Federal Railroad Administration

Research Results

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LOCOMOTIVE EXHAUST EMISSIONS

SUMMARY

The Federal Railroad Administration (FRA) funded a project to conduct locomotive emissions measurement tests using a portable, heavy-duty diesel truck emissions measurement system. Based on the quality of the data collected, the conclusion is the tested equipment can be adapted and/or enhanced for locomotive emissions measurement.

This research was funded by FRA in order to improve public and railroad personnel safety as well as to develop a complete locomotive emissions measurement system that would be portable, easy to use, and applicable for both stationary and over-the-road testing. Particulate matter and smoke measurements were not included in the project due to complexities and limited funding.

Emissions measurement of locomotives requires extensive preparation in instrumentation, data reduction and analysis. Insofar as the instrumentation is concerned, the use of a compact, lightweight, easy to use, and integrated emissions measurement system greatly reduces this complexity. A portable emissions measurement system that is used in the heavy-duty diesel truck industry was procured for the project. For data reduction, custom spreadsheets were developed to combine engine performance information with raw emissions concentration data in order to generate brake-specific and duty cycle emissions rates and successfully used them in post-processing emissions data.

A portable system was developed wherein the emissions and auxiliary instrumentation is transported in a cargo van and parked next to the locomotive for use as seen in Figure 1. This arrangement allows for efficient and portable measuring of locomotive emissions. The setup and measurement portion of an emissions test can be completed in 1-2 days using this system; a significant improvement over current logistics where the locomotive has to be taken out of service, and can result in significant revenue loss to railroads and car owners. Based on the test results, it appears that the tested system can be adapted to provide for an efficient means of measuring locomotive emissions.

Figure 1. Locomotive emissions measurement setup.

BACKGROUND

Locomotive fuel efficiency and safety in operations are two of the most important elements in ensuring the viability of the nation's railroads as we move into a new century of progress. Concurrently, as always, there is a need to protect the nation's people and the environment from the emission of harmful pollutants. Recognizing this need, Environmental Protection Agency (EPA) regulations require that emissions from all new or remanufactured locomotives comply with increasingly stringent limits as set forth in 40 CFR Part 92.

Presently, locomotive owners and managers have to either send their locomotives to an emissions testing laboratory or schedule with a very limited choice of companies to come to their site to do the testing. Both of these options are inefficient and require the locomotive to be removed from revenue service. The equipment currently being used and the meager availability of emissions testing companies increase this inefficiency. Due to how emissions testing evolved and the available technology during the period of evolution, most equipment used today is large and elaborate.

This FRA funded project begins to provide an efficient and more workable means to help solve the problem with the development of state-of-the-art emissions testing systems that can be applied on locomotives themselves and/or used as test stands for stationary testing. This report describes prototype emissions tests of a locomotive via a compact and portable emissions measurement system adapted for use on locomotives.

The project's goals are 1) to develop an efficient system that locomotive owners and managers can use as part of normal inspections, and 2) to develop an on-board over-the-road system to ascertain the difference between stationary and over-the-road emissions.

OBJECTIVES

The objective of this project is to increase public safety by making available to FRA and the railroad industry, a cost-effective and practical way to test locomotive emissions. The increased efficiency would catalyze more testing and pre-emptive maintenance, which subsequently makes for cleaner running locomotives. To this end, the railroad industry will more easily comply with EPA regulations to improve our nation's air as well as the health and safety of our nation's people.

METHODS

INSTRUMENTATION

After extensive research, a portable emissions measurement system was selected that is currently used in the heavy-duty diesel truck industry for measurement of locomotive emissions. Figure 2 below shows a front view of the emissions system.

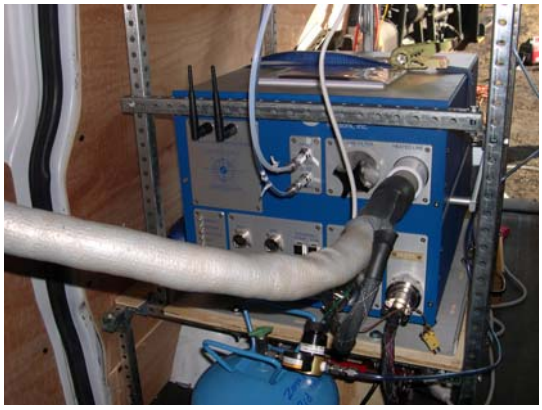

Figure 2. Portable emissions measurement system

A number of lab tests were carried out to become familiar with the measurement system. Auxiliary instrumentation was also developed to measure various engine and ambient parameters such as air box temperature and pressure, fuel-in temperature, crankcase suction pressure, ambient temperature and relative

humidity, etc. A stack extension was developed, which is used to securely hold the exhaust sample probe. Engine exhaust is sampled via this probe and sent to the emissions measurement system, wherein the constituent gaseous components are measured and recorded.

