCMS)

GCMS is a technique which is based on the **separation** and **analysis** of compounds that can be vaporized without decomposition. The separation of the compounds (usually collected in sampling canisters or other media) is carried out in the GC section.

The analysis is performed by a mass spectrometer (MS) or other analytical techniques – the mass spectrometer allows the chemical speciation of every compound separated by the GC.

- Suitable for the speciation analysis of gaseous hydrocarbons emitted by any diesel engine.



Calibration

- The periodic calibration of any monitor is crucial to produce a correct measurement. Accuracy and reliability are strictly connected to a proper calibration.
- For monitoring of gases compounds, the calibration is carried out by using calibration bottles (cylinders) with a specified known concentration.
- For electrochemical cells the calibration is based on the two points calibration procedure: the monitor is challenged with a **zero** and a **span** concentration. For other monitors the calibration is not linear: a multi point calibration is necessary.
- Follow the manufacturer's guidelines for proper calibration. The type and concentration of calibration gas, sample tubing, flow regulators and calibration adapters are important.
Only use certified calibration gas before its expiration date. Never use calibration gas after its expiration date.
- Record calibration data – time, set-up, conditions, operator, data.



Evaluation of Portable Instrumentation for Monitoring Gaseous Emissions

Requested by Alliance Coal and West Virginia Diesel Equipment Commission

Objective: Evaluate field instrumentations for the monitoring of undiluted gaseous emissions in diesel engine tailpipe

Methodology:

- Two commercially available portable analyzers used to measure tailpipe CO concentrations in West Virginia coal mines - A laboratory analyzer (reference).



Operating condition		1	2	3a	3b
Engine mode	Speed (rpm)	2200	2200	1400	1400
	Torque (lb*ft)	35	60	386	389
	Test duration (minutes)	20	15	10	2
NDIR	CO concentration (ppm)	139.8	103.6	3.0	2.9
	Standard deviation (ppm)	2.4	1.2	0.0	0.6
ECOM	CO concentration (ppm)	144.5	106.9	3.8	3.7
	Standard deviation (ppm)	2.6	3.9	0.5	1.5
iTx	CO concentration (ppm)	159.8	126.3	12.0	8.0
	Standard deviation (ppm)	7.9	10.4	1.4	0.0

Patts, L. and E. Cauda [2011]. "Carbon Monoxide Measurement in the Tailpipe of Diesel-Powered Underground Mining Equipment". Coal Age.



DPM monitoring in the tailpipe



- The goal is to roughly estimate the DPM emission out of the tailpipe.
- This is particularly important when a DPF is installed and it is *supposed* to be highly efficient.

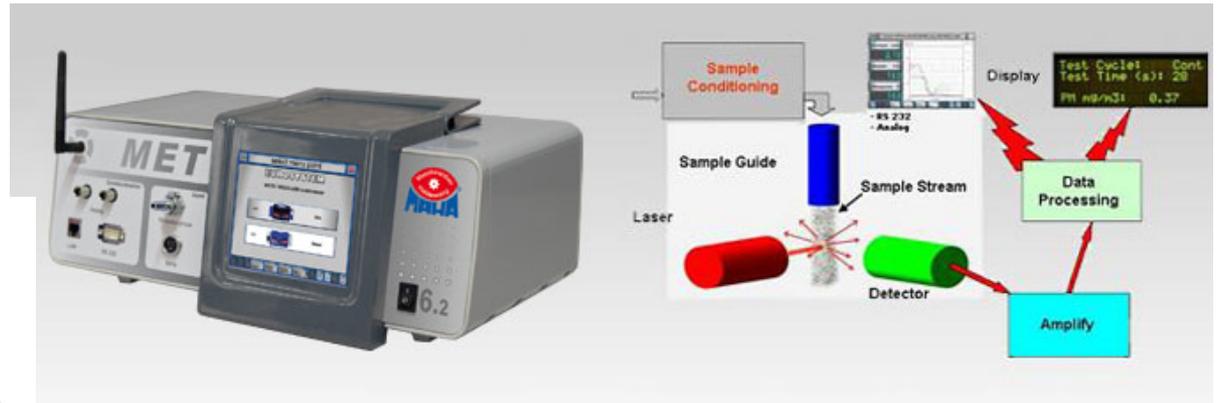
The consolidate technique is the opacity or smoke meter.

