Overview

The Mirenco Diesel Evaluation Procedure, MDEP, utilizes the latest in portable emissions monitoring equipment, computer software, and technical expertise to analyze the exhaust emissions coming from each piece of diesel powered equipment. MDEP is a standard diesel evaluation procedure measuring EPA regulated emissions. These measurement results determine the current state of combustion for each power unit.

Analyzing the exhaust stack(s) of diesel engines is becoming of greater importance for achieving maximum fuel savings and extending engine life. Scientists and doctors are continuing to find possible links between fossil fuel exhaust emissions and many different health related problems. Several emissions that are created by diesel engines are of concern to the world environment. The one that is having the greatest impact is Diesel Particulate Matter (DPM).

The causes of increased vehicle emissions, loss of fuel efficiency and increased DPM are numerous. In this Report, Mirenco will identify the most common problems associated with abnormal engine combustion. The data taken from an engine evaluation can be compared to other engines of the same model and/or year. The abnormal amounts of combustion loss can be linked to engines with some degree of internal combustion degradation. By comparing the emissions data from like engines, it will be possible to identify the good combustion from the bad combustion and in many cases our MDEP process can pinpoint an exact mechanical problem.

DPM Instrumentation and Analysis

Based on visible observation, diesel exhaust smoke can be grouped into two separate categories: blue and/or white and black, also known as DPM. The blue and/or white smoke represents a mixture of fuel and lubricating oil droplets in the exhaust. DPM or black smoke consists of solid particles of carbon centered with soluble hydrocarbons of unburned diesel fuel. One needs to always determine which color of smoke is generated from the diesel engine since the color of smoke is a very good indicator of specific combustion problems.

The DPM density test uses a sensor head that is placed in the exhaust stream in order to determine the density of the solid black particles in the exhaust plume. The sensor head which uses a light beam that is shined across the diameter of the exhaust stack measures the amount of light blocked by the solid particles. This measurement is reported as a DPM density percentage on a scale of 0-100%. Black smoke will be visible to the human eye between 10% and 15%. Since blue and white smoke does not visibly restrict the light sensor as does the black particulates, it is possible for the human eye to see blue and white exhaust plume colors below 10%

The MDEP diesel evaluation method that is used to determine the DPM density is an advanced procedure similar to the SAE J-1667 diesel acceleration smoke test used for heavy-duty diesel powered vehicles. MDEP puts an engine at idle through a series of accelerations while the vehicle is in neutral. The peak DPMs during the accelerations are then averaged. MDEP has become the standard for reducing fuel usage and for lowering vehicle operation cost.

MDEP which uses the newest, state of the art DPM equipment automatically compensates for atmospheric conditions such as relative humidity, barometric pressure, and ambient temperature (standard sea level conditions). Since DPM particles block the light, the instrument works by shining a light beam through the exhaust and then measuring the reduction in intensity which is caused by the exhaust DPM particles. Neutral density filters that reduce light intensity by a known amount are used for calibration.

Project, vehicle, and equipment preparations all need to occur before the test can be performed. With the vehicle in neutral, and with the engine warmed to acceptable levels, and with the air conditioning turned off, and with the engine brake disengaged, the engine is then accelerated to its maximum governed RPM speed. The RPM is held at this high governed speed for four seconds and then released. This process is repeated six times. As part of the sixth and last engine acceleration test and prior to the engine's RPM returning to idle, the technician then records the steady-state DPM value that is obtained during the continuous peak engine RPM. This value is identified and reported as the engine 'Continuous Smoke Trail'

By using the DPM evaluation results combined with the MIR 120 Second Five Gas Procedure, it is possible to determine the engine's real-time ability to burn fuel. Having only the DPM evaluations without the five gas results would make it difficult to make recommendations for corrective engine repair or engine adjustments that are needed to improve the fuel efficiency.