The diesel fuel is supplied at a constant volumetric rate to the engine. The load regulator controls the fuel consumption and the excess fuel is returned to the fuel tank. It is critical to measure the net fuel mass consumption rate of the engine for the proper calculation of the emissions values. A fuel mass flow measurement system was developed for this purpose.

An extensive amount of post-processing is required to convert raw gaseous concentrations, measured by the emissions measurement system, into brake specific emissions and duty-cycle emissions, as required by EPA. A computer program to automate a large portion of this post-processing was developed to increase the efficiency of the task.

EMISSIONS TESTING

Two locomotive emissions tests were collected in the field that collected emissions data as well as all the auxiliary parameters necessary for post-processing. Parameters such as engine speed, load regulator position, main generator volts and amperes, etc. were recorded from the locomotive computer.

POST PROCESSING

The emissions data collected were exported in an ASCII format. This raw emissions data and other parameters were combined to compute and output brake specific emissions and duty cycle emissions values.

FINDINGS

The compact and portable emissions measurement system was convenient to setup and use. Analysis of the raw concentration measurements indicated good precision and low noise in the data. The measured CO concentrations were in the lower 10% of the CO analyzer bench. To obtain the best possible accuracy and precision, the CO analyzer bench should be modified to accommodate the lower ranges.

Use of the computer program reduced the time required for post-processing the collected data and the time required for calculating brake-specific and duty cycle emissions value. Raw emissions measurements were plotted against time to analyze the emissions behavior of the engine. Figure 3 below shows a CO_2 concentration plot and Figure 4 shows a NO_X concentration plot.

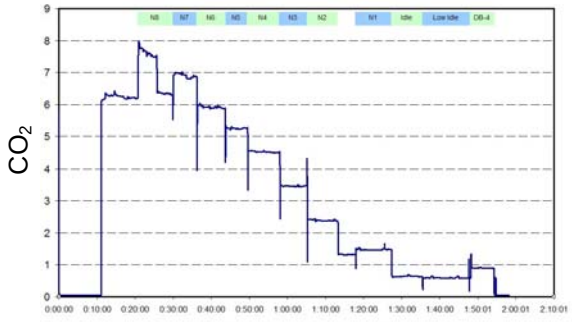

Figure 3. CO_2 (%) Vs. Time Plot

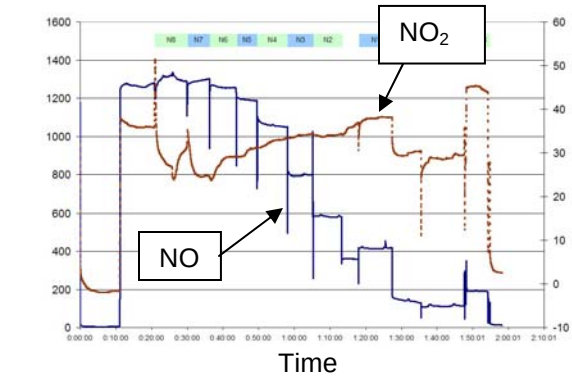

Figure 4. NO_X (ppm) Vs. Time Plot

As can be seen in the plots, the response time of the emissions measurement system is good and the system is capable of capturing any transients in the gaseous emissions.

CONCLUSIONS

The emissions measurement of locomotives requires extensive instrumentation. The use of a compact, lightweight, easy to use, and integrated emissions measurement system greatly reduces this complexity.

The lab tests conducted using the analyzer and the data provided by the system manufacturer have shown good repeatability in the emissions measurement capability of the system.

Significant amount of post-processing is also required to combine engine performance and emissions measurement data to generate brake specific emission rates and duty cycle emissions. Development of custom spreadsheets has been completed for this purpose and been successfully used in processing emissions data. These spreadsheets will be a valuable tool in future development work.

A few improvements that can be made to the analyzer system and the testing process have been made, and investigations continue into what areas need improvement.

There are plans to work with the system manufacturer to institute some minor changes to better adapt the analyzer for locomotive emissions measurement.

Overall, the first prototype locomotive test and subsequent post-processing and review of collected data have shown that a portable, compact and integrated system can be an efficient alternative for locomotive owners/ managers to use for locomotive emissions testing.

FUTURE ACTIONS

There are plans to conduct further stationary on-board locomotive emissions tests. These tests will allow gathering of emissions data that can be used to show repeatability of the overall emissions setup with respect to the off-board data collected previously.

There are also plans to conduct on-board in-use type locomotive emissions tests contingent upon availability of funding. These in-use type tests will be conducted on a main line track and will provide valuable in-use emissions data that can be used to compare and better understand the knowledge gathered using stationary tests.

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