- Full-flow or partial flow.
- Generally measure the opacity from a scale of 0% to 100%.
- Strongly affected by engine parameters.
- It is a good and cheap qualitative measurement



DPM monitoring in the tailpipe (2)

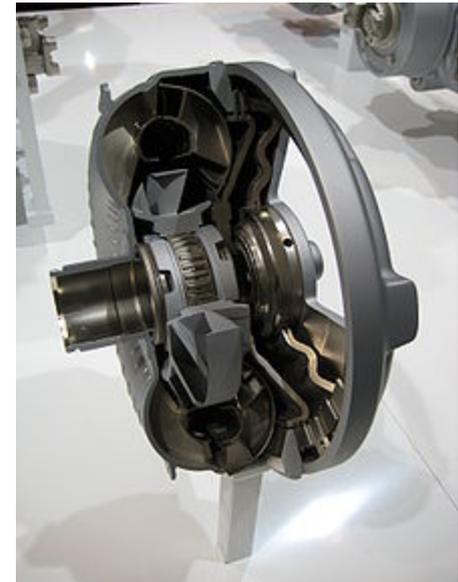
More advanced techniques have been proposed and they should be considered.



Procedures

If the engine needs maintenance most probably the emissions at full load will be far from the historic data.

- Torque converter stall
- Hydrostatic stall
- SAE J1667 Snap acceleration test.



Because the performance of a DOC at low temperature can be crucial it is recommended when possible to perform the check also in low and high idles



Orin use diesel engine emissions



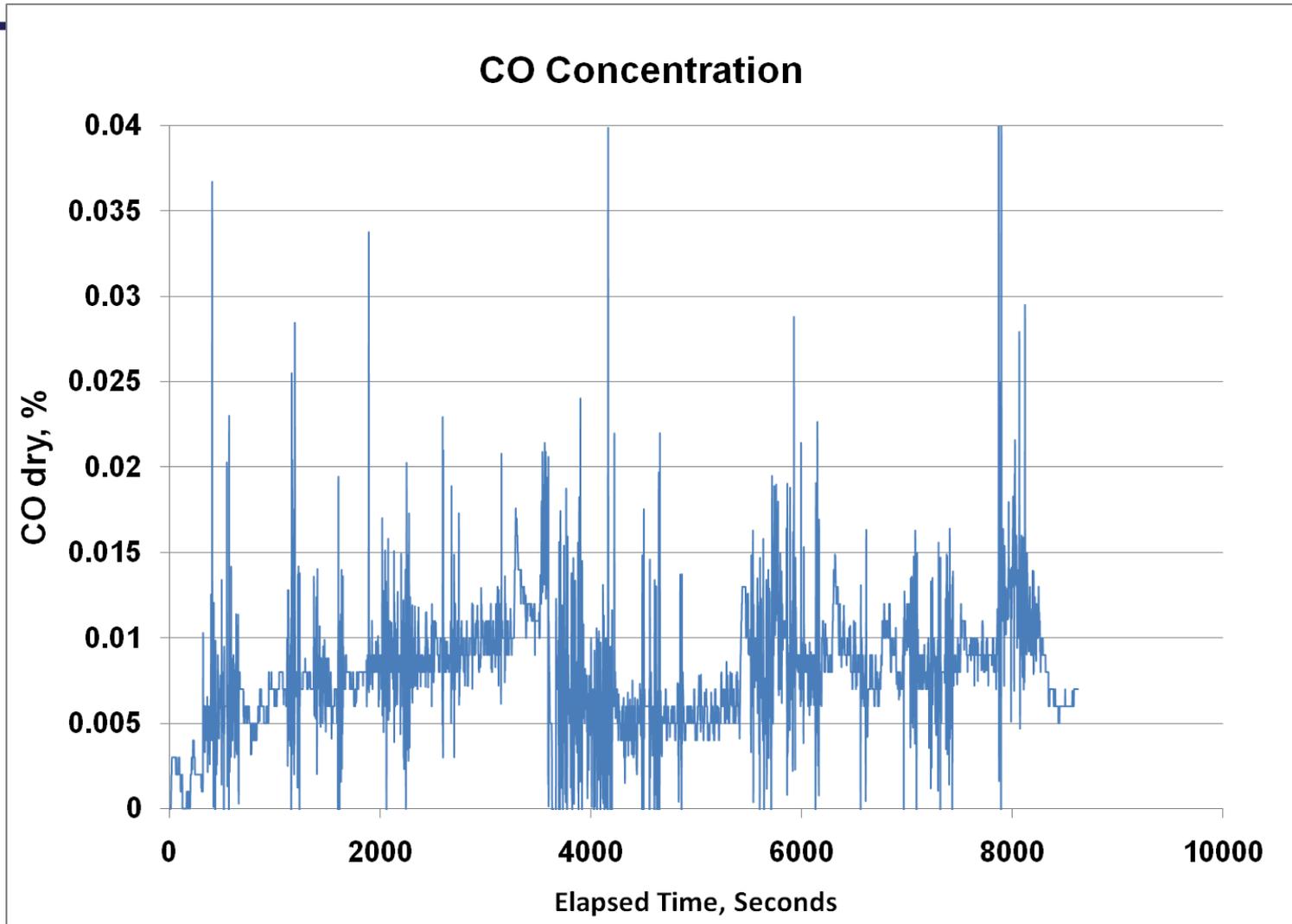
Objective: Evaluate the “in use” emissions of diesel engines in metal/ non metal mines