Explanation of DPM Plot

MIR 120 Second 5-Gas Transient Procedure

By following the MDEP evaluation procedure and using portable combustion analyzers, professional engine service technicians can monitor the "virtual heartbeat" of a diesel engine. This heartbeat consists of the DPM and five invisible gases: hydrocarbons, carbon monoxide, oxides of nitrogen, carbon dioxide, and oxygen. The five gas analysis of each vehicle is conducted at two different engine speeds, idle and fast idle. Comparisons are then made between similar engines models so that abnormalities can be identified.

Instrumentation Utilized

The MDEP evaluation procedure measures all EPA regulated emissions of diesel particulate and gas emissions in "real time". To maximize fuel savings and to extend engine life, the engine must burn the fuel as efficiently as possible.

The carbon dioxide, carbon monoxide, and hydrocarbons are each measured by using an infrared light. To measure these gases, separate optical filters with band passes specific to each chemical species are used. As with DPM, the gases reduce the intensity of the beam of filtered infrared light proportionally to the gasses concentration. The oxygen and the oxides of nitrogen are measured using chemical cells that produce a voltage that is proportional to the gasses concentration. These two chemical cells have a limited life and need to be periodically replaced. An initial calibration of the entire instrument is performed by measuring a calibration gas which has known concentrations of each of the chemical species.

Hydrocarbons (HC) Designated:

Any unburned hydrocarbons in direct injection diesel engines usually results from an under-mixing of air to fuel or from a combination of diesel fuel and engine crankcase oil. Some of the major causes for the unburned hydrocarbons include the following: fuel injector atomization failure, incorrect injection timing, or the engine is burning oil.

Carbon Monoxide (CO) Designated:

Carbon monoxide, which is an extremely toxic gas, results from a mixture of too much fuel or engine oil and too little air causing incomplete fuel oxidation during combustion. Without enough air or time to complete combustion, the fuel or engine oil will not burn completely. This fuel-rich mixture may occur in localized pockets throughout the combustion chamber due to the incomplete mixing of fuel and oxygen, or it may occur throughout the entire combustion chamber.

Oxides of Nitrogen (NO_x) Designated:

Since the major component of air is nitrogen, an air-breathing engine breathes mostly nitrogen. "Oxides of nitrogen" is the generic term for a mixture of nitric oxide (NO) and nitrogen dioxide (NO_2). (Note: Nitrogen dioxide dissolves in water to form powerfully corrosive nitric acid.) The NO_x forms not that nitrogen is part of the diesel and oxygen combustion process, but because nitrogen happens to be at or near a high temperature flame zone and also near oxygen. Past a certain point, small increases in temperature can yield large increases in NO_x.

The key to controlling the NO_x is to control the temperature of the flame zone and the amount of time that the gases are exposed to this high temperature. This causes a paradox since the longer times at higher temperatures raise the mechanical power output of the engine, which is its purpose, but creates greatly increased NO_x.

These factors have all been accounted for in the initial engine design. In order to maintain the lowest overall emissions from NO_x and the other constituents while also maintaining fuel economy requires that many engine parameters need to be balanced. This balancing act can only be managed through proper engine maintenance and monitoring.

When below normal NO_x evaluation results occur, they are an indication of poor fuel efficiency and poor engine performance. The probable causes of both below normal NOx and engine performance loss include the following: incorrect fuel injection timing, below normal air to fuel ratio, low fuel injection pressure, exhaust-gas recirculation malfunctions, and low cetane fuel.

