

"EXHAUST EMISSIONS FROM EMD SD50 ADVANCED OVERHAUL LOCOMOTIVES"

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Summary

Test results by the Association of American Railroads and the Southwest Research Institute indicate that Electro-Motive Division's (EMD) Advanced Overhaul (AO) service recommendation, with additional modifications to injection timing, may enable 16-645F3B engines in 50-Series locomotives to meet the U.S. Environmental Protection Agency's (EPA) expected proposed emissions standards (Notice of Proposed Rulemaking should be published in January 1997).

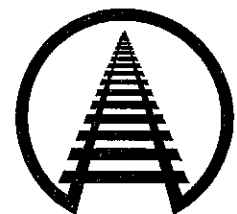
In all tests, measured carbon monoxide, hydrocarbon, particulate matter, and visible smoke were well below EPA's proposed limits. Oxides of nitrogen (NOx) for the AO engine were above the proposed limits on a weighted duty-cycle basis and exceeded the proposed throttle notch limit at notch 2. Retarding fuel injection timing (to 4° ATDC), however, resulted in average NOx values below the proposed limits. That test was conducted on only one engine and the 95-percent confidence band exceeds the limits. If the AO configuration on 16-645F3B engines with the 4 degree after top dead center (or ATDC) injection timing does not meet the proposed limits, it is likely that the regulations will allow the manufacturer to average emissions with other engine retrofit kits.

These results are based on tests of four EMD SD50 locomotives, which had recently been remanufactured and modified by CSX Transportation Company. They were tested to determine the emissions levels for the EMD 16-645F3B engine with EMD's AO service recommendation. The AO for this engine includes changes that seem likely for the remanufacturing kits that EPA will require for most locomotives that were originally manufactured during the 1970s through the 1990s.

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Suggested Distribution:

- Locomotive Dept.
- Research & Development
- Environmental Quality Dept.



Association of American Railroads
Research and Test Department

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INTRODUCTION AND CONCLUSIONS

As support to the railroads in dealing with the U.S. Environmental Protection Agency (EPA), the Association of American Railroads (AAR) worked with Southwest Research Institute (SwRI) to set up a locomotive exhaust emissions measurement facility in San Antonio, Texas. A series of emissions tests was conducted on a variety of locomotives to characterize the emissions from much of the fleet that is in operation today. Changes in emissions and fuel consumption were determined from relatively simple engine modifications, such as retarding the fuel injection timing. Electro-Motive Division's (EMD's) 50-Series locomotives have high-rated (high horsepower per cubic inch displacement) engines that have been less reliable and were originally found by EMD to have high NO_x emissions. EMD developed an "Advanced Overhaul" (AO) service recommendation to improve engine performance, reliability, and life, which also has the potential to reduce NO_x emissions. AAR and SwRI tested four CSXT AO SD50s for emissions, including several engine and fuel modifications.

The AO locomotives as configured for CSXT did not meet the NO_x limits that EPA is expected to propose for pre-2000 locomotive engines. With the fuel injection timing retarded an additional 2 degrees beyond the AO specification, however, the duty cycle-weighted NO_x met the limit on the one locomotive tested, but exceeded EPA's proposed throttle notch limits. When statistical confidence limits are applied, the AO "fails" the proposed EPA requirements.

It is important to note that EPA's test procedure and emissions limits are not yet settled, and how EPA finalizes their rulemaking will impact the ability of these and other engines to meet the standards. A critical variable is the correction factor for NO_x (based on humidity, temperature, and

barometric pressure) that has been in use for other EPA regulations for over two decades. EPA plans to develop a different correction factor for locomotives based on tests that are proposed to be conducted in 1997. There may be major changes in EPA's proposed throttle notch limits, which would also impact the ability of modified engines to meet the total regulation.

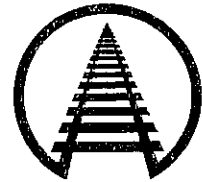
Locomotive Configurations Tested

Four EMD SD50 locomotives, which had recently been remanufactured and modified by CSXT, were tested to determine the emissions levels for the EMD 645F3B engine with EMD's AO. The AO for this engine includes changes that seem likely for the remanufacturing kits that EPA will require for most locomotives that were originally manufactured during the 1970s through the 1990s. Some of the changes are retarded fuel injection timing (2° after top dead center — ATDC), lowered rated engine speed, new fuel injector nozzle tip design, 4-pass aftercoolers, and more efficient radiator cooling fans. There are some other upgrades that do not affect the combustion process. Several other tests were conducted, including retrofitting one of the engines to original configuration to determine the engine baseline and changing the fuel injection timing to no retardation (top dead center or TDC).

Tests were conducted at the AAR-SwRI-Southern Pacific locomotive emissions facility in San Antonio, Texas. Emissions measured included NO_x, hydrocarbons, carbon monoxide, particulate matter, and smoke opacity. Instrumentation and procedures followed protocols developed by SwRI for AAR and conform to expected protocols from EPA.

AO Emissions Results

In all tests, the measured carbon monoxide, hydrocarbon, particulate matter, and smoke opacity were under EPA's proposed limits



and no data are presented here. NOx is the problem for this engine model and data reported here are limited to NOx.

The AO as configured for CSXT with 2 degree ATDC will not meet EPA's proposed NOx limits on a weighted duty cycle basis or at all throttle notches, as shown in Exhibit 1. The "envelopes" around the data bars show EPA's current proposed NOx limits. At 4 degree ATDC, the AO's mean NOx levels are under EPA's proposed limits. Manufacturers will be at considerable risk if the engines are tested and exceed the certification levels. They need to have some margin between their test levels and the EPA limits.