Methodology:

- Collected data of gaseous and solid emissions of three different vehicles equipped with diesel engines.
- Collected data before and after the installed aftertreatment control technology
- Measurement of gaseous emissions carried out by two different analytical techniques – FTIR (NIOSH analyzer) and SEMTECH-DS (Sensors Inc. -NIOSH Contract)



in use diesel engine emissions (2)



Key maintenance issues

Charge compression system

- Boost pressures needs to be monitored - intake, exhaust, fouling, and clogging can have an impact on the performance.
- Intake restrictions: air filters and other intake components .

- Temperature differentials across aftercoolers should be monitored.
- Fouling is the main source of issues – the exchange of heat is diminished if particles are deposited in the system

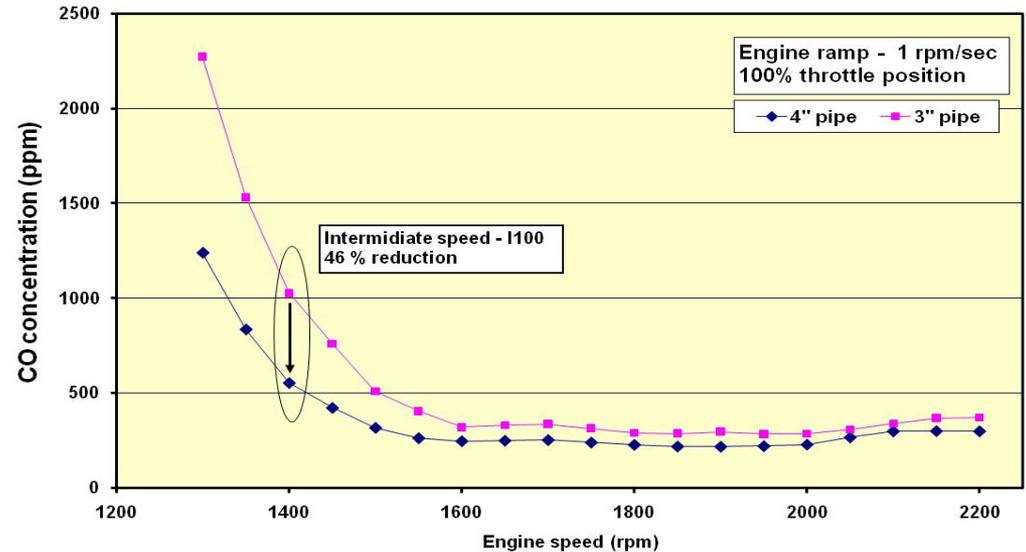
- High quality fuel and fuel filters are the best “preventive” maintenance strategy.
- Dust infiltration in the fuel tanks should be avoided.
- A water separator should be installed ahead of the fuel filter.