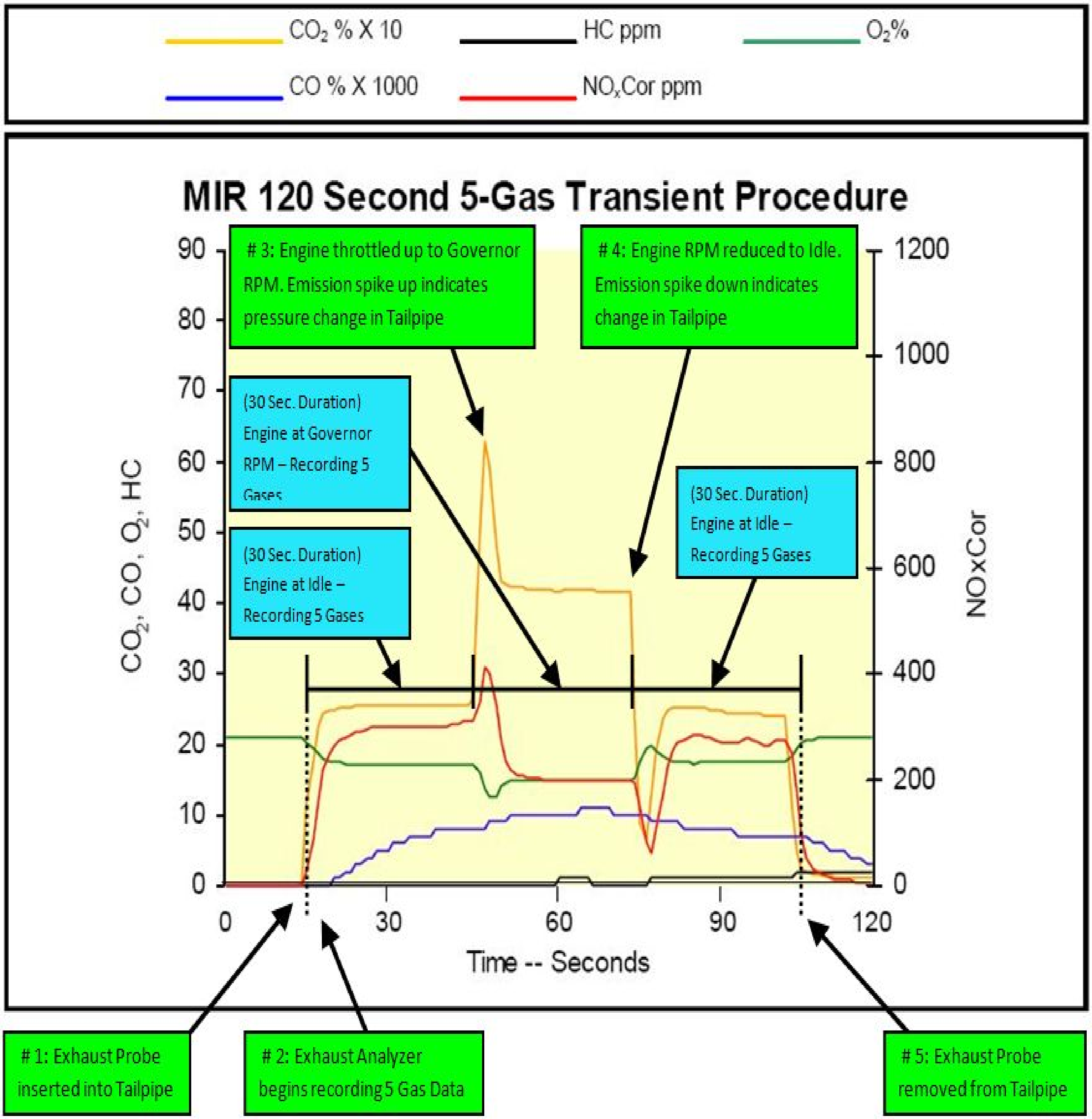
Carbon Dioxide (CO_2) Designated:

Carbon dioxide is found in the atmosphere and it is also one of the products of engine combustion. If an engine that burned fossil fuels had perfect combustion, the resulting emissions from the engine would be composed of CO_2 and H_2O. However, since no internal engine's combustion process is ideal, additional engine emissions result. Consequently, by measuring CO_{2},, the engine's power loading can be determined as normal or abnormal. A higher fraction than normal of CO_2 in the exhaust may indicate that the engine is powering something unexpected which could result in an increase in fuel expense.