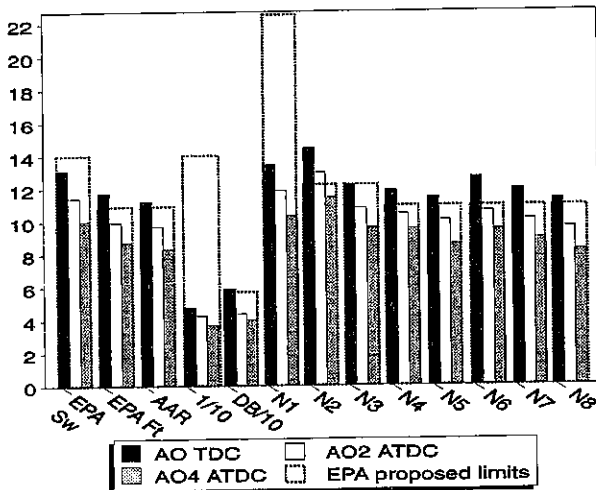


Exhibit 1. "Envelopes" around Data Bars show EPA's Proposed NOx Limits

Another way to look at these data is to calculate the 95-percent confidence limits. Exhibit 2 presents the NOx data in the same way as in Exhibit 1, but with the data bars at the upper 95-percent level. In other words, there is a 95-percent probability that the true NOx means are lower than the tops of the bars. The conclusions from Exhibit 2 are less promising. The weighted freight duty-cycle NOx levels all exceed EPA's proposed limit of 9.5 g/hp-hr. Even at 4 degree ATDC, some of

the individual throttle notch levels either exceed EPA's proposed limits or are close enough that some emissions test failures would be expected, if the 95-percent confidence limits are realistic.

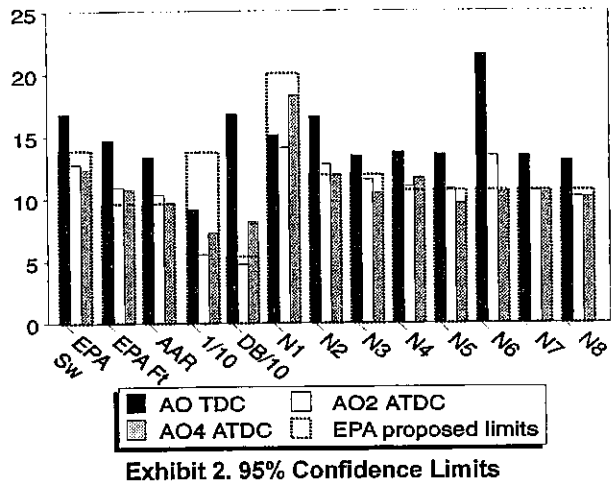


Exhibit 2. 95% Confidence Limits

The conclusions from Exhibit 2 do not rule out the AO with 4 degree ATDC as a certifiable retrofit kit. For one thing, a kit manufacturer would conduct many more tests than were done for this project. That should reduce the spread of the 95-percent confidence limits and might show the AO to be in compliance. If the AO with 4 degree ATDC still fails to meet all EPA limits, the manufacturer will have the option of certifying the engine with a higher NOx level than allowed, but offset it by averaging or trading the excess against another retrofit kit that has emissions credits for being lower than the EPA limits.

Retarding fuel injection timing increases fuel consumption. Exhibit 3 shows the brake specific fuel consumption (BSFC) at throttle notches 1 through 8 and weighted EPA switcher and freight duty cycles. In the freight duty cycle, which applies to SD50s, the weighted fuel consumption increases about 1.5 percent for the 4 degree ATDC compared to the normal 2 degree ATDC AO configuration.

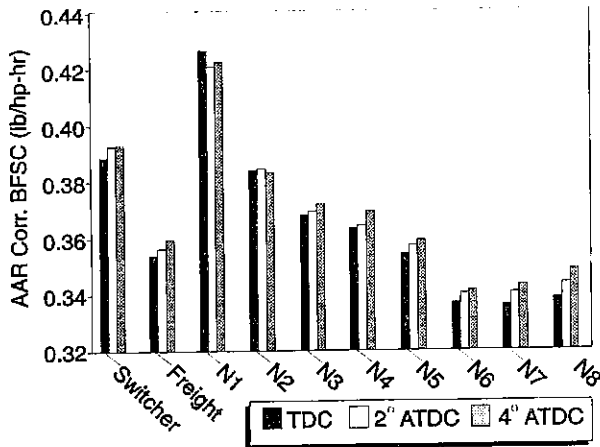
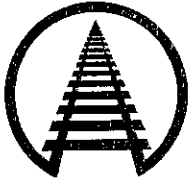


Exhibit 3. Brake Specific Fuel Consumption

The AO configuration provides significant reductions in exhaust emissions with no significant change in BSFC compared to an "original" engine. One of the engines was tested in the AO configuration, then rebuilt by SwRI to an as-built configuration with parts and engineering expertise contributed by EMD. It was tested, then rebuilt back to the AO, then tested again.

On the EPA proposed freight duty cycle, the AO version was 30-percent lower in HC, 12-percent lower in NO_x, and unchanged in PM. The CO doubled, but stayed well below proposed EPA standards. The BSFC had no significant change in all notches below 6. Both 6 and 8 had small reductions while notch 7 had a small increase. On a duty cycle basis, there should be no measurable change.

The objective of the AO was to increase engine life and reduce engine maintenance cost, while maintaining the same power rating. Because the top engine speed and combustion pressures were reduced while maintaining power, it seems likely that the AO will meet the objective. If so, there is no fuel penalty involved.

Note: Contact G.R. (Dick) Cataldi at (202) 639-2261 with questions or comments about this document. E-mail address: cataldi_dick@aar.com

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