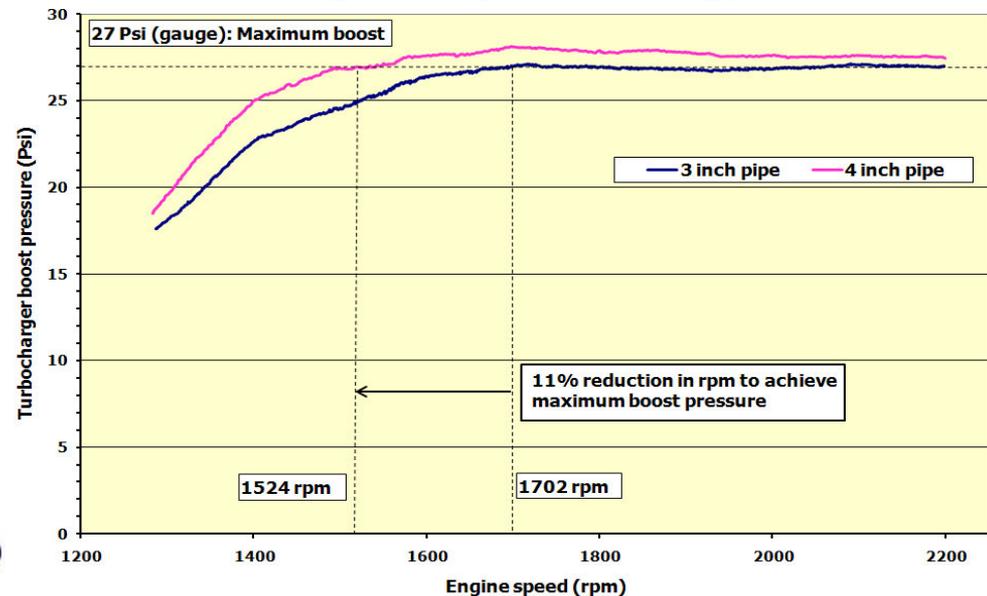
How important is 1"

- 904/400KW dyno engine CO levels were significantly **higher** than MSHA approval test levels
- **Engine maintenance condition and boost set levels** were tested and were within recommended values
- A 4" exhaust system was fabricated to lower the backpressure imposed by the 3" system and the **engine reached boost levels earlier**
- Earlier onset of max boost lowered **CO levels which were then comparable to approval values**

Carbon monoxide concentration comparison for 3" and 4" pipe



Boost pressure comparison for 3" and 4" pipe



EGR maintenance

EGR is about reduction of NO and NO₂

- For external EGR the level of these gases at manifold out and tailpipe out is good indication of the performance.
- The possible fooling of the cooler (external EGR) should be prevented.
- When possible and needed the pressures of the turbo-boost should be monitored.

DOC maintenance

- Regular measurement of gasses up and down stream the DOC is the must
- The two key actors are CO and NO₂
- Pressure across the DOC should be monitored – the pressure drop generated by a DOC should be minimal.



DPF maintenance



Are not good signs

- Presence of DPM in the tailpipe downstream of DPF
- Low pressure upstream of the DPF or extremely high pressure.
- An high smoke number downstream of the DPF
- Unusual levels of CO (\uparrow) and/or NO₂ (\downarrow) for catalyzed DPF

Good practice

- Regular inspection of the tailpipe
- Regular measurement of smoke number, pressure and gasses up/down stream the DPF (especially for catalytic DPF)
- Keep record of historic data for measurements – trends are the factor !!!
- Ashes can be a problem – accumulation of ashes can lead to extremely high back pressure and failures: follow manual for the DPF.



Questions??

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