Oxygen (O_2) Designated:

Oxygen, which is vital to every living creature, is also a necessary constituent when determining the combustion efficiency of a diesel engine. Knowing that the fraction of atmospheric oxygen is around 21% and that diesel engines use large quantities of air, the Mirenco analysis compares the oxygen levels that are exhausting out of the stack of the power unit at idle and fast idle. O_2 and CO_2 are the two gases that are linked to engine power and combustion. By comparing these two gases and by looking at the CO, NO_x and HC traces, we can determine how completely the engine is burning the fuel.

Explanation of MIR 120 Second 5-Gas Transient Procedure Plot

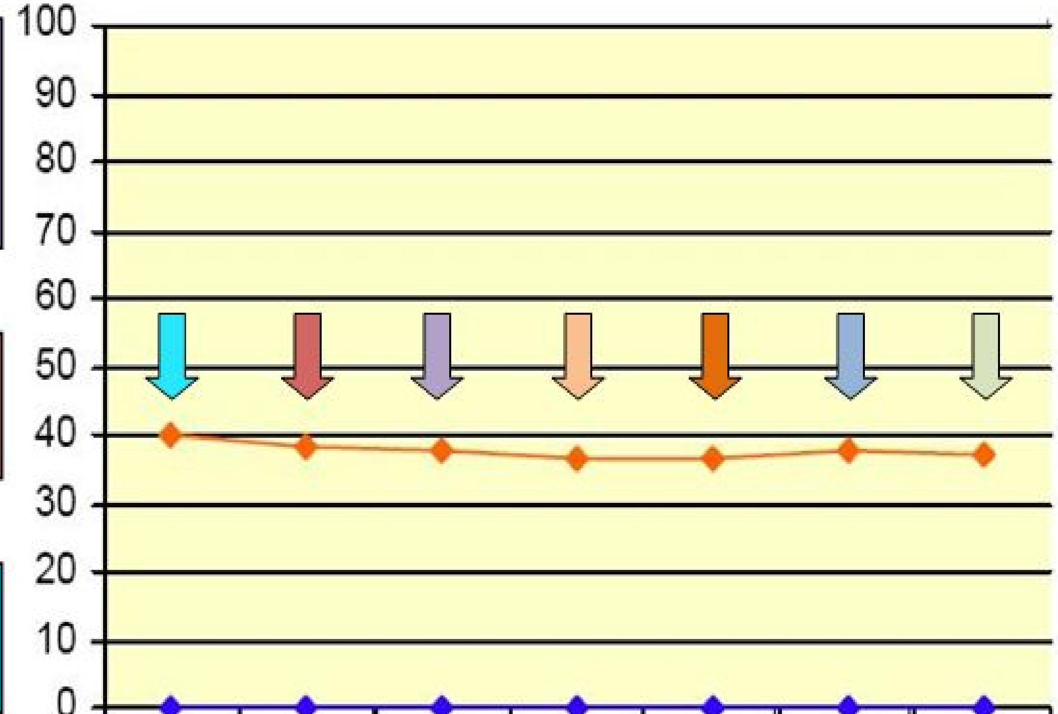


DPM Evaluation(s)

3rd test indicates if the emissions are due to problems with the engine injectors.

2nd test shows any emissions improvements.

1st test indicates whether the engine "loads up" on fuel.



4th test indicates if there is a timing and air starvation problem.

5th test helps to determine steady or variable smoke emissions.

6th test helps to confirm overall combustion status.

Average of tests 4,5,6 is used to calculate soot generation and fuel loss.

	Trail%	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	4_5_6 Avg
Baseline	1	40.0	38.0	37.8	36.6	36.7	37.4	36.9
Miles/Hrs 2,363								
Current Evaluation	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miles/Hrs 13,955								